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DEFECT TESTING OF FIVE CATALYST EQUIPPED FORD PROTOTYPE VEHICLES VOLUME I

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Mobile Source Air Pollution Control
Emission Control Technology Division
Ann Arbor, Michigan 48105

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by

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Prepared for

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Section 1

INTRODUCTION AND SUMMARY

The objective of the work performed under this contract was to provide test data on the performance of a known exhaust catalytic system under a variety of engine parameter conditions. The testing procedures were performed under the same conditions which applied to Contract Number 68-03-0452 (FTP/Short-Cycle Correlation Testing for 207(a) Implementation Catalyst-Equipped Vehicles - EPA-460/3-75-003-a). The FTP is discussed in detail in the Federal Register, Volume 37, Number 221, Section 85.075-9 through Section 85.075-26. The five short-cycle emission tests are:

1. Clayton Key Mode - Volumetric Procedure

2. Federal Three-Mode - Volumetric Procedure

3. Unloaded Test High Speed (2,500 rpm) and idle (derived from 1. and 2.) - Volumetric Procedure

4. Federal Short-Cycle - CVS Procedure

All testing was performed at the Olson Laboratories' facility, Anaheim, California.

Five catalyst-equipped experimental vehicles, owned by the Ford Motor Company, were tested in the program from February through April. All of the vehicles were loaned to the Environmental Protection Agency (EPA) and Olson for the duration of the testing.

All of the vehicles were Ford Galaxie, four-door sedans, equipped as follows:

- 400 Cubic-inch displacement V-8
- 2-Venturii carburetor
- Exhaust control system types:
  - air injection
  - catalytic reactor
  - exhaust gas recirculatin
- Canister-type evaporative system
- Automatic transmission
- 3.0 to 1 rear axle ratio
- HR78-15 radial ply tires
- Air conditioning
- Power steering
- Power brakes

The five vehicles tested were:

Ford Sd	Olson Sd	Final Mileage
T161	4170	25,822
T210	4164	24,220
T236	4165	10,522
T254	4169	11,883
T175	4162	09,653

The vehicles were tested using Indolene clear fuel except for one sequence when leaded fuel was used to induce the required defect. Baseline engine parameters were defined as the parameters recorded when the vehicles were received for Task Order 02.

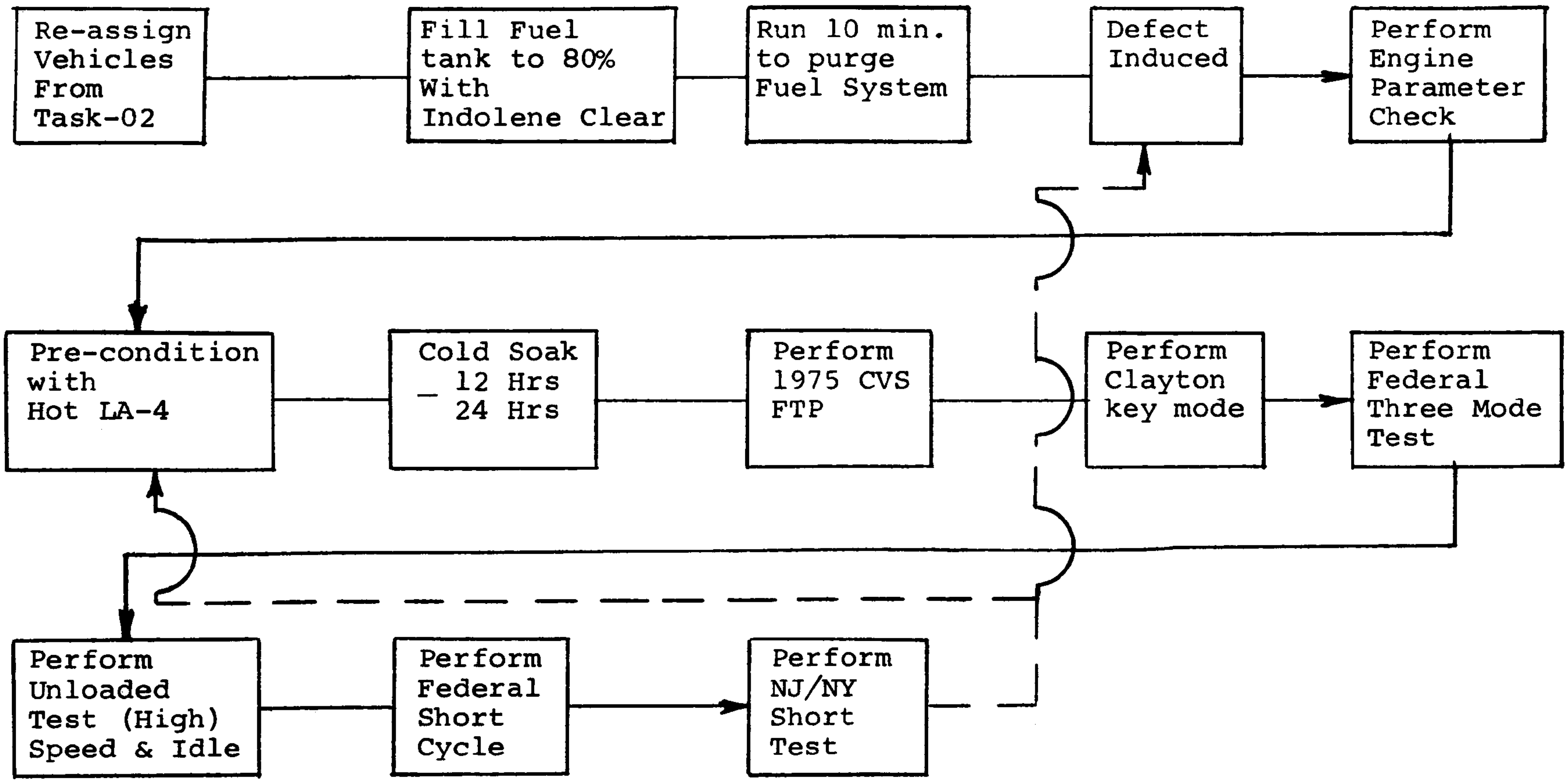
Re-assign Vehicles From Task-02
Fill Fuel tank to 80% With Indolene Clear
Run 10 min. to purge Fuel System
Defect Induced
Perform Engine Parameter Check
Pre-condition with Hot LA-4
Cold Soak 12 Hrs _ 24 Hrs
Perform 1975 CVS FTP
Perform Clayton key mode
Perform Federal Three Mode Test
Perform Unloaded Test (High) Speed & Idle
Perform Federal Short Cycle
Perform NJ/NY Short Test

Figure 1-1

The vehicles were preconditioned prior to baseline and each new induced defect by driving the vehicle on the dynamometer in accordance with the Hot LA-4 driving cycle. In the case of a repeated test, the previous test accounted for the vehicle's preconditioning. The preconditioning was followed by an FTP Cold Soak prior to the FTP Emissions Test. The sequence of events is shown in Figure 1-1.

All data was recorded on forms from which key-punched cards were obtained. These cards were input to a computer program that checked for completeness and accuracy of sequence. The program then converted volumetric data to mass units as required. The program produced a printed report for the EPA and punched a set of cards to an EPA format. A printed report of all test results was prepared from this program and is enclosed in Appendix A (Volume II).

Section 2

TEST PROCEDURES

2.1 GENERAL

The vehicles, upon receipt by Olson for Task Order 02 were given a distinct identification number. This number was retained and will allow correlation with Task 02. The emission test data from the five catalyst-equipped vehicles was collected after a selected defect or defects had been induced.

The defects which were introduced are as follows: 1) Inoperative EGR, 2) Insufficient EGR, 3) No secondary air injection, 4) Insufficient secondary air injection, 5) Leaks in vacuum lines, 6) Excessive fuel at idle, 7) Insufficient fuel at idle, 8) High idle rpm, 9) Low idle rpm, 10) Over-rich main fuel system, 11) Over-lean main fuel system, 12) Low fuel pump pressure, 13) PCV valve stuck open, 14) PCV valve stuck closed, 15) Clogged air filter, 16) Over-rich carburetor power circuit, 17) Insufficient fuel from carburetor power circuit, 18) Defective intake valve, 19) Defective exhaust valve, 20) Intermittant misfire, 21) Bridged spark plug, 22) Reduced efficiency of the catalyst, 23) Advanced ignition timing 24) Retarded ignition timing, 25) Excessive centrifugal advance, 26) Insufficient Centrifugal advance, 27) Excessive vacuum advance, and 28) Insufficient vacuum advance.

Catalyst inlet and outlet temperature and instananeous exhaust gas flow rates and temperature also were determined for 20 tests defined by the Project Officer.

2.2 FUEL

All vehicles were tested with Indolene clear fuel except in the case of Car No. 2, where Indolene-30 was used to create an inefficient catalyst situation. Both fuels were inspected in accordance with 37 Federal Register 221, Section 85.075-10 and SAE Technical Report J171, Paragraph 2.1. Each batch of fuel used in the program was analyzed and reported in Appendix B.

2.3 TESTING SEQUENCES

The following procedures apply to all vehicles tested under this program. The gas tank was drained and then filled to approximately 80 percent capacity (to the nearest gallon) with test fuel. The vehicle was then operated on a dynamometer for approximately 10 minutes to both purge the fuel system of as-received fuel and to prepare the vehicle for the as-received, state-of-tune inspection. Upon completion of the 10-minute operating period, the vehicle was inspected to determine its as-received, state-of-tune. The results of this inspection were then recorded on the form shown in Figure 2-1. Following the vehicle engine parameter inspection, a vehicle preconditioning was performed consisting of one LA-4 driving cycle with no collection of emissions data. The vehicles were then cold-soaked in preparation for emissions testing in accordance with the Federal Test Procedure (vehicle fueling and fuel heating excluded).

The FTP was then run after at least a 12-hour soak but less than 24 hours. Following the FTP emissions test, the vehicle was tested in accordance with the short test sequence. This short test sequence constituted the vehicle precondioning for the second FTP emissions test on the

Olson Laboratories, Inc. Testing Services Division

1	11	13	15	18	22	25
A CARD	MO	DAY	YR	MFG	YR	MAKE/MODEL

33	46	48
SERIAL NUMBER	ST	LICENSE NUMBER

56	57	60	62	71	73
CYL	CID	BBL	EXHAUST CONTROLS	EVP	VEHICLE NO

CUSTOMER

Name ______ Address ______

City ______ State ______ Zip ______

Phone ______ Comments ______

SCHEDULING

Date ______ Time ______ Scheduled By ______

Directions: ______

1	11	13	15	18	20	22	24	26	30	35
B	MO	DAY	YR	A/C	P/S	P/B	TR	TR TYPE	AXLE	TIRE SIZE

45	52	57	62	66	73
ODOMETER	DWELL	TIMING	RPM	CO.%	VEHICLE NO

PERFORMANCE SCHEDULE

Ready for Inspection ☐

Pre-Inspection Complete — Accept ☐ Reject ☐

Mechanic ______

1st Test Complete ☐

Run No. ______

Cold Soak Time In ______ Time Out ______

2nd Test Complete ☐

Run No. ______

Cold Soak Time In ______ Time Out ______

3rd Test Complete ☐

Run No. ______ ☐

Car Returned ______ ☐
DATE/TIME

VEHICLE INSPECTION

	OK	Bad	COMMENTS
1] Oil Level	☐	☐	______
2] Radiator Level	☐	☐	______
3] Condition of Hoses	☐	☐	______
4] Transmission Level	☐	☐	______
5] PCV Valve	☐	☐	______
6] Ignition Wires	☐	☐	______
7] Belts	☐	☐	______
8] Tires	☐	☐	______
9] Exhaust System	☐	☐	______
10] Brakes	☐	☐	______
11] Air Cleaner	☐	☐	______
12] Other ______	☐	☐	______

Figure 2-1

vehicle when required. Following the completion of the second FTP on the vehicle, another short test sequence was performed. The data for each bag analysis was recorded on keypunch information sheets (Figures 2-2 and 2-3) for each defect. After the introduction of each defect, or defects, and prior to each baseline test, the vehicles were preconditioned following the same procedure.

2.3.1 Short Test Sequence

The short test sequence consists of the following tests and soak periods in the order shown:

1. Soak - 6 minutes
2. Clayton Key Mode (Idle in drive)
3. Soak - 6 minutes
4. Federal Three-Mode (Idle in neutral)
5. High-Speed Unloaded Test (2,500 rpm)
6. Soak - 6 minutes
7. Federal Short-Cycle
8. Soak - 6 minutes
9. New Jersey/New York Composite Cycle

Mass analysis of the exhaust samples taken during the Federal Short-cycle and NJ/NY Composite Cycle was found to be difficult due to the small sample volume obtained. In many cases, the volume was depleted before analyzer stabilization could be obtained. To solve this problem, two tests were run, one-after-another, for each of the two cycles for the last 20 vehicles tested, with the result that twice the volume was collected over twice the cycle driving distance. These factors-of-two cancel in the mass calculation. The doubled volume was found to be sufficient to ensure instrument stabilization.

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TEST INFORMATION

1 C CARD | 2 R/T | 4 RUN NO. | 11 MO | 13 DAY | 15 YR | 18 WB | 21 DB | 24 BARO | 30 INERTIA | 35 IHP | 40 AHP

P.I.C. ________________ T.D. ________________

45 ODOMETER | 73 VEHICLE NO.

EPA CERTIFICATION

COLD

1 D CARD | 2 R/T | 4 RUN NO. | 11 P IN | 17 HC, PPM | 22 CO, PPM | 28 CO_2, % | 33 NO_x, PPM

SAMPLE

43 TEMP | 46 V/REV | 52 REV | 58 HC, PPM | 62 CO, PPM | 66 CO_2, % | 71 NO_x, PPM | 73 VEHICLE NO.

BACKGROUND

STABILIZED

1 E CARD | 2 R/T | 4 RUN NO. | 11 P IN | 17 HC, PPM | 22 CO, PPM | 28 CO_2, % | 33 NO_x, PPM

SAMPLE

43 TEMP | 46 V/REV | 52 REV | 58 HC, PPM | 62 CO, PPM | 66 CO_2, % | 71 NO_x, PPM | 73 VEHICLE NO.

BACKGROUND

HOT

1 F CARD | 2 R/T | 4 RUN NO. | 11 P IN | 17 HC, PPM | 22 CO, PPM | 28 CO_2, % | 33 NO_x, PPM

SAMPLE

43 TEMP | 46 V/REV | 52 REV | 58 HC, PPM | 62 CO, PPM | 66 CO_2, % | 71 NO_x, PPM | 73 VEHICLE NO.

BACKGROUND

KEY MODE

1 G CARD | 2 R/T | 4 RUN NO.

HI: 11 MPH | 14 HC, PPM | 19 CO, % | 25 NO, PPM

LO: 30 MPH | 33 HC, PPM | 38 CO, % | 44 NO, PPM

IDLE: 49 MPH | 52 HC, PPM | 57 CO, % | 63 NO, PPM | 73 VEHICLE NO.

Figure 2-2

2-5

74-06-7-2

Olson Laboratories, Inc. Testing Services Division

EPA FED. 3-MODE

1 H CARD | 2 R/T | 4 RUN NO. | HI 11 MPH | 14 HC, PPM | 19 CO, % | 25 NO, PPM

LO 30 MPH | 33 HC, PPM | 38 CO, % | 44 NO, PPM | IDLE 49 MPH | 52 HC, PPM | 57 CO, % | 63 NO, PPM | 73 VEHICLE NO.

UNLOADED TEST

1 J CARD | 2 R/T | 4 RUN NO | 11 RPM | 16 HC, PPM | 21 CO,% | 27 NO, PPM

48 COMMENTS | 73 VEHICLE NO.

EPA FED. SHORT CYCLE

1 K CARD | 2 R/T | 4 RUN NO. | 11 P IN | 17 HC, PPM | 22 CO, PPM | 28 CO_2, % | 33 NO_x, PPM

SAMPLE

43 TEMP | 46 V/REV | 52 REV | 58 HC, PPM | 62 CO, PPM | 66 CO_2, % | 71 NO_x, PPM | 73 VEHICLE NO.

BACKGROUND

COMPOSITE NJ/NY TEST

1 L CARD | 2 R/T | 4 RUN NO. | 11 P IN | 17 HC, PPM | 22 CO, PPM | 28 CO_2, % | 33 NO_x, PPM

SAMPLE

43 TEMP | 46 V/REV | 52 REV | 58 HC, PPM | 62 CO, PPM | 66 CO_2, % | 71 NO_x, PPM | 73 VEHICLE NO.

BACKGROUND

CATALYST SPEC. TEST

1 M CARD | 2 R/T | 4 RUN NO. | 11 RPM | 16 HC, PPM | 21 CO,% | 27 NO, PPM | 32 HC, PPM | 37 CO,% | 43 NO, PPM

BEFORE CATALYST | AT TAIL PIPE

48 COMMENTS | 73 VEHICLE NO

Figure 2-3

74-67-3

2.3.2 Soak - 6 Minutes

The 6-minute soak procedure is performed as follows. After the completion of the preceding test, the vehicle engine is stopped, the vehicle hood is closed if it was open, and the auxiliary air cooling fan is turned on if it was not previously in use. The fan remains in operation for 3 minutes. At the end of 3 minutes, the auxiliary air fan is turned off and the vehicle's engine is started. The engine is allowed to idle in neutral for 3 minutes. Upon the completion of this 3-minute idle period, the next test in the sequence is initiated.

2.4 TEST DESCRIPTIONS

2.4.1 Federal Test Procedure

The Federal Test Procedure is performed as described in Federal Register, Volume 37, Number 221, Section 85.075-9 through 85.075-26 (evaporative emissions testing is excluded). Vehicle preconditioning for vehicles 4101 to 4150 consisted of one short test sequence as described in 2.3.1, or, for vehicles 4151 to 4170, an initial LA-4 driving cycle. In addition to the bag emissions data taken during the FTP, continuous trace data was recorded for HC, CO, CO_2 and NO_x.

2.4.2 Clayton Key Mode

This short test consists of three steady-state operating conditions, as described below, from which exhaust samples are taken by the volumetric procedure. HC and CO values are obtained using a Horiba Instruments GSM 300; and NO values are obtained from the continuous trace information. The vehicle is operated in each mode until the exhaust emissions stabilize. The vehicle hood is closed and the auxiliary cooling fan is not in operation while conducting this test.

For this class of vehicle (5,000 pounds):

Trans. Range	Dyno Load (hp @ mph)	High Speed Cruise (mph)	Low Speed Cruise (mph)	Idle
Drive	30 @ 50	48 to 50	32 to 35	Automatic Trans. in Drive

2.4.3 Federal Three-Mode

This short test consists of three steady-state operating modes (similar to Clayton Key Mode) with the dynamometer loads simulating the average power which occurs at the appropriate speed on the FTP. Emissions are measured by the volumetric procedure for each mode as described for the Key Mode test. The vehicle is operated in each mode until emissions stabilize with the hood closed and no auxiliary cooling fan in use.

For this class of vehicle (5,000 pounds):

Transmission Range	High-Speed Mode Speed mph	High-Speed Mode Load hp	Low-Speed Mode Speed mph	Low-Speed Mode Load hp	Idle Mode
Drive	50	36	30	18	Automatic Transmission in Neutral

2.4.4 High-Speed Unloaded Test

HC, CO and NO exhaust emissions are measured by the volumetric procedure at an engine speed of 2,500 rpm with the transmission in neutral. The vehicle is operated in this mode until the emissions stabilize. The vehicle hood is closed and there is no auxiliary cooling fan in use while conducting this test.

2.4.5 Federal Short-Cycle

This is a nine-mode, CVS test of 125 seconds duration which follows the driving schedule shown below:

Mode	Time in Mode (seconds)
0 - 16 mph acceleration	6.0
16 - 29 mph acceleration	23.0
29 mph cruise	10.0
29 - 37 mph acceleration	18.0
37 - 42 mph acceleration	4.5
42 - 37 mph deceleration	2.5
37 - 20 mph deceleration	32.0
20 - 0 mph deceleration	7.5
Idle	21.5
	125.0 seconds total

The dynamometer loadings and transmission shift points follow the procedure as required for the FTP.

During the performance of the Federal Short-Cycle, the vehicle hood is closed and the auxiliary cooling fan is not in operation.

2.4.6 Composite of NJ ACID Test and NY Short Test

This is a six-mode, CVS test of 75 seconds duration which follows the driving cycle shown below:

Mode	Time in Mode (seconds)
Idle	22
0 - 30 mph acceleration	15
30 mph cruise	15
30 - 10 mph deceleration	12
10 mph cruise	7
10 - 0 mph deceleration	4
	75 seconds total

All vehicles are tested at an inertia weight of 3,000 pounds and 3.5 hp at 30 mph. This test is performed with the vehicle hood closed and without the use of an auxiliary air cooling fan.

2.5 PROCEDURAL PRECAUTIONS

2.5.1 Dynamometer Warm Up

If the dynamometer had not been operated during the 2-hour period immediately preccding the test, it was warmed up for 15 minutes by operating it at 30 mph using a non test vehicle. A non test vehicle is defined as a vehicle not scheduled for any emission test in the following 12 hours.

2.5.2 Pedal Operation

All operation of the accelerator and the brake pedals was accomplished with the right foot only.

2.5.3 Invalid Tests

Departures from the driver's trace beyond the limits allowed normally causes an invalid test. Those departures which were generally due to the malfunctioning vehicles were immediately noted on the trace itself. Those few departures that were due to driver error were repeated.

Section 3

DEFECT SCHEDULE

The details of the "Defect Vehicle Test Schedule" were supplied by the Project Officer. Each defect was incorporated into the five selected Ford catalyst-equipped prototype vehicles. The scheduled defects by vehicle are included in the following pages.

3.1 SCHEDULE MODIFICATIONS

The schedule was modified with the approval of the Project Officer and is included in the text in final form. The changes are as follows:

Car No. 1

Step 6 - The missfire generator was inadvertently left on 10 percent for the first test so an additional test was added as Step 21 (Test 23) prior to the final baseline.

Car No. 2

Step 14 - The emission did not return to normal following the test using leaded fuel so a final baseline was run and the remaining two steps deleted from that vehicle were added to Car No. 4.

Car No. 4

Step 13 and 16 - None of the Ford vehicles had a vacuum spark disconnect circuit so both steps were deleted. They were replaced with the final two steps from Car No. 2 which followed the last scheduled baseline on this vehicle.

Car No. 5

Step 9 - The power circuit was improperly disabled so that extraneous values were noticed. The carburetor was disassembled and the power circuit reexamined. The resulting defect had the effect of disabling the power circuit so that the manifold vacuum had to effect on the valves operation producing an ultra rich situation. The test was repeated with the defect reinduced. Both sets of data were reported since the first set was significant due to the H_2S odor which became obvious during the hot "505" portion of the FTP.

C A R S E T U P P R O C E D U R E

STEP NO.	TYPE OF DEFECT	PROCEDURE	NO. OF TESTS THIS STEP	TOTAL NO. OF TESTS
		CAR NO. 1		
1	Baseline	Check CO at idle with secondary air disconnected upstream of the catalyst. Reconnect secondary air.	1	1
2	Rich idle	Richen idle system to either 5 percent CO before catalyst with secondary air disconnected or 100 rpm drop due to enrichment from lean best idle. Reconnect secondary air.	2	3
3	Rich idle	Richen idle system to 8 percent CO before catalyst with secondary air disconnected. Reconnect secondary air.	1	4
4	Baseline	Return idle mixture to original setting.	0	4
5	Intermittent missfire	Introduce intermittent missfire (electronically short cylinders at random) at 10 percent missfire rate.	2	6
6	Intermittent missfire	Introduce intermittent missfire at 3 percent missfire rate.	1	7
7	Baseline	Return ignition system to original condition and setting.	0	7
8	No EGR	Deactivate EGR system	2	9
9	Baseline	Set all parameters (CO, ignition, and EGR to original baseline values and test.	1	10
10	Clogged air filter	Using a new air filter element mask 95 percent of its flow area or sufficient to cause a ten-fold increase in Δp and then test vehicle. Leave the	1	11

STEP NO.	TYPE OF DEFECT	PROCEDURE	NO. OF TESTS THIS STEP	TOTAL NO. OF TESTS
		CAR NO. 1 (Continued)		
10	Cont'd	open zone of the element in two quadrants of the circumference. Δp to be read at 50 mph key mode loading. (Δp to be measured across element only - do not include Δp across air horn.)		
11	Clogged air filter	Mask or otherwise choke the flow of air through the air filter element so as to obtain a five-fold increase in Δp across the air filter at 50 mph key mode loading. (Δp to be measured across element only - do not include Δp across air horn.)	2	13
12	Baseline	Return the car to the original condition.	0	13
13	Intermittent missfire plus idle system too rich	Introduce intermittent missfire at 10 percent missfire rate as in Step No. 5 plus richen the idle system to 5 percent CO before catalyst with secondary air disconnected. Reconnect or 100 rpm drop.	1	14
14	Intermittent missfire plus idle system too lean	Introduce intermittent missfire at 10 percent missfire rate as in Step No. 5 plus lean out the idle system to .5 percent CO or lowest CO level possible without missfire, before catalyst with secondary air disconnected. Reconnect.	1	15

CAR SETUP PROCEDURE

STEP NO.	TYPE OF DEFECT	PROCEDURE	NO. OF TESTS THIS STEP	TOTAL NO. OF TESTS
		CAR NO. 1 (Continued)		
15	Intermittent miss-fire plus EGR plugged	Deactivate the EGR system plus introduce intermittent miss-fire at 10 percent rate as in Step No. 5.	1	16
16	Baseline	Return the vehicle to original condition. Run one baseline test.	1	17
17	Idle system too rich plus EGR not working	Deactivate EGR system plus richen idle system to 5 percent before catalyst with secondary air disconnected.	1	18
18	Idle system too rich plus ignition timing advanced	With 5 percent idle CO advance basic idle timing 6 degrees. EGR system operating normally.	2	20
19	Idle system too rich plus ignition timing retarded	With 5 percent idle CO retard basic idle timing by 6 degrees.	1	21
20	Idle system too rich plus main fuel system too rich	Install main fuel jets which are three sizes too large as per Car No. 2, Step. No. 6 and set idle CO at 5 percent level with secondary air disconnected.	1	22
21	Intermittent miss-fire	Introduce intermittent miss-fire at 3 percent missfire rate.	1	23
22	Baseline	Return the vehicle to original condition. Run one baseline test.	1	24

CAR SETUP PROCEDURE

STEP NO.	TYPE OF DEFECT	PROCEDURE	NO. OF TESTS THIS STEP	TOTAL NO. OF TESTS
		CAR NO. 2		
1	Baseline	Check CO, timing, dwell, etc., and record. Perform one baseline test on vehicle.	1	1
2	Advanced basic ignition timing	Using a distributor with vacuum and centrifugal advance characteristics representative of the five cars under test, advance the idle timing by 6 degrees (not to exceed audible knock during first large acceleration on FTP when engine is hot).	2	3
3	Baseline	Return timing to original setting.	0	3
4	Insufficient secondary air	Modify the secondary air supply system (larger pulley, air leak, etc.), so as to obtain approximately a 50 percent reduction in secondary air injection. Clamp off air. Pump output = 6 psi. Clamp off to 3 psi.	2	5
5	Baseline	Return secondary air injection system to normal.	0	5
6	Over rich main fuel system	Install main fuel jets which are three sizes (.003 inches) larger than original fuel jets, e.g., 47F to 50F jet sizes. Fuel float level remains as previously set.	2	7
7	Baseline	Return main fuel jets to original size.	0	7
8	High rpm idle	Increase engine idle speed by 150 rpm to approximately 800 rpm. All other parameters remain as at lower idle speed.	1	8

STEP NO.	TYPE OF DEFECT	PROCEDURE	NO. OF TESTS THIS STEP	TOTAL NO. OF TESTS
		CAR NO. 2 (Continued)		
9	High rpm idle	Increase engine idle speed by 70 to 100 rpm to between 725 and 750 rpm.	2	10
10	Baseline	Set all parameters to original baseline levels and test.	1	11
11	Inefficient catalyst	Drain the zero lead fuel from the vehicle and refuel with leaded regular gasoline. Operate the vehicle so as to consume the tank of gasoline. Replenish the gasoline supply and test the vehicle once. Remove the leaded fuel and replace with unleaded (30 percent of tank volume). Repeat the test. Fill the vehicle with leaded fuel. Test again.	3	14
12	Inefficient catalyst plus intermittent missfire	With the catalyst operating inefficiently as in Step No. 11, introduce a 10 percent intermittent missfire rate and test on leaded fuel.	1	16
13	Inefficient catalyst plus rich idle	Set idle CO at 5 percent (without secondary air). Ignition system operating normally. Test using leaded fuel. Return all components to normal and operate the car on unleaded fuel at high loads and speed so as to reactivate the catalyst.	1	17

STEP NO.	TYPE OF DEFECT	PROCEDURE	NO. OF TESTS THIS STEP	TOTAL NO. OF TESTS
		CAR NO. 2 (Continued)		
14	Baseline	Test the car on unleaded fuel. If the emissions have returned to the original baseline level proceed with the next step. If the emissions have not returned to "normal" operate for one further tank of unleaded fuel. If the emissions have still not normalized the remainder of this vehicle's tests will be performed on another vehicle.	2	18A & 18B

CAR SETUP PROCEDURE

STEP NO.	TYPE OF DEFECT	PROCEDURE	NO. OF TESTS THIS STEP	TOTAL NO. OF TESTS
		CAR NO. 3		
1	Baseline	Check CO, timing, dwell, etc., and record. Perform one baseline test on the vehicle.	1	1
2	Retarded timing (basic)	Using a distributor with vacuum and centrifugal advance characteristics representative of the five cars under test, retard the idle timing by 6 degrees.	2	3
3	Baseline	Return car to original condition.	0	3
4	Early power circuit activation	Search the Ford Motor Company parts specifications and determine the power value part number which is designed to "come in" soonest, i.e., about 10 inches. Install this part in the carburetor.	2	5
5	Baseline	Return car to original condition.	0	5
6	No secondary air injection	Deactivate the secondary air injection system.	2	7
7	Baseline	Return car to original condition.	0	7
8	Timing over advancing (vacuum)	Modify the vacuum advance mechanism so as to give early advancing without impacting the maximum advance obtained. Modify so as to obtain the same advance at 10 inches as would normally be obtained at 15 inches.	2	9

C A R S E T U P P R O C E D U R E

STEP NO.	TYPE OF DEFECT	PROCEDURE	NO. OF TESTS THIS STEP	TOTAL NO. OF TESTS
		CAR NO. 3 (Continued)		
9	Baseline	Return car to original condition. NOTE: The following tests contain two or more common defects.	1	10
10	Rich idle plus intermittent missfire of spark plugs	Richen idle system to either 5 percent CO before catalyst with secondary air disconnected or 100 rpm drop rich from lean best idle plus introduce intermittent missfire at a 10 percent missfire rate.	1	11
11	Baseline	Return car to original condition.	0	11
12	EGR not working plus ignition timing advanced	Deactivate EGR system plus advance the idle timing by 6 degrees (no audible knocks).	2	13
13	Baseline	Return car to original condition. Run one baseline test.	1	14
14	Reduced flow from secondary air system plus over rich main fuel system	Modify secondary air supply system to obtain approximately a 50 percent reduction in secondary air injection plus install main fuel jets which are three sizes larger than original fuel jets.	2	16

CAR SETUP PROCEDURE

STEP NO.	TYPE OF DEFECT	PROCEDURE	NO. OF TESTS THIS STEP	TOTAL NO. OF TESTS
		CAR NO. 3 (Continued)		
15	Reduced secondary air flow plus lean main fuel system	Remove oversize jets and install undersize jets (two sizes smaller) and retest with reduced secondary air flow, (reduction same as Step No. 14).	1	17
16	Baseline	Return car to original condition.	0	17
17	Retarded ignition timing plus high idle rpm	Increase idle rpm 100 rpm and retard idle basic timing by 6 degrees.	1	18
18	Baseline	Return the car to original condition. Run one base-line test.	1	19

CAR SETUP PROCEDURE

STEP NO.	TYPE OF DEFECT	PROCEDURE	NO. OF TESTS THIS STEP	TOTAL NO. OF TESTS
		<u>CAR NO. 4</u>		
1	Baseline	Check CO, timing, dwell, etc., and record. Perform one baseline test on vehicle.	1	1
2	Timing under advancing (vacuum)	Modify the vacuum advance mechanism so as to give late advancing without impacting the maximum advance obtained. Modify so as to obtain the same advance at 10 inches as would be obtained at 5 inches.	2	3
3	Baseline	Return car to original condition.	0	3
4	Timing over advancing (centri-fugal)	Modify the centrifugal advance mechanics so as to give early advancing without increasing the maximum cen-trifugal advance possible. Modify so as to obtain the same advance at 1,500 rpm (distributor) as would be obtained at 2,000 rpm norm-ally. Norm = 10 degrees at 2,000 rpm Dist.	2	5
5	Baseline	Return car to original condition.	0	5
6	Timing under advancing (centri-fugal)	Modify the centrifugal advance mechanism so as to give late advancing without impacting the vacuum advance circuit or the maximum amount of centrifugal advance. Modify so as to obtain the same advance at 2,000 rpm (distri-butor) as would be obtained at 1,500 rpm normally.	2	7

STEP NO.	TYPE OF DEFECT	PROCEDURE	NO. OF TESTS THIS STEP	TOTAL NO. OF TESTS
		CAR NO. 4 (Continued)		
7	Baseline	Return car to original condition. Perform one baseline test.	1	8
8	Vacuum line leaking	Remove one of the nonemission control device vacuum lines from the Christmas tree. Meter if necessary to prevent excessive lean missfire which could cause engine stalling.	2	10
9	Baseline	Return car to original condition.	0	10
10	PCV valve stuck closed	Remove PCV valve and plug PCV line allowing no possible crankcase ventilation.	1	11
11	PCV valve stuck open	Remove blockage in PCV line and reconnect with PCV valve in circuit but locked open.	1	12
12	Baseline	Return to original condition by reinstalling good PCV valve.	0	12
13	Baseline	Perform one baseline test.	1	13
		NOTE: The following tests contain two or more defects.		
15	Idle system too rich plus secondary air disconnected	Richen idle system to 5 percent CO before catalyst with secondary air disconnected	1	14
17	Idle system too rich plus PCV valve blocked	With idle CO at 5 percent, plug PCV system so that there is no flow into the intake manifold.	1	15

STEP NO.	TYPE OF DEFECT	PROCEDURE	NO. OF TESTS THIS STEP	TOTAL NO. OF TESTS
		CAR NO. 4 (Continued)		
18	Baseline	Return vehicle to original condition. Perform one baseline test.	1	16
19	One defective spark plug	Disconnect the high tension lead to one spark plug to simulate a bridged plug or failed lead.	1	17
20	Baseline	Perform one baseline test	1	18

CAR SETUP PROCEDURE

STEP NO.	TYPE OF DEFECT	PROCEDURE	NO. OF TESTS THIS STEP	TOTAL NO. OF TESTS
		CAR NO. 5		
1	Baseline	Check CO, timing, dwell, etc., and record. Perform one baseline test on the vehicle.	1	1
2	Idle system lean	Lean idle system to either .5 percent CO before catalyst with secondary air disconnected or 100 rpm drop lean from lean best idle. Do not allow excessive missfire, however.	2	3
3	Baseline	Return idle setting to original setting.	0	3
4	Idle system low rpm	Decrease idle rpm 75 to 100 rpm while holding all other parameters at manufacturer's specifications.	2	5
5	Idle	Decrease idle rpm by 150 rpm providing missfire is not encountered.	1	6
6	Baseline	Return car to original setting.	0	6
7	Lean main fuel system	Install main fuel jets which are two sizes (.002 inches) smaller than original fuel jets. Fuel float level remains same as with original jets.	2	8
8	Baseline	Remove jets and reinstall original jets. Run one baseline test.	1	9
9	Carburetor power circuit	Disable carburetor power circuit so that the vehicle receives no power circuit operation.	2	11
10	Baseline	Return vehicle to original condition by reactivating power circuit.	0	11

STEP NO.	TYPE OF DEFECT	PROCEDURE	NO. OF TESTS THIS STEP	TOTAL NO. OF TESTS
		CAR NO. 5 (Continued)		
11	EGR circuit reduced flow	Reduce EGR flow in EGR circuit by approximately 50 percent by blocking EGR tube to carburetor base plate.	2	13
12	Baseline	Restore full EGR flow and return vehicle to original condition.	0	13
13	Fuel pump low pressure	Reduce fuel pump pressure by 25 percent and test vehicle once.	1	14
14	Baseline	Restore full fuel pump pressure and run one baseline test.	1	15
15	Valves defective	Remove cylinder head from vehicle. Obtain one replacement exhaust valve from a Ford dealer and cut a wedge in the face of the valve which has an area removed corresponding to 5 to 10 percent of the total valve face area. Install valve in the front cylinder and reinstall head. Maintain the same valve lash for the original valve removed.	2	17
16	Valves defective intake	Remove cylinder head and defective exhaust valve. Obtain the corresponding intake valve for this vehicle and also take a wedge of 5 to 10 percent of the total valve face from the intake valve. Install the front cylinder. Install original nondefective exhaust valve.	2	19
17	Baseline	Remove cylinder head and defective valve. Reinstall original valve. Run one baseline test.	1	20

3.2 TEMPERATURE AND FLOW MEASUREMENT

Catalyst inlet and outlet temperature and instantaneous exhaust gas temperature and flow rates were measured on 20 vehicles. The Project Officer specified the tests on each vehicle which were to be measured.

The tests are listed below by test and run number.

	Test	Run No.
Car No. 1	5	A08156
	6	A08190
	7	A08232
	11	A08265
	14	A08306
	15	A08319
	19	A08443
	20	A08446
	23	A08478
	24	Not Complete (A08504)
Car No. 2	15	A08214
	16	A08231
	17	A08253
	20	No Test (See 254)
Car No. 3	6	A08100
	7	A08180
Car No. 4	15	A08241
	17	A08266
	20	A08537
Car No. 5	6	A08125
	14	A08278
	20	A08477

A Honeywell multi-point temperature recorder 0 to 2,000^{o}F full scale Chromel-Alumel thermocouples installed in the available ports were used to monitor the catalyst inlet and outlet temperature.

A Honeywell Electronic 19 recorder was used to record exhaust flow rates and temperatures. The exhaust flow rate was recorded for the range of 0 to 200 acfm full scale and the exhaust gas temperature was spanned at 0 to 50 mv Iron-Constantan thermocouples full scale. A J-Tec experimental model ultra sonic vortex shedding flow meter was installed between the tail pipe and the CVS. The flow and temperature were measured in the center of the stream.

The mechanic's defect inducement sheets are included in the appendix.

Section 4

TEST EQUIPMENT

4.1 MAJOR EQUIPMENT

Hydrocarbon (HC) measurements were made by flame ionization instrumentation (FID), carbon monoxide (CO) and carbon dioxide (CO_2) by NDIR instrumentation, and oxides of nitrogen (NO_x) measurement by the chemiluminescence (CL) method. The following major equipment was used:

Scott Model 116 Flame Ionization Analyzer using 40 percent H_2 - 60 percent N_2 fuel with the following full-scale ranges:

0 - 100 ppm	Carbon
0 - 300 ppm	Carbon
0 - 3,000 ppm	Carbon

Beckman 108A Flame Ionization Analyzer using 40 percent H_2 - 60 percent N_2 fuel with the following full-scale ranges:

0 - 1,000 ppm	Carbon
0 - 3,000 ppm	Carbon
0 - 10,000 ppm	Carbon

Horiba AIA-21 NDIR carbon monoxide analyzer with a full-scale range of 0 to 750 ppm.

Horiba AIA-2 NDIR Analyzers with the following full-scale ranges:

Carbon Monoxide	0 to 0.2 percent
Carbon Monoxide	0 to 10 percent
Carbon Dioxide	0 to 15 percent

Beckman 315 B Analyzers with the following full-scale ranges:

Carbon Monoxide	0 to 0.3 percent
Carbon Monoxide	0 to 3 percent
Carbon Dioxide	0 to 4 percent

Scott Model NO Analyzer of the chemiluminescence type. This analyzer incorporates a thermal converter for the conversion of nitrogen dioxides (NO_2) to nitric oxide (NO). The NO analyzer full-scale ranges are as follows:

0 to 100 ppm	NO
0 to 250 ppm	NO
0 to 1,000 ppm	NO

TECO NO Analyzer of the chemiluminescence type. This analyzer incorporates a thermal converter for the conversion of nitrogen dioxide (NO_2) to nitric oxide (NO). The NO analyzer full-scale ranges are as follows:

0 to 1,000 ppm	NO
0 to 2,500 ppm	NO
0 to 10,000 ppm	NO

The operating ranges specified for the above sampling conditions and analytic system(s) were expected to cover the concentrations encountered in the performance of this program. In two cases, the undiluted continuous trace data for HC exceeded 3,000 ppm.

The Constant Volume Sampler (CVS) conforms to the specifications listed in 37 Federal Register 221 (Section 85.075-20).

The Laminar Flow Element (Meriam Model 50 MC 2-4) was used for calibration of the CVS.

Teh instrument used tor measurement of undiluted HC and CO emissions is a Horiba Instrument, GSM 300. This portable, repair-garage-type instrument is capable of measuring hydrocarbons in ranges of 0 to 400 ppm and 0 to 2,000 ppm carbon and carbon monoxide in concentration ranges of 0 to 2 percent and 0 to 10 percent.

The dynamometer used is a Clayton Variable Inertia Flywheel Dynamometer with 250-pound increment inertia loading weights (below 3,000 pounds inertia weight) and road-loading characteristics. This dynamometer is suitable for use in emission testing up to 5,500 pounds inertia weight.

Continuous trace data were collected for HC, CO, CO_2, and NO. The recorders used were Honeywell Electronic 194, two-pen recorders. The following chart speeds were used:

6 inches per minute for all volumetric measurements, other than the FTP traces which were run at 3 inches per minute.

3 inches per minute for FTP mass measurements from the bag samples.

6 inches per minute for Federal Short-Cycle and Composite NJ/NY mass measurements for vehicles 4101 to 4170.

4.2 CALIBRATION

Analyzers, constant volume sampler, dynamometer calibration gases, and capabilities of personnel were qualified to the satisfaction of the Project Officer prior to the start of the vehicle testing. Calibration curves for the exhaust analyzers, were checked on a monthly basis with zero and span checks made prior to the analysis of each sample. An NO_x converter efficiency check was made weekly. The CVS was checked daily utilizing the Propane Injection Test. The dynamometer calibration was checked monthly. The EPA/Army calibration gases used in the performance of the Task Order 02 project were returned to the Army and replaced with "Golden Standard" gases from the EPA/Olson surveillance program at Levittown, Pennsylvania.

The HC, CO, CO_2, and NO_x instruments were calibrated against these gaseous standards. Each CO and CO_2 instrument was calibrated with at least five points spread somewhat evenly across each range.

Calibration of the FID and the CL analyzer was with at least three points across each range.

Samples of data forms used for analyzer curve generation, CVS and mass bench propane injection tests, and daily start-up check sheets for mass and volumetric benches are given in Figures 4-1 to 4-4, respectively.

All instruments were calibrated prior to commencing this group of testing. A new mass bench had been installed in January and February and a complete calibration was performed using "Golden Standard" gases from the EPA/Olson surveillance test program at Levittown, Pennsylvania.

A calibration check was performed on April 10, 1975 on the analyzers and ranges used in the previous month. New curves were required for HC, 0 to 3,000 ppm and CO_2, 0 to 4 percent on the mass train and CO, 0 to 3,000 ppm on

ANALYZER CURVE GENERATION DATA

DEPT. NO. ________ TRAIN ________ DATE ________ PIC ________

ANALYZER ________ RANGE ________

PURPOSE ________

MAKE ________ MODEL ________ SERIAL NO. ________

DETECTOR NO. ________ CELL LENGTH ________ RANGE SELECT ________

ANALYZER DATA: TUNE ________ GAIN ________ ZERO ________

FLOW RATES (Sample, By-pass, etc) ________

____

OTHER PARAMETERS (Sample, Oxygen, Air, Fuel-pressure) ________

____

CURVE DATA: Deflection = [Recorder /_/ [DVM /_/ Zero Gas = [Zero Air /_/ [Nitrogen /_/

Cylinder	Type	Concentration	Deflection	Comp. No.
Zero Gas		0.00	0.0	0

Computer Information: Data Tables Changed Y__N__; Curve Fit

Method ________

Strip Charts Attached /_/ Data Tables Attached /_/

Comments: ________

____

____

____

Figure 4-1

PROPANE INJECTION TEST

Date:__________ CVS Frame #__________ PIP__________

Train #__________ Dept. #__________ Time__________ AM PM

I. Calculation of V_{mix} (Total Volume of Mixture)

A. P_B = Barom. Pres. = ______ In. Hg x 25.4 = ________ mm Hg

B. P_I = Pump Inlet Dpr = ______ In. H_2O x 1.868 = ________ mm Hg

C. P_p = Pump Inlet Pres. = $P_B - P_I$ = ____________ mm Hg

D. P_O = Pump Outlet Pres. = ______ In. H_2O ΔP = ______ In. H_2O

E. T_p = Pump Inlet Temp. = ________ $^{o}F + 460^{o}F$ = ________ ^{o}R

F. $P_p \div T_p$ = ________

G. N = Pump Revs = ________ Time = ________ min; RPM = ________

H. V_O = Pump Vol. per Rev = ________ ft 3/rev

I. $V_{mix} = \frac{P_p}{T_p} \times N \times V_O \times .69474$ = ________ ft^3

II. A. Weight Exp. B. Bag Analysis

Cylinder (gms)		Bag	Deflection	Range	Concentration (ppm)
Before =	____	Sample	____	____	____
After =	____	Bkgd	____	____	____
Δ =	____			Conc =	____

III. Mass Calculation (Mass = V_{mix} x 17.3 x Conc x 10^{-6})

Mass = ________ gms

$$\text{Error} = \frac{\Delta - \text{Mass}}{\Delta} \times 100 = \_\_\_\_ \%\ H/L$$

COMMENTS:____________________

QC Use	
Approved	____
Rejected	____
By	____

Figure 4-2

OLSON LABORATORIES, INC.

TESTING SERVICES DIVISION

MASS START-UP CHECK SHEET

DEPT NO.	SHIFT	TRAIN	DATE	P.I.C.	WEEKLY	DAILY

CALIBRATION

	HIGH								INTERMEDIATE						
	RNG	GAIN	ZERO	CYL NO.	CONC	DEFL	PRESS.	TUNE	GAIN	ZERO	CYL NO.	CONC	DEFL	PRESS.	MFGRS MODEL NO.
CO	0.3														
	3.0														
FIA	500														
	1K														
	4K														
NO_x	250														
	1K														
CO_2	4.0														
ZERO															

RECORDER				PRESSURE						BYPASS	CONV	REACTOR	LEAK CHECK				
CHART SP	ZERO	GAIN	DVM CORR		SAMPLE	FUEL	AIR	OZONE		FLOW RT	IND TEMP	OPR PRESS.		FIA	CO	CO_2	NO_x
				FIA									FL MTR OBS				
				NO_x							°C	MM	MAG OBS				

CVS

1 MIN. COUNT	IN. PRESS.	OUT. PRESS.	T.P. PRESS.	VOL/REV	FLEX	ADAP	BAGS	LIGHTS	PUMPS	SWITCHES	TEMP CONTROL

COMMENTS

FORM GC 02 1 FEB 72 WHITE/SITE FILE CANARY/QUALITY CONTROL PINK/REGIONAL MANAGER

Figure 4-3

OLSON LABORATORIES, INC.

TESTING SERVICES DIVISION

7-MODE START-UP CHECK SHEET

DEPT NO.	SHIFT	TRAIN	DATE	P.I.C.	WEEKLY	DAILY

CALIBRATION

	HIGH								INTERMEDIATE						
	RNG	GAIN	ZERO	CYL NO.	CONC	DEFL	PRESS.	TUNE	GAIN	ZERO	CYL NO.	CONC	DEFL	PRESS.	MFGRS MODEL NO.
CO	0.3														
	10														
FIA															
	1K														
	3K														
NO_x	1K														
	2.5K														
CO_2	15														
ZERO															

RECORDER				PRESSURE						BYPASS	CONV	REACTOR	LEAK CHECK				
CHART SP	ZERO	GAIN	DVM CORR		SAMPLE	FUEL	AIR	OZONE		FLOW RT	IND TEMP	OPR PRESS.		FIA	CO	CO_2	NO_x
				FIA									FL MTR OBS				
				NO_x							°C	MM	MAG OBS				

COMMENTS

Figure 4-4

4-8

FORM GC 02 FEB 74 WHITE/SITE FILE CANARY/QUALITY CONTROL PINK/REGIONAL MANAGER the volumetric train. The new curves were generated and sent to Warner Lee at Aerospace Corporation. A dynamometer curve check was performed April 7, with no change required. Recalibration of the CVS was not found to be necessary.

Analyzer calibration curve points, CVS calibration, and dynamometer calibration curve point tables are presented in Appendices C, D, and E, respectively.

Section 5

DATA PREPARATION

Test data were entered on punched, interpreted cards (except driver traces) in a format approved by the Project Officer shortly after contract award. The format is identical to that used for Task Order 02.

5.1 TEST DATA

Vehicle information consists of basic parameters such as vehicle program identification number, make, model-year, accumulated mileage, date(s) of test(s), engine displacement, carburetion, transmission type, emission control systems on the vehicle, inertia weight, horsepower settings, license number, owner identification, VIN, engine parameter settings and identification of control systems either inoperative or functioning improperly. (See Figure 2-1.)

Exhaust emission test results include ambient temperature, barometric pressure, humidity, mass emissions in each bag from the FTP and each CVS sampled short test, and concentration emissions from each mode for all other short tests. (See Figures 2-2 and 2-3.) NO_x is reported as NO_2 both as measured and corrected for relative humidity. The humidity correction factor was calculated from a method provided by EPA dated March 8, 1974.

Grams-per-mile emissions for the FTP were calculated per the Federal Register, Volume 37, Number 221, Section 85.075-26.

Mass emissions for the Federal Short-Cycle test were computed by the following formulas:

$$m = Vdc/a$$

where:

m = mass emissions in grams-per-mile

V = total CVS flow = volume per revolution times revolution count

d = density of the exhaust component

c = measured concentration in the bag less the background concentration

a = cycle length in miles (0.7536)

Measured concentration values for the composite NJ/NY test are reported, but mass emissions were not computed.

Fuel usage, in miles per gallon, was calculated from the bag data according to the carbon balance technique and reported for each FTP on each vehicle.

All data were transmitted to Warner Lee at Aerospace Corporation for statistical analysis upon completion of an error screening process and computer run. This submittal was made on the Friday of the week following actual testing. Each submittal included all emissions strip charts, the driver's trace, CVS temperature trace, computer summary printout for all tests for that week, and the test data on punched 80-column computer cards.

5.2 REPORTS

5.2.1 Weekly Reports

Data were recorded on punched, interpreted and verified cards. Cards, strip charts and computer printouts covering each week's work were sent to Warner Lee at Aerospace Corporation, El Segundo, California, by the Friday of the following week.

Weekly progress reports were made by telephone to the Task Project Officer or his representative during the morning of the last day of the business week (normally Friday).

5.2.2 Monthly Reports

Olson furnished letter-type monthly reports to the Task Project Officer and one copy to the Contracting Officer by the 15th of the month following the month being reported on. These reports outlined the progress made, together with slippages and procedures for correction.