Emission Laboratory Correlation Study Between EPA and the Motor Vehicle Manufacturers Association of the United States, Inc.

by

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ABSTRACT

This report presents the results of an emission laboratory correlation study involving EPA and the Motor Vehicle Manufacturers Association of the United States, Inc. (MVMA). It specifically compares test equipment characteristics and vehicle emission measurements at the test facilities of EPA, American Motors Corporation, Chrysler Corporation, Ford Motor Company, General Motors Corporation, and International Harvester Company.

In general, the facilities involved in this study exhibited a high degree of equipment and emission test correlation. Factors which may affect emission measurement correlation, including dynamometers, constant volume samplers, gas analysis systems, and ambient conditions, are presented and discussed.

Introduction:

On February 13, 1974, EPA representatives attended a meeting of MVMA's Exhaust Emission Measurement Panel to discuss details of a proposed cross-correlation program. At that meeting, EPA and representatives of American Motors Corporation (AMC), Chrysler Corporation, Ford Motor Company, General Motors Corporation (GMC), and International Harvester Company (IHC) approved a three phase correlation program which was designed to check equipment, procedures, and vehicle emission levels at all participating laboratories. Upon initiation of Phases I and II of the study, the committee reassembled to discuss the details of the tests which would be useful in Phase III. That meeting, held on April 9, completed the organizational tasks of the cross-correlation program.

Objective:

It is the intent of this report to present the EPA test results relating to the MVMA correlation program and to compare these results to available data from other laboratories. Conclusions will emphasize the impact of this correlation study upon EPA emission testing activities.

Organization of Testing:

All cross-checks tests conducted for this study were performed at the following facilities: EPA-Ann Arbor, American Motors Corporation-Detroit, Chrysler Corporation Proving Ground-Chelsea, Ford Motor Company Automotive Emissions Office-Dearborn, General Motors Corporation Motor Vehicle Emissions Laboratory-Milford. All tests except the 1975 level emission tests were also performed at the International Harvester Company facility. In an attempt to minimize the variables involved in this study, all correlation checks were conducted at one certification site at each laboratory, when possible. At EPA, all checks relating to this program were conducted on certification site #5.

Summary of Cross-Check Tests:

Phases I and II - These portions of the correlation study were designed to expose differences in facilities, equipment, and procedures (Phase I) and to quantify the effects of any such differences (Phase II). The data were generated by technical groups from Ford and GMC.

Original data relating to these phases of the study were obtained by GMC's Vehicle Emission Laboratory Plant Assistant Group during the week of March 11. At that time, the following checks were performed at EPA:

1. Equipment checks to determine the types of instruments in usage, their calibration procedures, and the techniques and frequencies of their maintenance.

2. Observations of certification testing to check and compare test procedures.

3. A hand-calculation of a 1975 certification test to check the accuracy of the computer's computations.

4. Static gas checks to determine analyzer accuracy over a range of concentrations.

5. An efficiency check of the NOx converter.

6. Dynamometer coast-down checks at the 3000 and 5000 pound inertia settings.

7. A strobotac check of the driver's aid speed calibration.

8. A CVS check using the propane injection technique.

Similar checks were performed by the GMC group at all participating facilities.

Ford's input to Phases I and II of the program was begun during the week of March 25, when technicians from the Ford Automotive Emissions Office performed the following tests at EPA:

1. Dynamometer torque checks using Ford's Emission Test Cell Performance Analyzer.

2. The complete CVS-analyzer system was checked using Ford's mass simulator.

Similar tests were conducted at all participating laboratories by the Ford AEO group.

Phase III - This phase of the study consisted of vehicle emission test cross-checks. These checks were accomplished in two stages.

1. GMC's 1974 level hot start repeatable car was tested at all participating facilities. Data were collected and analyzed by the GMC group (April 10 - 26).

2. Each participating manufacturer, except IHC, tested a 1975 level vehicle at EPA after completing several tests on that vehicle at its facility. Data were collected and compiled by EPA.

Data which describes the vehicles used in these tests are summarized in Table 1.

Table 1

Vehicle Specifications

Manufacturer	V.I.D.	Inertia (lbs.)	C.I.D.	Control System
GMC[1]	PG-73277	4500	350	Engine Modification
GMC[2]	PG-72709	4500	350	EGR, AI, Catalyst
AMC	D40-32L(F)	3000	232	EGR
Chrysler	965	4500	318	EGR, Catalyst Engine Modification
Ford	33Q55D	4000	302	Catalyst

[1] 1974 Hot-start vehicle

[2] 1975 Cold-start vehicle

Test Procedures:

Because most of the checks involved in Phases I and II of this study followed standard, established procedures, those procedures will not be elaborated here. However, the vehicle emission tests (Phase III) were conducted under unique procedures which deserve further documentation.

Two types of emission tests were conducted during this study: 1975 cold-start certification tests and 1372 second hot-start tests. Hot-start tests were run on only one vehicle, the GMC 1974-level repeatable car. Prior to testing, this vehicle was warmed on the dynamometer and the proper dynamometer loading was set. The test vehicle was then brought to an idle to begin the test. Two sets of collection bags were used for each test. A minimum of four hot-start tests were run on this vehicle at each laboratory all of which were driven by a GMC driver. In addition to the emission data which were generated, the vehicle was equipped with instrumentation which measured several vehicle parameters, including throttle angle, manifold vacuum, wheel torque and wheel horsepower. No evaporative measurements were taken during any of these vehicle emission tests.

To complete Phase III testing, three valid 1975 cold-start certification tests were run at EPA on each of the four test vehicles. Test procedures were based on the Federal Test Procedure (FTP)[1]. Prior to its first EPA test, each vehicle was preconditioned in accordance with §85.075-12(c) of the FTP. Subsequent tests were conducted on consecutive days so that further preconditioning was unnecessary. An exception was the GMC vehicle, which was dynamometer preconditioned to allow an approximate 14 hour soak period before each test. Vehicle fueling was performed in accordance with §85.075-13(a)(2) of the FTP. Artificial heating of the fuel, as elaborated in §85.075-13(a)(4), was performed exclusively on the Chrysler vehicle. Other procedures followed §85.075-14 through §85.075-20 and §85.075-22 through §85.075-26 of the FTP. Test drivers were provided by EPA for tests at the Ann Arbor laboratory, however, GMC chose to supply a driver for tests on its vehicle.

Data Analysis:

Phase I and II - Analysis of the information gathered during these phases of the study can best be presented under the topics outlined in the preceding cross-check test summary. Data cited in this analysis are summarized in Appendices A and B.

1. Equipment Audit - The most pronounced differences in test equipment between the involved laboratories were found to be related to dynamometer types. EPA, GMC, and Chrysler laboratories employed direct-drive dynamometers, while Ford, AMC, and IHC used belt-drive types. Also, AMC and IHC dynamometers were equipped with 200 horsepower power absorbers, while the other laboratories' dynamometers employed 50 horsepower absorbers. The effect of these differences were studied during Phase II of this program, and the results of that study will be presented later in this report.

Other differences in facilities' equipment were discovered, but none of these differences should significantly affect test results. Suggestions for possible improvements in each laboratory were presented by the GMC group, whose major recommendation to EPA was improvement of the existing equipment calibration and maintenance documentation.

2. Test Observation - Observation of a 1975 certification test at the EPA facility revealed no major procedural questions. However, a leakage of water from the CVS-tailpipe interface was observed during the test. The GMC group recommended possible solutions to this problem.

3. Hand Calculation of Test Results - The accuracy of computer calculations was verified at all facilities except IHC, where a problem was discovered with the computer results. A 5% error was revealed in the computer CO mass calculation of the test results in question.

4. Static Gas Checks - To analyze the data from these checks, mean values of all cylinder concentrations were calculated from the facility readings. Each facility's reading was then compared to the mean value (See Appendix A-4). Discrepancies of greater than 3% of the mean were considered significant.

The best correlation of facility readings was experienced in CO_2 measurements. The only significant discrepancy revealed was AMC's 5.5% difference from the mean value at an approximate CO_2 concentration of 0.5%. NO_x correlation was also excellent, with the only problems experienced being at low concentrations (less than 25 ppm). Two readings at each GMC and IHC were found to be significantly variant from the mean at low concentration.

Significant differences in low concentration HC readings were revealed between facilities. On four cylinders with concentrations less than 50 ppm HC, GMC readings were consistently higher than the mean (3.4 to 6.8%) as were EPA readings (2.7 to 3.7%). Chrysler and IHC readings of these cylinders were consistently lower than the mean (3.5 - 7.5% and 1.2 - 8.2% respectively). One AMC reading was also significantly different from the mean; 6.4% lower at approximately 2 ppm concentration. All readings of HC cylinder's above 50 ppm concentrations were within 3% of the cylinder's mean concentration reading.

Correlation of CO static gases was generally good at high concentrations with some problems at lower concentrations. In the 250-2600 ppm range, only two readings differed significantly from the mean. At about 2500 ppm, the GMC value exceeded the average by 3.1%, while at about 1500 ppm, the AMC value was 4.1% lower than the mean. Below 250 ppm, all IHC readings were significantly below mean values (16.4 - 100%), thus new means were calculated from the other five data points. Using this new mean as the comparator, EPA readings were significantly low in the 0-60 ppm range (3.2 - 19%), while Ford values were 3.2 - 3.3% lower than the five-laboratory mean in the 0-30 ppm range. All readings fell outside the $\pm$ 3% range at about 10 ppm, with EPA and IHC deviation being the largest.

5. NO_x Converter Efficiency - A problem was discovered at AMC as a result of the 86.3% efficiency calculated during the check. Maintenance of the converter raised its efficiency to 95.6%. Other calculated NO_x converter efficiencies were: GMC-100%, Ford-95.3%, EPA-98.3%, Chrysler-91.5%, and IHC-94.0%.

6. Dynamometer Coast-Down Checks - All coast-down checks revealed absorbed horsepower within $\pm$ 0.5 hp of the Federal Register specification except: Chrysler, + 0.68 hp @ 5000# inertia; AMC, - 0.74 hp @ 3000# inertia and - 1.64 hp @ 5000# inertia; IHC, + 1.3 hp @ 4000# inertia and + 1.2 hp inertia @ 5000# inertia.

7. Speed Calibration Check - All speed meter calibrations, except Fords, were accurate as checked. A 0.6% error was measured at Ford.

8. CVS Propane Injections - Four of the six laboratories involved reported CVS errors of less than 2%. The CVS error at Chrysler was measured at 6.75%, and upon a new calibration it measured 4.0%. The IHC error was 5.45%.

9. Ford Mass Simulation - Because of the high variability of the mass simulation, differences between laboratory analytical systems were difficult to substantiate with the Ford mass data. These data are tabulated in Appendix B-1.

10. Ford Dynamometer Checks - These checks compared power absorption unit (PAU) and inertia characteristics of the dynamometers involved in the cross-correlation study. PAU curve areas varied within about 4% of the mean value, with a maximum deviation from the average of 4.55% at AMC. The 50 mph PAU load varied within about 3% of the mean value, 3.08% being the largest difference (at IHC). Inertia checks of each dynamometer's 4500 pound simulation revealed an average value of 4642 pounds, with discrepancies from this mean as high as + 4.83% (at GMC). However, high test-to-test variability at each site made the significance of these inertia differences questionable. A summary of these dynamometer-check data may be found in Appendix B-2.

Phase III - Data gathered during this portion of the study provided vehicle emission level comparisons as well as further dynamometer characterizations.

1. Repca I Data - Ideally, emission levels measured on GM's repeatable car could best be analyzed using sophisticated statistical methods. Unfortunately, such an analysis is difficult because of the changing emission characteristics of this vehicle. This is exemplified by the fact that Repca I HC, NO_x, and CO_2 emissions, as measured at the GMC laboratory, were significantly different (90% confidence level) at the end of the MVMA program than at the beginning. Consequently, a less rigorous analysis, which accounts for changing vehicle characteristics, must be employed.

Such an analysis is the "Bogie" method derived by GMC personnel.[2] This analysis uses previous tests on the vehicle to establish confidence limits on its emissions. At the beginning of the MVMA program, Repca I had "Bogie" emission numbers as listed in Table 2. Comparison of each facility's measurements to these data gives an indication of significant emission discrepancies.

Table 2

Repca I "Bogie" Numbers (Grams/Mile)

	Mean	Upper 95% Limit	Lower 95% Limit
HC	1.38	1.50	1.26
CO	22.2	25.1	19.3
NO_x	3.21	3.55	2.87
CO_2	611	628	594

Using the above guidelines, the most pronounced discrepancies revealed were in CO_2 and NO_x levels. Significantly high CO_2 levels were measured at AMC and IHC site #1, while significantly high levels of NO_x were measured at IHC site #4. The other laboratories were within vehicle variability in measurements of CO_2 and NO_x. Only one site experienced significant problems in measurements of HC or CO, that being IHC site #4, which reported consistently low HC levels. More detailed Repca I emission data are summarized in Appendices C-1 through C-5.

During emission testing on the repeatable car, GM technicians recorded dynamometer torque characteristics using their total torque tester. Data from these determinations are plotted in Appendices C-6 through C-8. Analyses of these data show minor site-to-site differences in steady-speed power absorption and in work done over the LA-4 cycle. The most pronounced tendencies were discovered at AMC and IHC, where the test vehicle generally expended more work to complete the driving schedule than it did at other facilities. Statistical analyses of torque and horsepower data verify this tendency (See Table 3).

Table 3

Repca I Work Analysis

Significant Differences Among Laboratories (95% Confidence)[3]

Laboratories	Average Torque	Average Horsepower	Positive Torque	Positive Horsepower
All	Yes	Yes	Yes	Yes
All except IHC	Yes	Yes	No	No
All except IHC, AMC	Yes	No	No	No

As a final dynamometer check, Repca I was driven over a prescribed driving schedule to determine inertia. These data are presented in Appendix 9. All dynamometers were within specifications except EPA #5 and IHC #4, where significantly low inertia values were calculated.

2. 1975-level Vehicle Tests - Unfortunately, the 1975-level vehicles tested at EPA did not approach the repeatability of Repca I. However, results of these tests did reveal some significant discrepancies. EPA's measurement of lower CO_2 emissions than manufacturers, which was the case for all vehicles, was the most apparent trend. Also pronounced, were EPA's measurements of lower HC emissions on the GMC and Ford vehicles. Other mean emission differences, although often large, were within the variability of the vehicles in question. Presentation of the complete 1975-level vehicles data is made in Appendix D.

Discussion:

Data generated during this cross-correlation study revealed several factors which may contribute to laboratory correlation problems. These factors may be considered in four categories: (1) dynamometer effects, (2) analysis system effects, (3) CVS effects, and (4) ambient effects.

Dynamometer Effects - During Phase III of this study, GMC generated data which directly compared dynamometer loading to vehicle emissions. Regression analyses of these data do not reveal a good correlation between loading and NO_x and CO_2 emissions (See Table 4). The analyses do show, however, the highest degree of correlation between NO_x and positive torque (.50). Also of some significance are the correlation coefficients of CO_2 to positive torque (.47) and NO_x to positive horsepower (.46). These coefficients indicate that vehicle loading does affect NO_x and CO_2 emissions, but to a lesser degree than other, undefined variables. Graphical presentations of NO_x and CO_2 emissions versus loading parameters, which include least-square fit lines and standard estimate of errors, are made in Appendices C-10 through C-13.

Table 4

Regression Analysis of Repca I NO_x and CO_2 Emissions Versus Vehicle Loading

Loading Parameter	Correlation Coefficients	
	NO_x	CO_2
Average Torque	.32	.37
Positive Torque	.50	.47
Negative Torque	.18	.10
Average Horsepower	.37	.29
Positive Horsepower	.46	.24
Negative Horsepower	.12	.28

These regression analyses do indicate that relatively high CO_2 and NO_x emissions, as measured at IHC and AMC, can be particularly attributed to relatively high vehicle loading at those facilities.

Another dynamometer factor investigated during this study was the accuracy of inertial simulation. Unfortunately, tests conducted independently by GMC and Ford on the same dynamometers did not produce similar results. Discussions with the involved personnel documented that current techniques for determining dynamometer inertia are not sufficiently perfected to produce accurate and repeatable results. Therefore, data which showed significant inertial discrepancies between dynamometers are deemed to be inaccurate, and any effect of dynamometer inertia on vehicle emissions is thus deemed undefinable.

A final dynamometer factor which may have affected test results is the accuracy of the speed calibration. GMC data generated during Phase III shows that speed differences as large as 2 mph were measured at the 50 mph calibration point (See Appendix C-6). Because a vehicle's speed significantly affects its expenditure of energy, it is believed a speed calibration error could significantly affect CO_2 emissions. This could be a possible explanation of relatively low CO_2 emissions at EPA during latter stages of Phase III vehicle tests.

Analysis System Effects - In general, vehicle emission correlation results during this study were not affected by analysis system errors. The only large discrepancies in gas analyzer measurements were at very low concentrations of HC and CO, hence the measurement of catalyst-equipped vehicle emissions may have been slightly affected. However, since such discrepancies are a very minor factor in the passing or failing of a 1975 or 1976 emission certification test, they are not of major concern at this time.

CVS Effects - Checks of the various CVS systems employed in this study showed large variations in propane injection results. However, these data do not differentiate between the CVS repeatability and the repeatability and the reproducibility of the propane injection technique. Consequently, it can be concluded that CVS calibration inaccuracies may add to the test variability between laboratories, but the extent of this influence cannot be isolated using the available data.

Ambient Effects - It should be emphasized that various ambient conditions, namely temperature, pressure, and humidity, may significantly affect the degree of inter-laboratory correlation. In this study, conclusions regarding the effects of these ambient parameters are extremely difficult to derive because of the large number of other variables under consideration.

Conclusions:

1. The EPA-MVMA emission correlation study demonstrated the ability of various laboratories, employing different equipment and personnel, to measure very similar emission levels. Test-to-test variability made any determination of "average" or "typical" differences between laboratories very difficult.

2. Vehicle loading was a minor factor affecting NO_x and CO_2 emission levels. In general, increased loading tended to result in higher NO_x and CO_2 emissions.

3. Extensive checks of the gas analysis systems of the involved laboratories revealed only minor discrepancies in gas measurements. The most pronounced discrepancies were at very low concentrations, where the effect on passing a certification test would be minimal.

4. Other factors which may influence emission laboratory correlation were revealed. These factors include dynamometer speed calibrations, CVS accuracy, and ambient conditions. More specifically-designed test programs would be required to further investigate the contribution of these factors to current emission correlation discrepancies.

Recommendations:

1. Future correlation programs that include round-robin vehicle tests should be more carefully scheduled. Because vehicle characteristics may vary over time, the vehicle(s) should be tested in as short a time span as possible with frequent "baseline" tests at one facility.

2. In programs designed to isolate the cause of correlation problems, diagnostic checks should be performed either just before or just after vehicle emission tests.

3. Because of statistical considerations, the same number of emission tests should be conducted at each laboratory on a round-robin vehicle. The base laboratory should choose a "typical" cell and conduct the specified number of tests at the beginning, periodically throughout, and at the end of the program.

References

1. Federal Register, Volume 37, Number 221, November 15, 1972 (as amended).

2. Letter from David I. Buist, General Motors Proving Ground, to Lewis E. Duffing, MVMA; Exhaust Emission Measurement Panel Correspondence; June 12, 1974.

3. Practical Statistics Simply Explained, Dr. Russell Langley, 1970, pp. 212-221.

4. Letter from Lewis E. Duffing (MVMA) to Rick Lowery (EPA), June 24, 1974.

5. Letter from David W. Hermance, General Motors Proving Ground, to Lewis E. Duffing, MVMA; Exhaust Emission Measurement Panel Correspondence; May 10, 1974.

APPENDICES

APPENDIX A

Phase II Data

Generated by

General Motors Corporation

General Information

	GM	Ford	EPA	Chrysler	AMC	In't Harvester
Analyzers						
HC	Beckman 400 0-100 ppm H_2/N_2 Fuel	Beckman 400 0-20 ppm 0-100 ppm H_2/H_e Fuel	Beckman 400 0-50 ppm 0-100 ppm H_2/N_2 Fuel	Beckman 400 0-100 ppm H_2/H_e Fuel	Beckman 400 0-100 ppm H_2/H_e Fuel	Beckman 400 0-30 ppm 0-330 ppm H_2/H_e Fuel
LCO	Bendix 8501 0-500 ppm 0-1000 ppm 0-2500 ppm	Beckman 315B 0-500 ppm 0-1500 ppm 0-4000 ppm	Bendix 8501 0-500 ppm 0-1000 ppm	Beckman 865 0-3000 ppm	Beckman 315B 0-250 ppm 0-1250 ppm 0-3500 ppm	Beckman 315B 0-2500 ppm
HCO	Beckman 315B 0-5000 ppm 5 1/4" cell	-	Beckman 315A 0-2500 ppm 2 1/4" cell	-	-	-
NO_x	TECO 10A 0-150 ppm Air Ozone Source	Philco 0-25 ppm 0-100 ppm O_2 Ozone Source	TECO 10A 0-100 ppm O_2 Ozone Source (calibrated as NO_x)	Beckman 951 0-250 ppm O_2 Ozone Source (atmospheric press. reaction)	TECO 10A 0-100 ppm Air Ozone Source	TECO 10A 0-100 ppm Air Ozone Source
CO_2	Beckman 315B 0-3.5% 1/8" cell	Beckman 315B 0-4% 0-7% 1/8" cell	Beckman 315A 0-3.5% 1/8" cell	Beckman 864 0-4.5%	Beckman 315A 0-7.5% 1/8" cell	Beckman 865 0-5%
Bench	Scott 1 pump/analyzer Ice Bath for LCO & HCO	Philco 1 pump/analyzer Ice Bath for LCO	Homebuilt plumbed per register Water Trap for LCO & HCO (no flow in reset)	Beckman 1 "push" type pump Ice Bath for LCO	Scott FID & CO on common flow stream w/ Ice Bath & 1 pump CO_2 & NO_x - 1 pump each (no flow in reset)	Homebuilt 1 "push" type pump Water Trap for CO (no flow in reset)
CO Conditioning Agents	Ascarite Drierite Separate Tubes	Ascarite Drierite Common Tube	Ascarite Silica Gel Common Tube	Malcasorb Aquasorb Separate Tubes	Ascarite Silica Gel Separate Tubes	- Drierite One Tube
CVS	Delco 102 Cal w/LFE on Outlet Δ P 70" H_2O @ 1332 rpm 6 bag	Philco Cal LFE on Inlet (Critical Flow Venturi) - 6 bag	AMI Trans Drive Cal LFE on Inlet ΔP 72" H_2O @ 1464 rpm 4 bag	Heath Cal LFE on Outlet ΔP 12.2" H_2O @ 1041 rpm 6 bag	Scott 301 Cal LFE on Inlet ΔP 13.5" H_2O @ 891 rpm 5 bag	Scott 301 Cal LFE on Inlet ΔP 28" H_2O @ 1191 rpm 4 bag
Driver's Aid	HP7100 6" = 60 mph 6"/1 minute Computer generated Trace	HP7100 5" = 60 mph 4"/1 minute Pre-printed Trace	Varian 5" = 60 mph 4"/1 minute Pre-printed Trace	PCS CRT 6" = 50 mph 22.5"/1 minute Computer generated Trace	Varian 5" = 60 mph 4"/1 minute Pre-printed Trace	Varian 5" = 60 mph 4"/1 minute Pre-printed Trace
DYNO	Clayton CT-50 Direct Drive Auto Loading	Clayton CT-50 Belt Drive (Oil Can-Type Load Cell)	Clayton CT-50 Direct Drive Auto Loading (Auto Load Not In Use)	Clayton CT-50 Direct Drive Auto Loading	Clayton C150 Belt Drive (Oil Can-Type Load Cell)	Clayton CT-200 Dog Clutch/Belt Dr. (Oil Can-Type Load Cell)
Computer	SEL8600 On-Line	Xerox Sigma III On-Line	IBM 370 Off-Line	PCS HP-2100 On-Line	Honeywell Off-Line	DEC Off-Line

David W. Hermance
May 9, 1974

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Functional Checks

		GM	Ford	EPA	Chrysler	AMC	IH
NO_x Converter Efficiency (% Efficient)		100	95.3	98.3	91.5	86.3 95.6 after maint.	94.0
Propane Injection (% Error)		+1.06*	-1.60	-.97	-6.75 -4.0 CVS recal.	+1.37*	+5.45
Sample Line Hang-up (PPM C_3)		.09	.35	.3	.0	.05	.6
Coast Down Horsepower (Actual HP - Chart HP)	3000 #IW	-.26	-.42	-.39	-.42	-.74	+1.3*
	5000 #IW	-.14	-.07	-.17	+.68	-1.64	+1.2
Roll Speed Cal (MPH)		46.3	46.0	46.3	46.3	46.3	46.3
Wet CO_2 Check (PPM CO)		0	0	0	1.2 ppm	0	10 ppm
Dual Blend Check (PPM CO)	Without Ascarite	1460	1476	1453	1478	1501	Not Done
	With Ascarite	1485	1492	1475	1466	1530	
Mass Calculations (% Error)	HC	0.0	-0.1	0.0	0.0	0.0	0.9
	CO	0.0	0.0	0.0	0.0	0.0	-5.1
	NO_x	0.0	0.0	0.0	-0.2	-0.5	-.4

*IW = 4000 lbs

Calibration & Maintenance Frequencies

	GM	Ford	EPA	Chrysler	AMC	IH
Propane Injection	Daily	Monthly	Weekly	Weekly	Weekly	Not Done
NO_x Converter Efficiency	Daily	Weekly	Weekly	Weekly	Weekly	Monthly
CO Column Check	Daily	Monthly	Daily	Not Done	Each Shift	N/A
Analyzer Calibration	Monthly	Monthly	Weekly	AR	Monthly	Monthly
Analyzer Spot Check	N/A	N/A	N/A	Monthly	N/A	N/A
Pull Down Leak Check	Daily	Each Test	Each Test	Each Shift	Daily	Daily
Dyno Spot Check	Monthly	Weekly	Weekly	Monthly	Not Done	Not Done
Dyno Calibration	AR	Monthly	Monthly	AR	Maintenance	Maintenance
CVS Calibration	AR	6 mo. or AR	AR	AR	AR	Installation
FID Peaking	Monthly	Installation	Weekly	Not Done	Annual	Installation

Gas Results

	Tag Value	GM	Ford	EPA	Chrysler	AMC	IH
HC	.05	.05	.05	.05	.0	.05	.05
	2.08	2.06	2.00	2.05	1.9	1.85	2.0
	6.63	6.81	6.45	6.55	5.9	6.45	6.1
	10.23	10.39	10.05	10.2	9.2	10.15	9.45
	30.6	30.77	30.65	30.85	28.7	30.25	27.3
	59.2	59.26	59.05	59.2	56.4	59.25	55.8
	96.35	96.47	96.65	96.3	93.8	96.05	93.8
	Methane	72.3	62.25	61.2	56.7	64.05	55.8
CO	.4	.02	0	0	0	1	0
	8.84	8.98	8.0	6.7	8.7	9	0
	32.0	32.2	30.4	30.4	32.0	32	10
	54.7	54.4	53.8	51.5	54.6	54	30
	100.2	98.0	99.4	96.6	99.1	101	80
	247	247.6	249.4	247.5	256.5	249	250
	505	506.7	496	513.4	518.6	511	510
	718	709.5	708	719.7	730.7	720	700
	1026	1022	1018	1025.2	1022	1041	1010
	1539	1530	1532	1547	1530	1454	1500
	2638	2632	2509	Off Scale	2567	2506	Off Scale
NO/NO_x	0.0	.1	0	.1	.2	.2	.0
	4.8/4.85	4.75	4.64	4.6	4.7	4.6	5
	8.5/8.5	8.0	7.9	7.7	7.7	7.8	7
	22.45/22.5	22.43	21.47	21.7	21.8	21.3	21
	46.8/47.0	46.4	45.1	45.2	46.1	44.7	45
	75.3/75.8	76.0	73.3	74.2	74.7	72.8	73
	96.3/97.6	97.1	93.7	95.8	95.0	92.4	96
			*	**		***	
CO_2	.0003	.00	.00	.00	.01	.00	.00
	.50			.522	.51	.48	.52
	1.03			1.018	1.04	1.03	1.02
	1.55	1.53	1.53	1.52	1.52	1.56	1.52
	2.64	2.63	2.63	2.68	2.56	2.71	2.60

* Span Tag Low 1.5 ppm
** Read in NO_x Mode
*** Span Tag Low 1.1 ppm

4-18-74
DWH

MVMA FACILITIES STATIC GAS CHECK

Mean Readings and % Deviation from Mean

Gas	Mean Value	% Deviation from Mean					
		GMC	Ford	EPA	Chrysler	AMC	IHC
HC	1.98	4.2	1.2	3.7	-3.9	-6.4	-1.2
	6.38	6.8	1.2	2.7	-7.5	1.2	-4.3
	9.91	4.9	1.4	3.0	-7.1	2.4	-4.6
	29.75	3.4	3.0	3.7	-3.5	1.7	-8.2
	58.16	1.9	1.5	1.8	-3.0	1.9	-4.1
	95.51	1.0	1.2	0.8	-1.8	0.5	-1.8
CO	6.9	30.2	16.0	-2.9	26.0	30.5	-100
	* 8.3	8.5	-3.3	-19.0	5.1	8.7	--
	27.8	15.7	9.2	9.2	15.0	14.9	-64.1
	* 31.4	2.5	-3.2	-3.2	1.9	1.9	--
	49.7	9.4	8.2	3.6	9.8	8.6	-39.7
	* 53.7	1.4	0.3	-4.0	1.8	0.6	--
	95.7	2.4	3.9	1.0	3.6	5.6	-16.4
	* 98.8	-0.8	0.6	-2.2	0.3	2.2	--
	250	-1.0	-0.2	-1.0	2.6	-0.4	0.0
	509	-0.5	-2.6	0.8	1.8	0.3	0.1
	714	-0.7	-0.9	0.7	2.2	0.7	-2.0
	1023	-0.1	-0.4	0.2	-0.1	1.8	-1.3
	1515	1.0	1.1	2.1	1.0	-4.1	-1.0
	2553	3.1	-1.7	--	0.5	-1.9	--
NO/NO_x	4.7	0.7	-1.6	-2.4	-0.3	-2.4	6.0
	7.7	4.1	2.8	0.2	0.2	1.5	-8.9
	21.6	3.8	-0.6	0.5	0.5	-1.4	-2.8
	45.4	2.2	-0.7	-0.5	1.5	-1.6	-0.9
	74.0	2.7	-0.9	0.3	0.9	-1.6	-1.4
	95.0	2.2	-1.4	0.8	0.0	-2.7	1.1
CO_2	.51	--	--	2.8	0.4	-5.5	2.4
	1.03	--	--	-0.9	1.3	0.3	-0.7
	1.53	0.0	0.0	-0.7	-0.7	2.0	-0.7
	2.64	-0.2	-0.2	1.7	-2.8	2.8	-1.3

*Calculations excluding IHC reading.

APPENDIX B

Phase II Data

Generated by

Ford Motor Company

MVMA FACILITIES GAS ANALYTICAL SYSTEM PERFORMANCE

GAS & TEST MODE	MVMA MEAN*	% VARIABILITY	FORD	% DIFF FROM MEAN	EPA	% DIFF FROM MEAN	GENERAL MOTORS	% DIFF FROM MEAN	CHRYSLER	% DIFF FROM MEAN	AMERICAN MOTORS	% DIFF FROM MEAN	INTR'L. HARV.	% DIFF FROM MEAN
C_3H_8 BAG 1 (grams)	3.75	6.46	3.70	- 1.33	3.70	- 1.33	3.85	+ 2.67	3.31	-11.73	3.94	+ 5.07	3.97	+ 5.87
BAG 2 (grams)	1.75	7.64	1.81	+ 3.43	1.67	- 4.57	1.81	+ 3.43	1.51	-13.71	1.84	+ 5.14	1.85	+ 5.71
BAG 3 (grams)	3.12	7.39	3.33	+ 6.73	2.84	+ 8.97	3.28	+ 5.13	2.83	- 9.29	3.16	+ 1.28	3.30	+ 5.77
GRAMS/MILE	0.69	6.75	0.71	+ 2.90	0.65	- 5.80	0.71	+ 2.90	0.61	-11.59	0.71	+ 2.90	0.73	+ 5.80
CO BAG 1 (grams)	48.33	7.92	43.35	-10.30	47.55	- 1.61	49.97	+ 2.36	46.67	- 3.43	47.97	- 0.74	54.94	+13.68
BAG 2 (grams)	19.43	6.03	19.50	+ 0.36	19.26	- 0.87	20.43	+ 5.15	17.73	- 8.75	20.97	+ 7.93	18.68	- 3.86
BAG 3 (grams)	30.15	1.99	30.00	- 0.5	(22.37)	------	31.02	+ 2.89	29.40	- 2.49	29.96	- 0.63	30.39	+ 0.8
GRAMS/MILE	7.69	3.89	7.48	- 2.73	(7.01)	------	7.92	+ 2.99	7.27	- 5.46	7.82	+ 1.69	7.95	+ 3.38
NO BAG 1 (grams)	9.02	8.98	7.86	-12.86	9.04	+ 0.22	9.50	+ 5.32	9.08	+ 0.67	8.43	- 6.54	10.18	+12.86
BAG 2 (grams)	3.48	5.07	3.21	- 7.56	3.33	- 4.31	3.61	+ 3.74	3.47	- 0.29	3.60	+ 3.45	3.65	+ 4.89
BAG 3 (grams)	6.24	10.26	6.00	- 3.85	5.37	-13.94	6.57	+ 5.29	6.21	- 0.48	6.03	- 3.37	7.28	+16.69
GRAMS/MILE	1.46	7.17	1.34	- 8.22	1.37	- 6.16	1.53	+ 4.79	1.46	0	1.42	- 2.74	1.62	+10.96
CO_2 BAG 1 (grams)	216.14	4.68	226.09	+ 4.60	225.01	+ 4.10	204.58	- 5.35	206.53	- 4.45	218.49	+ 1.09	(257.62)	------
BAG 2 (grams)	214.41	8.51	240.17	+12.01	229.32	+ 6.95	204.33	- 4.70	191.67	-10.61	218.49	+ 1.90	202.46	- 5.57
BAG 3 (grams)	198.23	2.95	(252.00)	------	199.94	+ 0.86	204.58	+ 3.20	191.47	- 3.41	192.72	- 2.78	202.46	+ 2.13
GRAMS/MILE	55.38	5.14	(64.14)	------	58.68	+ 5.96	54.52	- 1.55	51.95	- 6.19	56.35	+ 1.75	(57.15)	------

*Mean values exclude rejected outliers and dependent values; excluded values are listed in parentheses.

MVMA FACILITIES DYNAMOMETER PERFORMANCE

DATE	FACILITY & CELL	MEAN CYCLE WORK (FT-LBS)	% FROM MEAN	PAU CURVE AREA (HP-MPH)	% FROM MEAN	50 MPH LOAD (HP)	% FROM MEAN	CALCULATED INERTIA (LBS)	TEST TO TEST % VARIABILITY	% FROM MEAN
03-16-74	FORD 3	1048231	-1.16	498.3	+1.22	25.35	-1.89	4504	2.28	-2.97
03-27-74	EPA 5	1050500	-0.95	490.9	-0.28	25.64	-0.72	4512	2.82	-2.80
03-28-74	GM 1	1079375	+1.30	471.7	-4.18	26.17	+1.34	4866	3.40	+4.83
04-02-74	CHRYSLER 6	1060263	-0.02	471.8	-4.16	25.90	+0.30	4733	2.49	+1.96
04-04-74	AMC 1	1023825	-3.46	514.7	+4.55	25.27	-2.15	4583	1.43	-1.27
04-09-74	INT'L. HARVESTER 1	1106050	+4.29	506.7	+2.93	26.62	+3.08	4653	3.99	+0.24
	GRAND MEAN	1060541		492.3		25.83		4642		

APPENDIX C

Phase III Data

GMC Repeatable Car

Generated by

General Motors Corporation

MVMA CROSS-CORRELATION

Phase III

April 1974

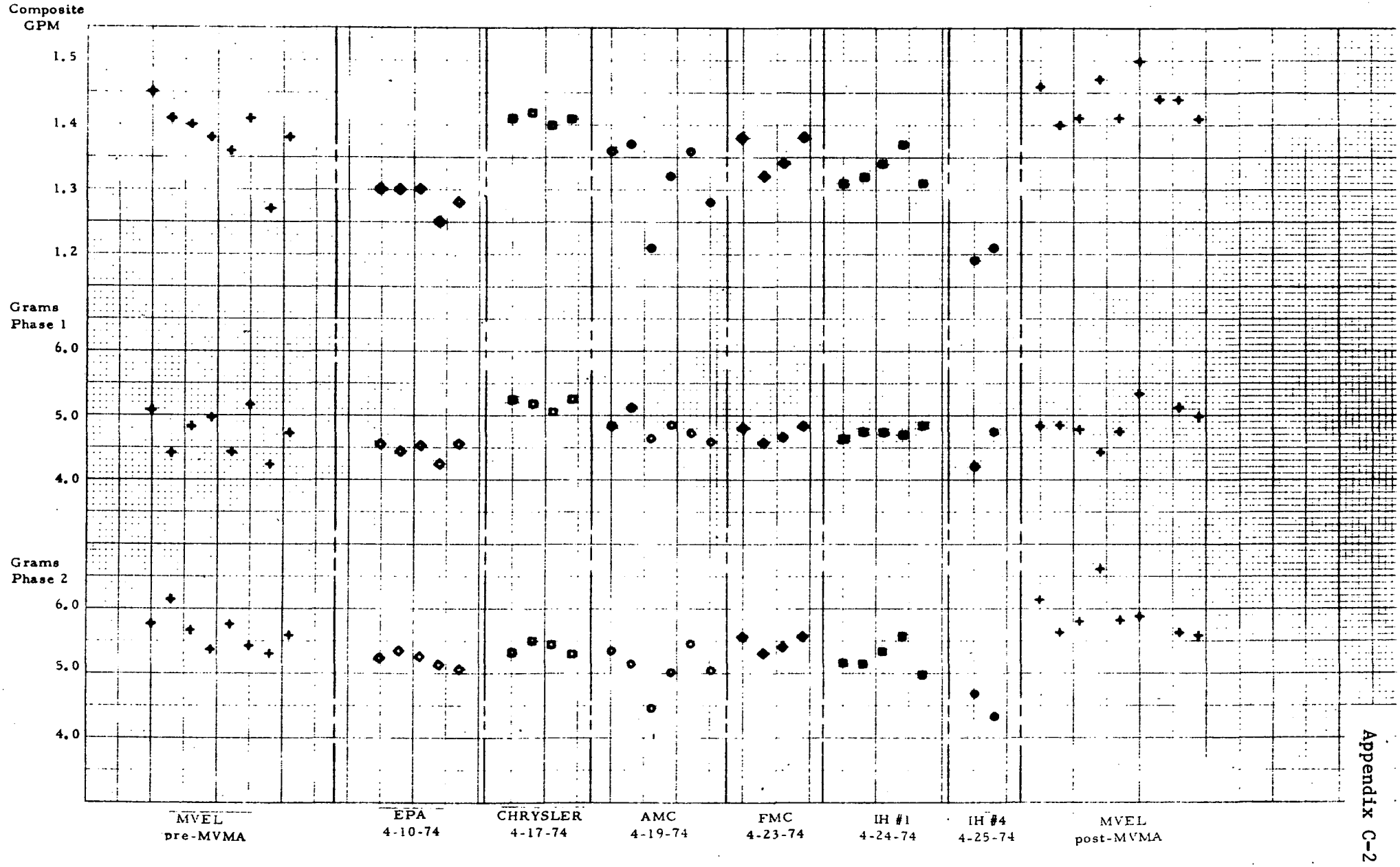
Vehicle - GM REPCA I

	GM +	EPA #5	Chrysler #6	AMC #1	Ford #2	IH #1 *	IH #1	GM +
No. of Tests	8	5	4	6	4	5		9
HC								
Mean	1.38	1.29	1.41	1.32	1.36	1.33	1.20	1.44
Std. Deviation	.05	.02	.01	.06	.03	.02	.01	.03
Range	.18	.05	.02	.16	.06	.06	.02	.10
95% Max.	1.42	1.31	1.42	1.37	1.39	1.36	1.23	1.46
95% Min.	1.34	1.26	1.40	1.26	1.32	1.30	1.17	1.41
CO								
Mean	23.0	21.1	20.0	21.1	21.2	22.6	23.2	22.4
Std. Deviation	.99	.51	.18	1.09	.29	.88	.05	.91
Range	3.05	1.30	.50	2.80	.80	2.39	.10	3.1
95% Max.	23.8	21.7	20.3	22.2	21.6	23.6	23.4	23.1
95% Min.	22.2	20.6	19.8	20.0	20.8	21.6	23.1	21.8
NO_x								
Mean	3.23	3.15	3.48	3.52	3.47	3.48	3.65	3.48
Std. Deviation	.20	.07	.02	.04	.08	.10	.06	.16
Range	.69	.20	.05	.14	.20	.28	.12	.44
95% Max.	3.40	3.23	3.51	3.56	3.58	3.60	3.83	3.60
95% Min.	3.07	3.07	3.46	3.47	3.35	3.36	3.47	3.36
CO_2								
Mean	618	607	626	665	593	598	700	628
Std. Deviation	8.9	4.1	5.0	14.1	4.8	11.3	2.5	9.0
Range	23	11	14	42	11	28	5	31
95% Max.	625	612	632	674	600	611	707	635
95% Min.	611	603	619	651	587	585	692	621

+ GM data from five different sites and different drivers

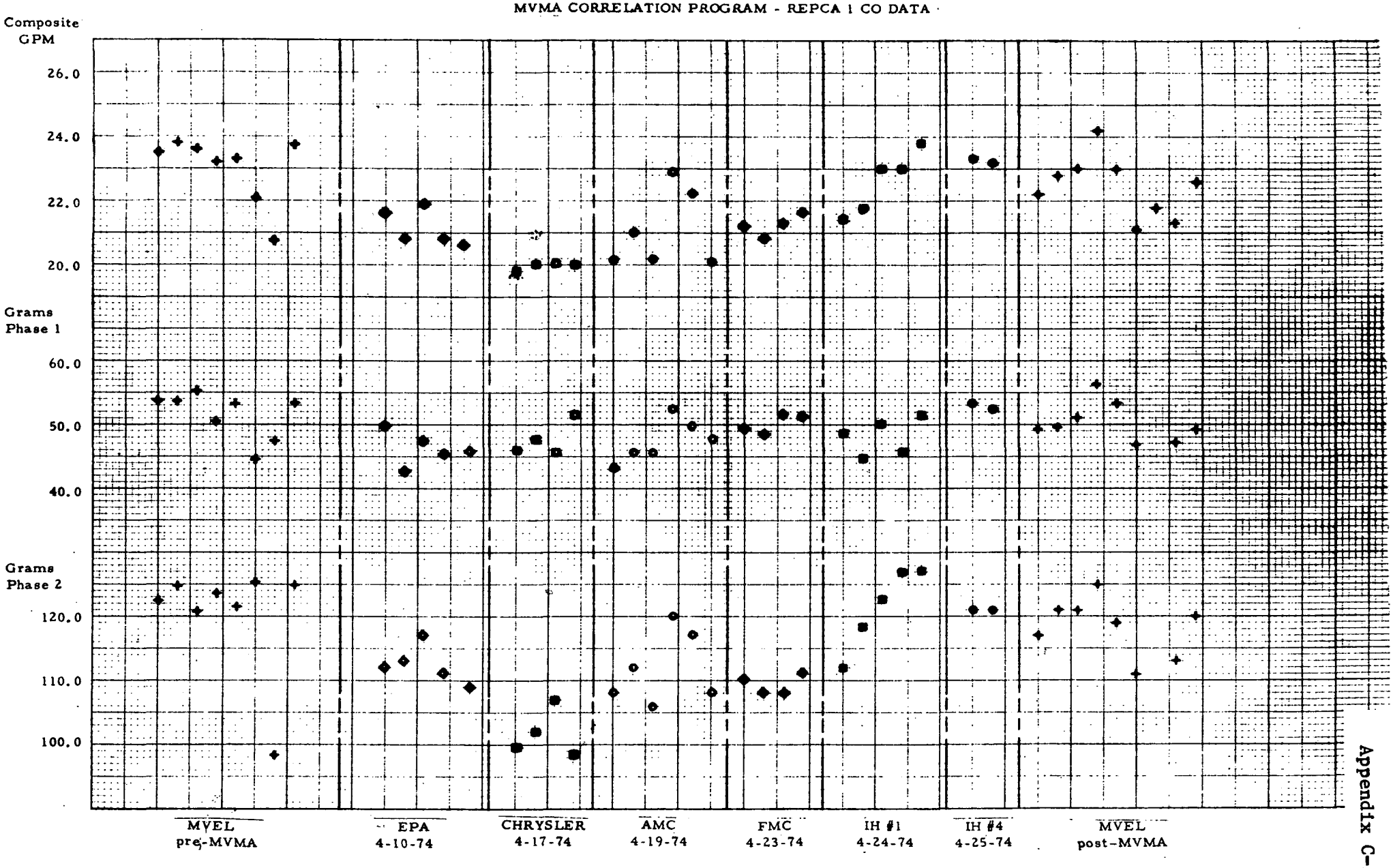
* IH #1 data corrected for change in CVS flow rate

MVMA CORRELATION PROGRAM - REPCA 1 HC DATA

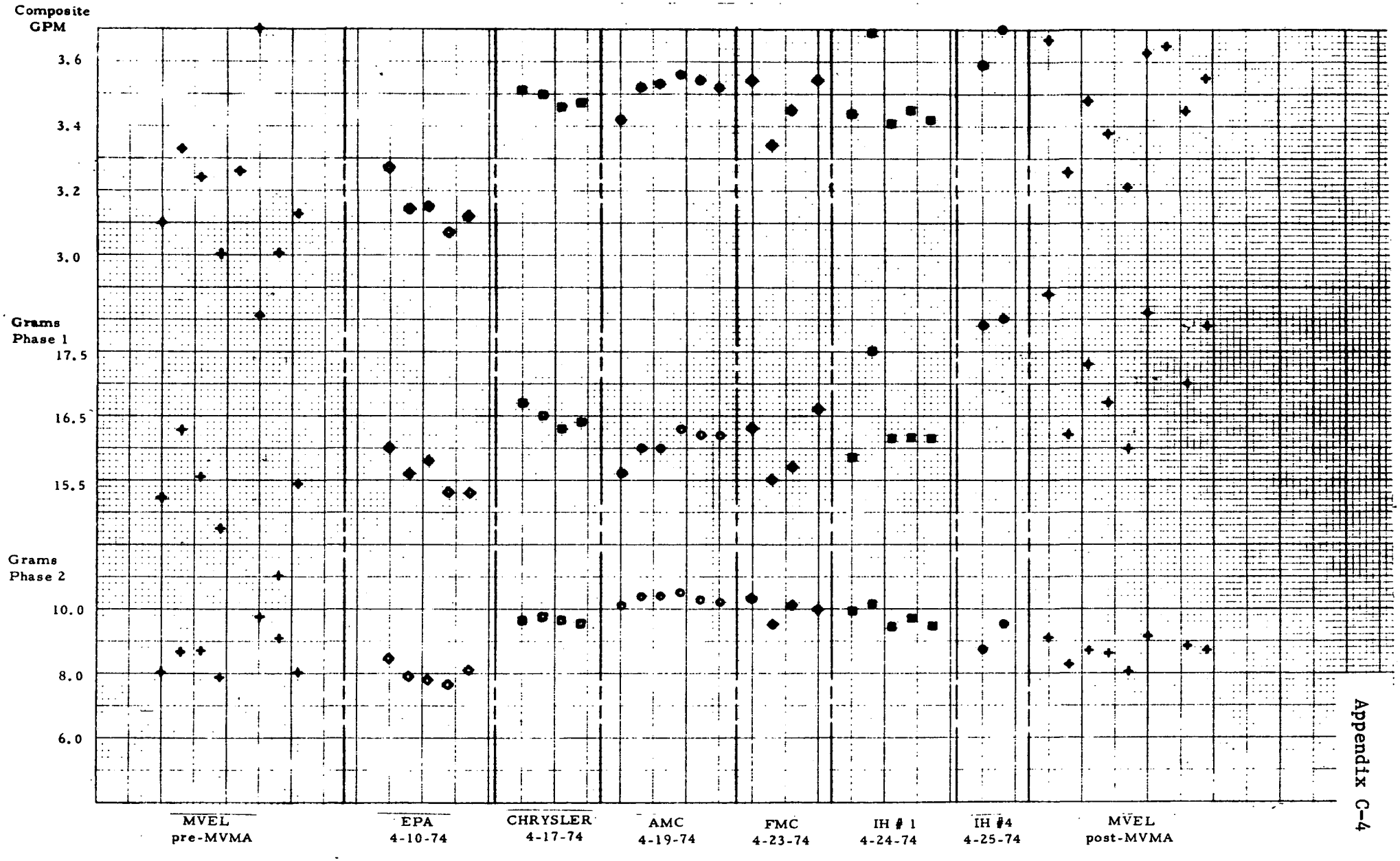


Appendix C-2

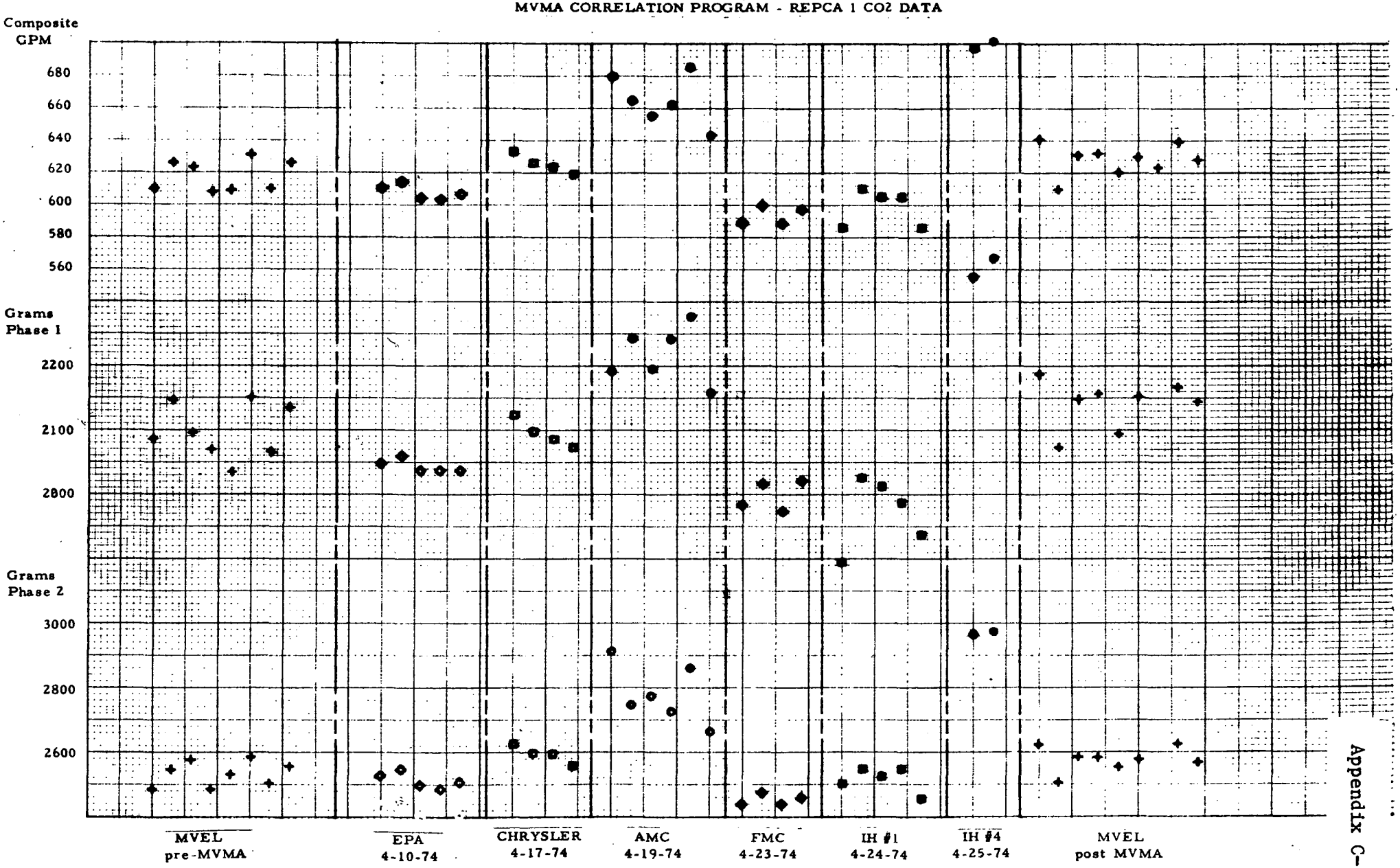
MVMA CORRELATION PROGRAM - REPCA 1 CO DATA



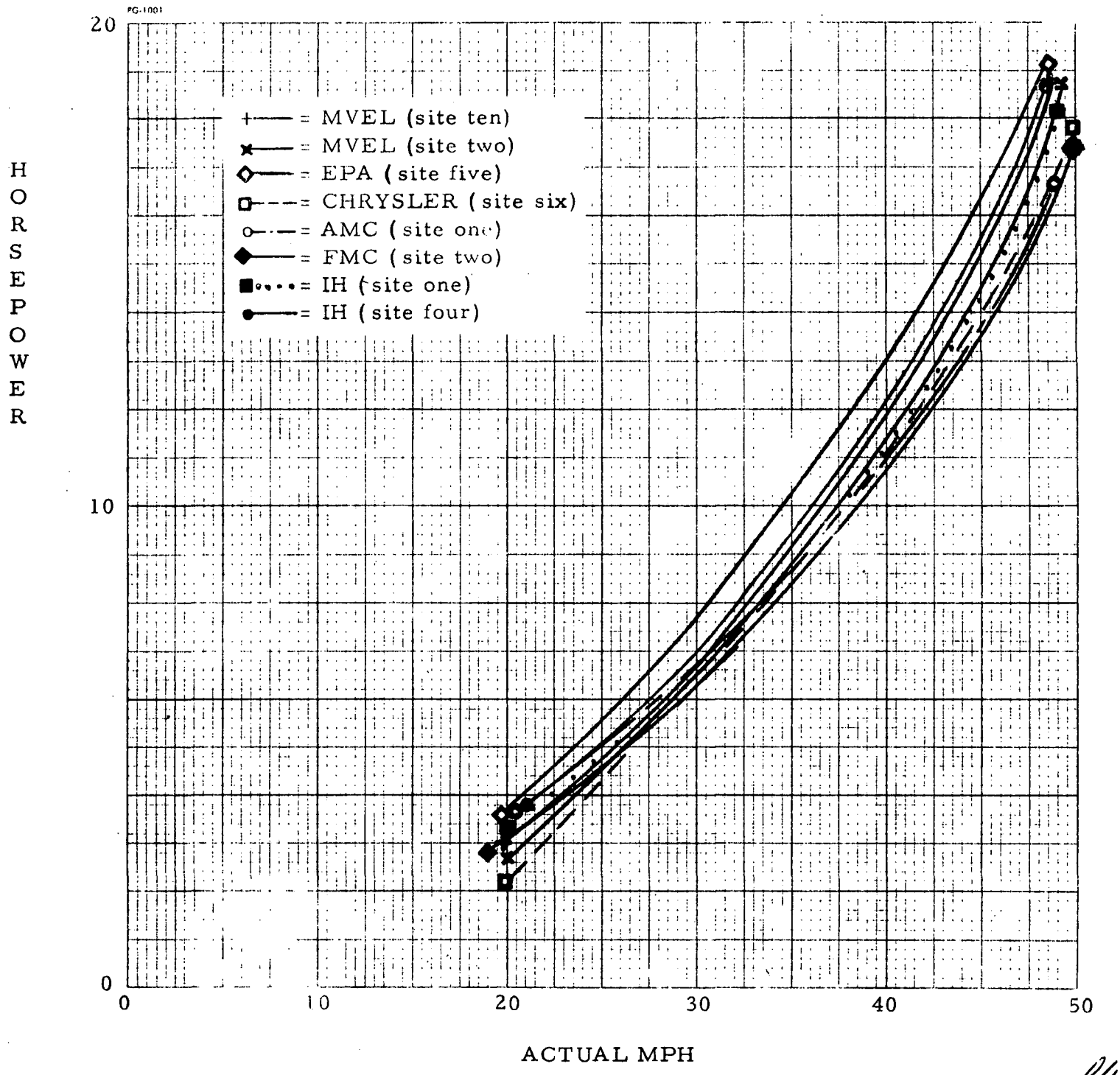
MVMA CORRELATION PROGRAM - REPCA 1 NOx DATA



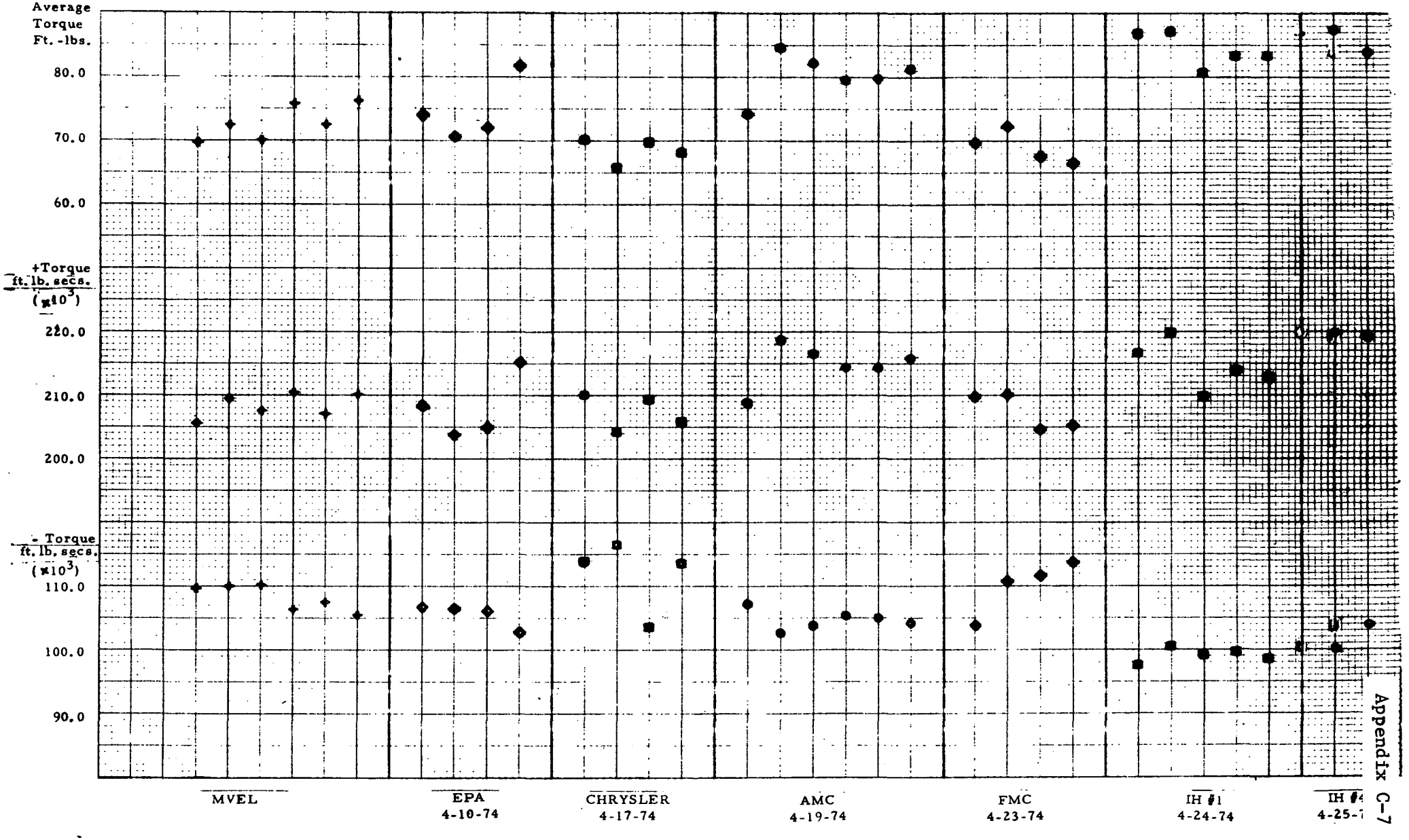
MVMA CORRELATION PROGRAM - REPCA 1 CO2 DATA



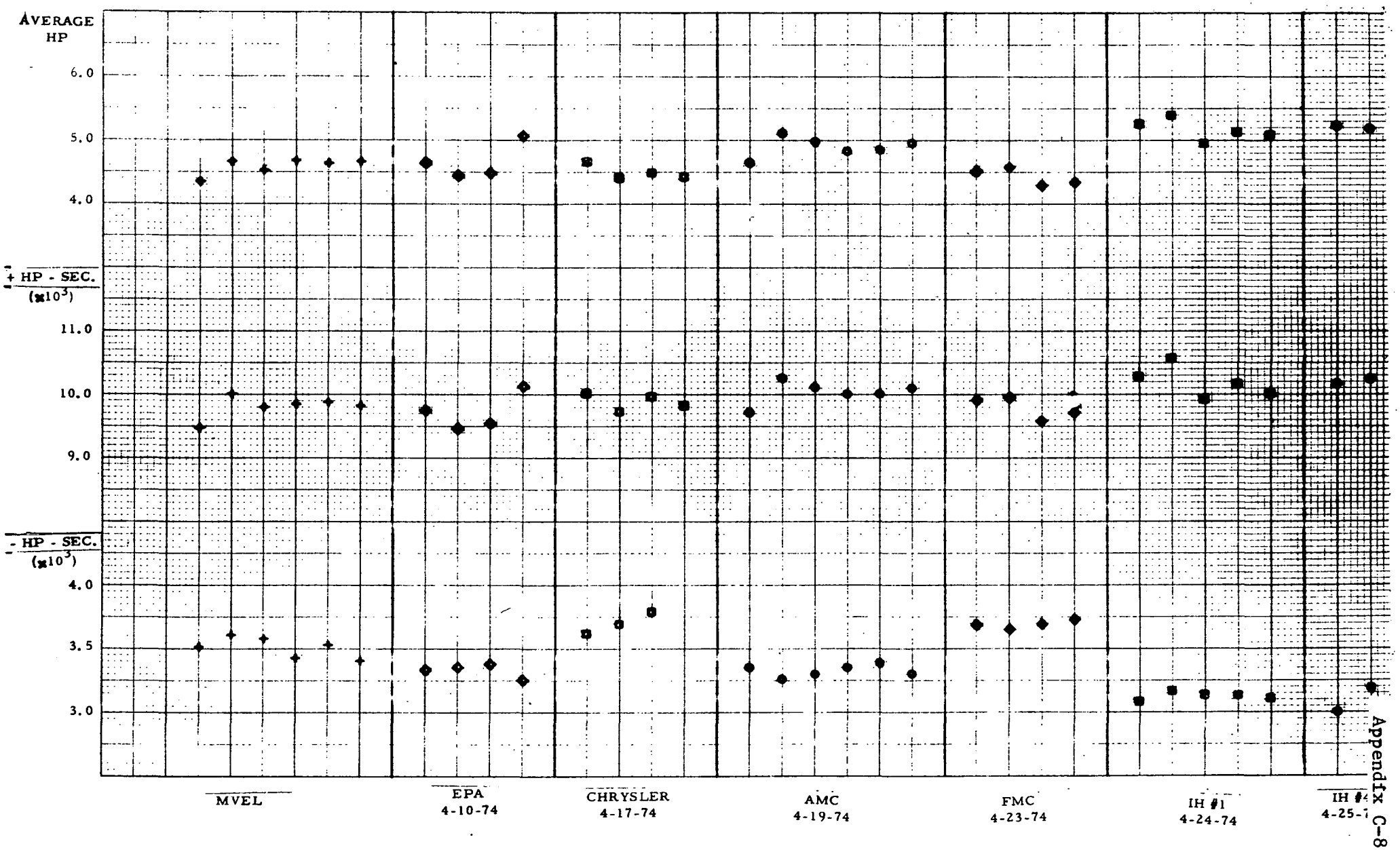
MVMA CROSS-CORRELATION - REPCA 1
HP vs ACTUAL MPH
LOCATION COMPOSITE OF BEST FIT LINES



MVMA CORRELATION PROGRAM - REPCA 1 TORQUE DATA



MVMA CORRELATION PROGRAM - REPCA 1 HORSEPOWER DATA



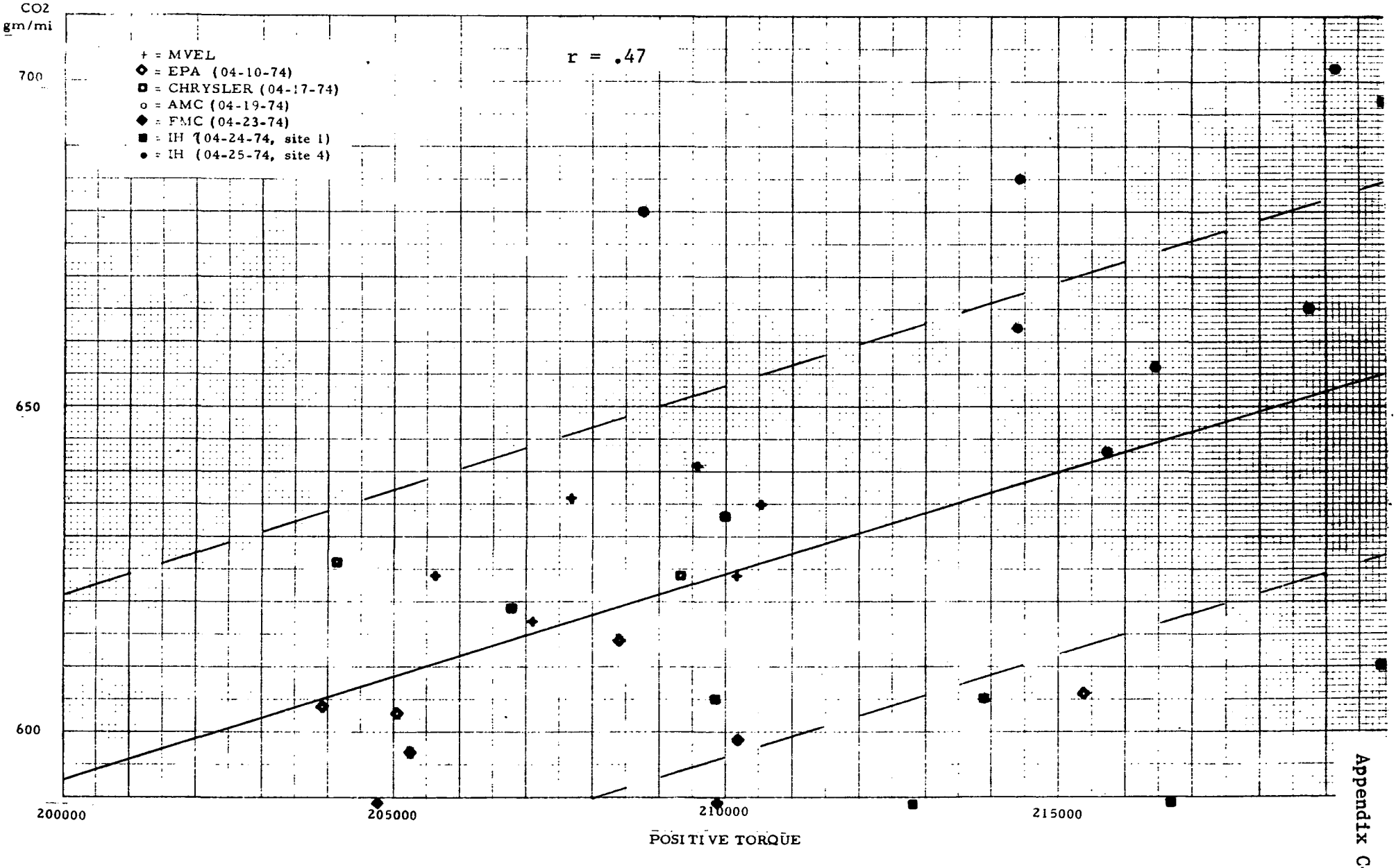
- Total Torque Tester Results

Facility	Absorber Horsepower	Inertia System	Roll Configuration
GM M-VEL	50	Direct Drive	Paired
EPA	50	Direct Drive	Single
Chrysler	50	Direct Drive	Paired
AMC	200	Belt Drive	Single
Ford	50	Belt Drive	Paired
IH #1	200	Belt Drive	Paired
IH #4	200	Belt Drive	Paired

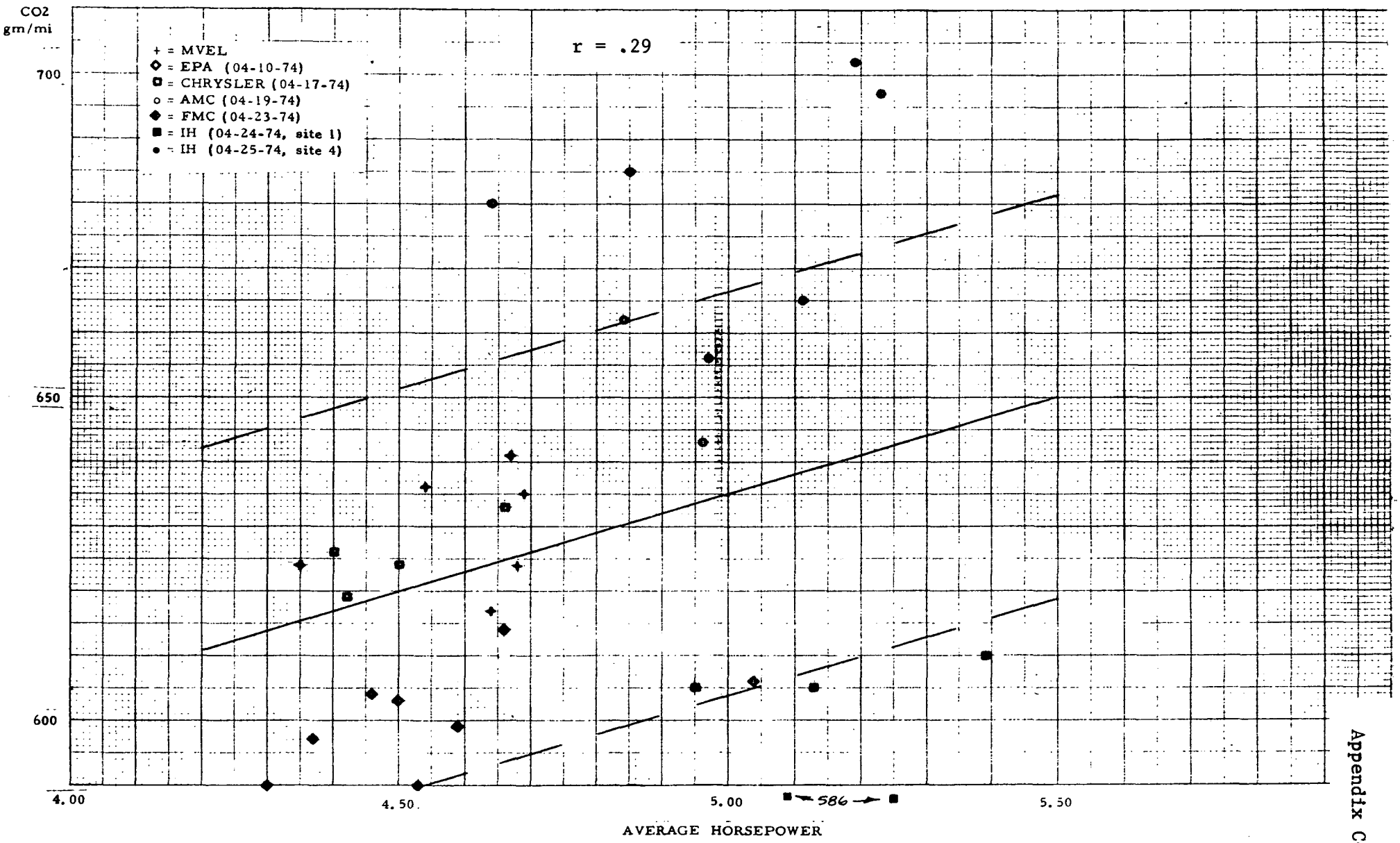
Facility	Theoretical Inertia (ft-lbs)	Actual Inertia (Average) (ft-lbs)	Percent Difference
GM M-VEL	457.3	442.8	-3.2
EPA	471.1*	428.1	-9.1
Chrysler	457.3	446.3	-2.4
AMC	457.3	446.7	-2.3
Ford	457.3	451.8	-1.2
IH #1	457.3	429.6	-6.1
IH #4	457.3	452.8	-1.0

* Data generated with "cold-start" testing on FRODO.

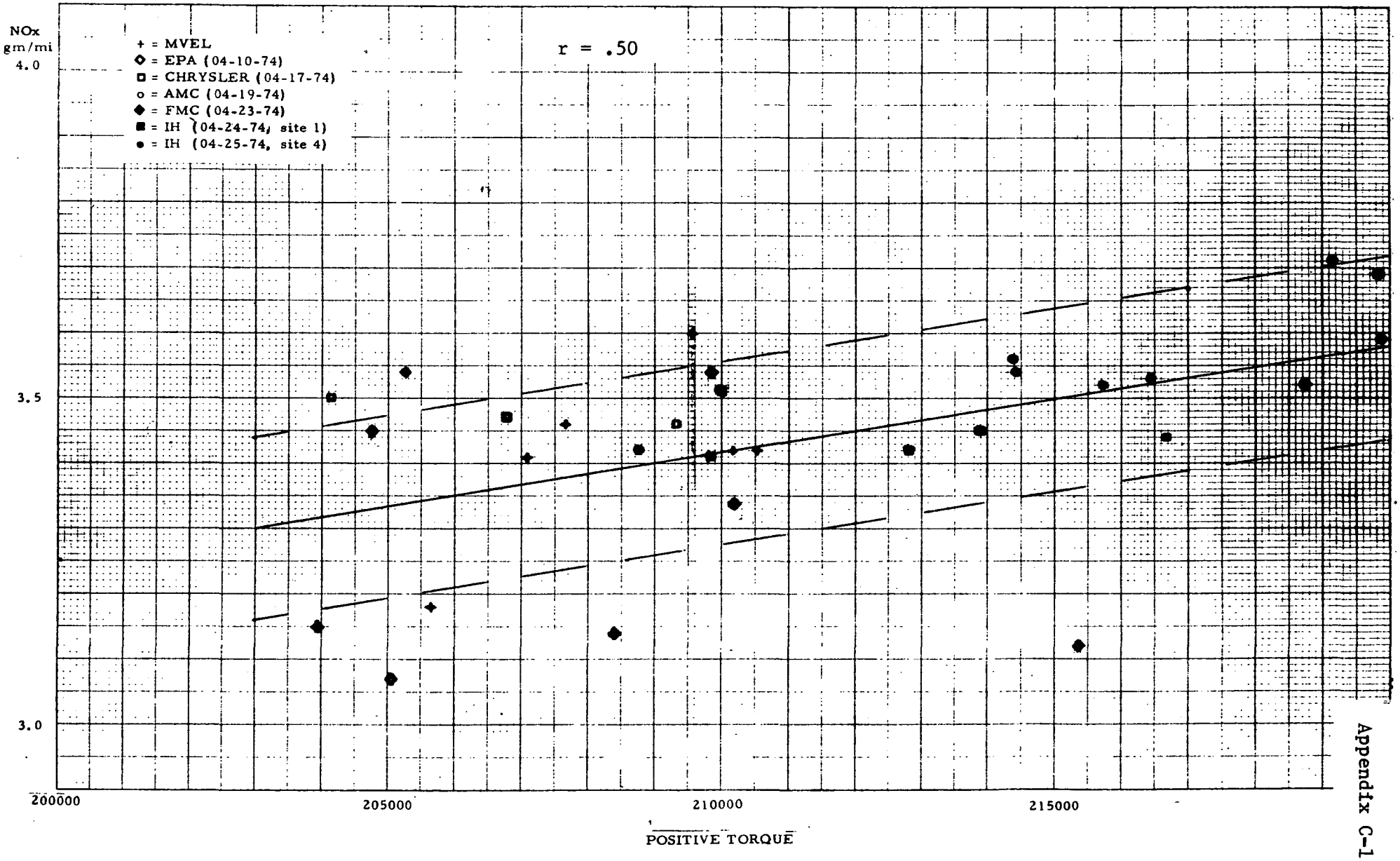
MVMA CORRELATION PROGRAM - REPCA I
(CO2 vs POSITIVE TORQUE)



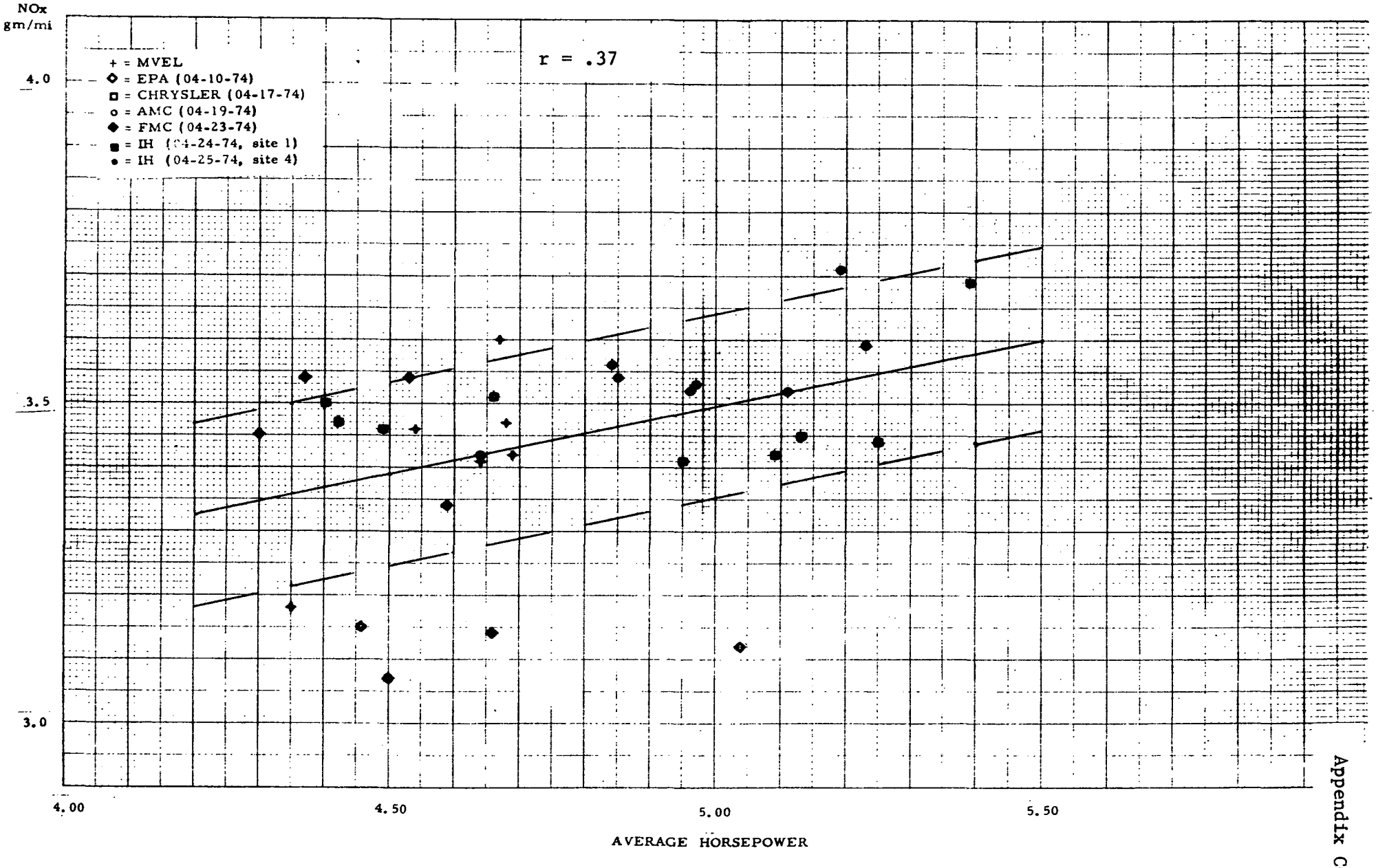
MVMA CORRELATION PROGRAM - REPCA 1
(CO2 vs AVERAGE HORSEPOWER)



MVMA CORRELATION PROGRAM - REPCA 1
(NOx vs POSITIVE TORQUE)



MVMA CORRELATION PROGRAM - REPCA 1
(NOx vs AVERAGE HORSEPOWER)



APPENDIX D

Phase III Data

1975 Emission-Level Vehicles

EPA - MVMA CROSS - CORRELATION STUDY

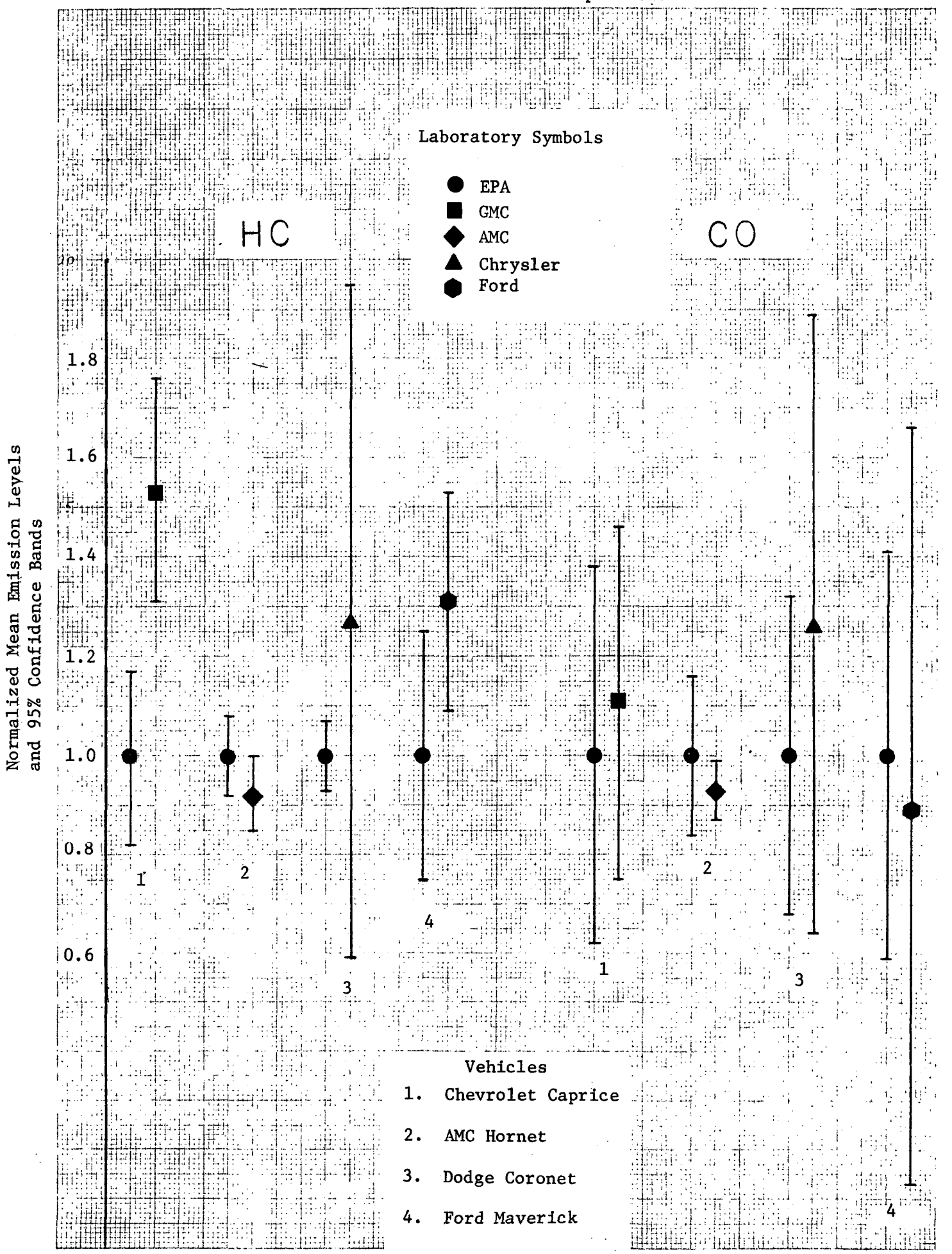
Phase III

Cold-Start 1975 Emission Test Results

Weighted Values (grams/mile)

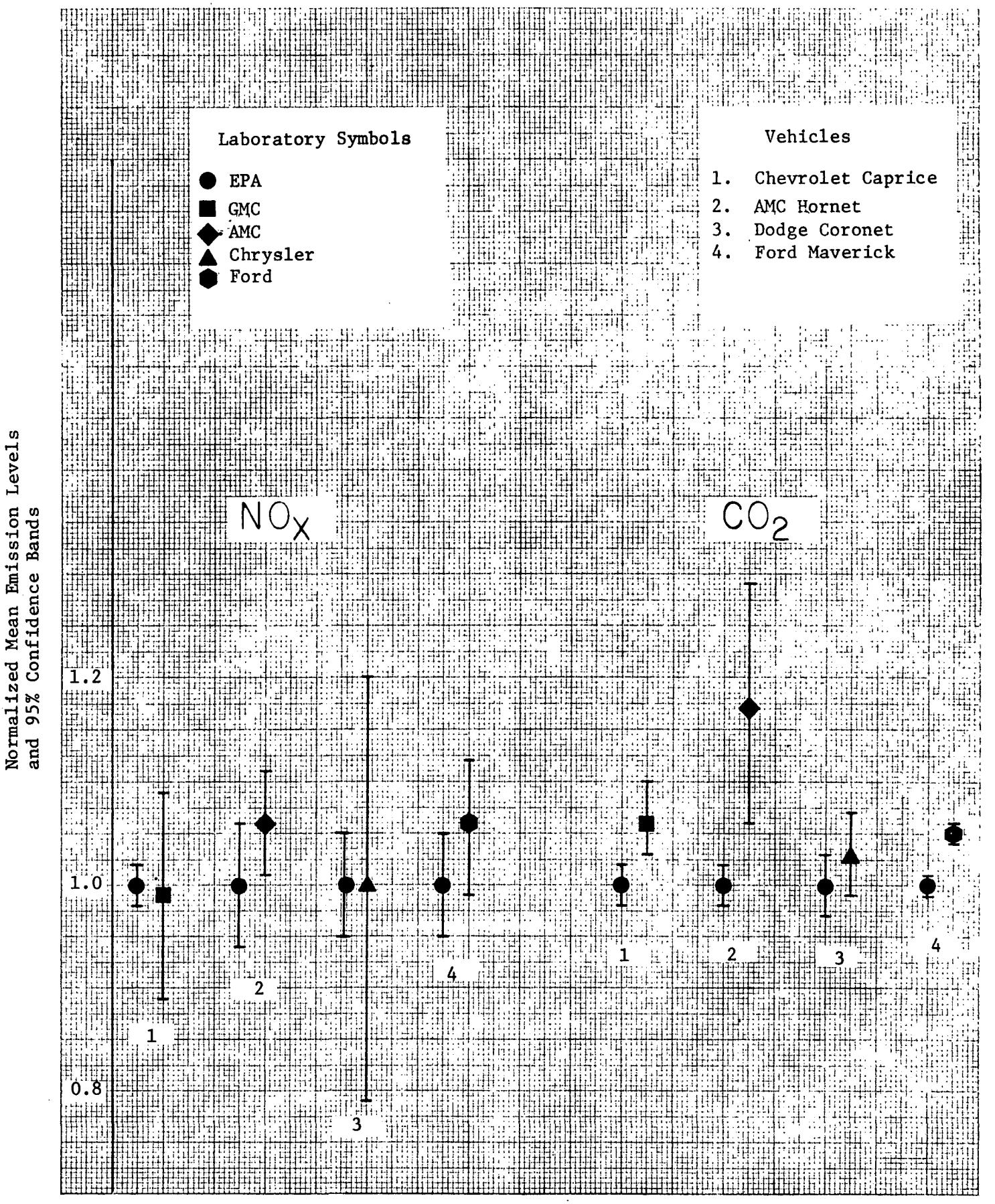
Vehicle I.D.	GM PG 72709	EPA	Chrysler #965	EPA	AMC D40-32L(F)	EPA	Ford 33Q55D	EPA
HC								
Mean	.219	.14	.542	.427	.98	1.06	.20	.155
Std. Deviation	.016	.01	.150	.014	.04	.04	.02	.019
95% Max.	.248	.17	.842	.455	1.06	1.15	.24	.194
95% Min.	.190	.12	.241	.398	.90	.98	.17	.116
CO								
Mean	2.39	2.2	7.00	5.54	9.09	9.77	1.64	1.84
Std. Deviation	.39	.4	1.80	.89	.29	.77	.70	.38
95% Max.	3.17	3.0	10.61	7.33	9.67	11.31	3.04	2.60
95% Min.	1.61	1.3	3.40	3.76	8.51	8.24	.25	1.08
NO_x								
Mean	2.40	2.43	2.649	2.65	2.87	2.71	1.46	1.38
Std. Deviation	.12	.02	.079	.07	.07	.07	.04	.04
95% Max.	2.65	2.46	3.21	2.79	3.01	2.86	1.55	1.46
95% Min.	2.15	2.39	2.09	2.51	2.73	2.56	1.37	1.31
CO_2								
Mean	732.7	689.23	667.2	648	534.6	457	845.32	804
Std. Deviation	12.4	6.74	14.5	11	24.9	4	5.59	6
95% Max.	757.4	702.70	696.2	671	584.4	464	856.49	815
95% Min.	708.0	675.75	638.2	625	484.7	450	834.14	793

EPA-MVMA Correlation
1975-Level Vehicle Emission Comparisons



EPA-MVMA Correlation

1975-Level Vehicle Emission Comparisons



MVMA Correlation - AMC

Vehicle Hornet D40-32L(F) Test Lab. AMC

	Test No.	HC	CO	NO_x	CO_2	Fuel Consumption (mpg)	Barometric Pressure (in. Hg)	K-Factor
Cold Transient (g)	1	5.06	90.28	10.11	2100.49			
	2	5.10	96.16	9.69	2042.00			
	3	4.89	102.47	9.38	1921.79			
	4	4.88	102.65	8.48	1935.48			
Cold Stabilized (g)	1	3.28	15.70	12.24	2264.45			
	2	3.21	13.58	12.75	2237.18			
	3	3.21	11.88	12.19	1997.07			
	4	3.16	11.23	12.26	1995.37			
Hot Transient (g)	1	2.59	30.36	8.11	1875.59			
	2	4.06	22.37	9.64	1815.67			
	3	3.82	19.26	9.21	1750.55			
	4	3.70	19.14	9.02	1755.46			
Total (g/mile)	1	0.92	9.58	2.83	564.9	15.17	29.34	0.9033
	2	1.03	9.02	2.99	553.4	15.49	29.20	0.9216
	3	1.00	8.92	2.86	509.5	16.79	29.21	0.9293
	4	0.98	8.84	2.81	510.4	16.77	29.34	0.9264

MVMA Correlation - Ford

Vehicle Maverick 33Q55D Test Lab. EPA

	Test No.	HC	CO	NO_x	CO_2	Fuel Consumption (mpg)	Barometric Pressure (in. Hg)	K-Factor
Cold Transient (g)	1	2.03	32.10	4.74	3097.03	10.1		
	2	1.37	19.26	5.18	3079.44	10.2		
	3	1.44	28.81	4.93	3098.23	10.1		
Cold Stabilized (g)	1	0.21	0.52	4.87	3125.22	11.1		
	2	0.22	0.16	5.29	3148.63	11.0		
	3	0.17	0.15	5.20	3197.06	10.8		
Hot Transient (g)	1	0.50	2.70	5.46	2706.12	11.7		
	2	0.50	2.32	5.69	2683.10	11.8		
	3	0.42	5.53	5.29	2742.72	11.6		
Total (g/mile)	1	0.182	2.12	1.34	800	10.9	28.58	0.9835
	2	0.146	1.30	1.43	800	11.0	29.05	0.9480
	3	0.137	2.09	1.38	812	10.8	28.96	0.9404

MVMA Correlation - GMC

Vehicle "Frodo" PB72709 Test Lab. EPA

	Test No.	HC	CO	NO_x	CO_2	Fuel Consumption (mpg)	Barometric Pressure (in. Hg)	K-Factor
Cold Transient (g)	1	2.14	38.67	11.13	2592.72	12.0		
	2	1.79	29.50	11.00	2524.85	12.4		
	3	1.70	24.84	10.84	2524.67	12.4		
Cold Stabilized (g)	1	0.14	1.43	6.12	2825.97	12.3		
	2	0.09	0.15	6.20	2747.09	12.6		
	3	0.16	0.45	5.85	2798.59	12.4		
Hot Transient (g)	1	0.26	3.35	13.03	2264.47	14.0		
	2	0.23	4.52	12.88	2236.88	14.2		
	3	0.27	2.79	13.10	2252.66	14.1		
Total (g/mile)	1	0.16	2.7	2.44	697.54	12.7	28.80	0.8791
	2	0.13	2.1	2.44	681.04	13.0	29.06	0.8300
	3	0.14	1.7	2.40	689.10	12.9	28.82	0.9368

MVMA Correlation - Chrysler

Vehicle Coronet 965 Test Lab. EPA

	Test No.	HC	CO	NO_x	CO_2	Fuel Consumption (mpg)	Barometric Pressure (in. Hg)	K-Factor
Cold Transient (g)	1	4.67	66.05	11.59	2334.38	13.0		
	2	4.62	99.95	10.02	2257.24	13.1		
	3	4.64	76.68	10.40	2271.40	13.2		
Cold Stabilized (g)	1	0.54	4.03	7.90	2711.10	12.8		
	2	0.55	4.71	7.78	2630.92	13.1		
	3	0.49	3.52	7.54	2626.92	13.2		
Hot Transient (g)	1	0.95	4.62	13.62	2214.77	14.3		
	2	1.11	5.36	13.02	2096.28	15.1		
	3	1.51	4.15	13.11	2105.03	15.1		
Total (g/mile)	1	0.412	4.68	2.75	664	13.3	28.91	0.8898
	2	0.422	6.77	2.60	640	13.7	28.62	0.9541
	3	0.446	5.18	2.60	640	13.7	28.71	0.9237

MVMA Correlation - AMC

Vehicle Hornet D40-32L(F) Test Lab. EPA

	Test No.	HC	CO	NO_x	CO_2	Fuel Consumption (mpg)	Barometric Pressure (in. Hg)	K-Factor
Cold Transient (g)	1	4.83	78.28	5.49	1719.77	17.1		
	2	4.99	98.70	8.34	1662.69	17.4		
	3	4.79	95.91	8.93	1700.38	17.1		
Cold Stabilized (g)	1	3.87	18.70	12.71	1844.08	18.4		
	2	3.91	23.12	11.31	1811.23	18.7		
	3	3.63	17.59	12.16	1814.03	18.7		
Hot Transient (g)	1	3.69	25.99	8.97	1550.58	19.9		
	2	3.98	26.96	8.51	1534.99	20.0		
	3	3.35	22.55	8.89	1538.00	20.1		
Total (g/mile)	1	1.07	8.96	2.69	462	18.4	28.95	0.9020
	2	1.11	10.8	2.63	453	18.6	28.59	0.9581
	3	1.01	9.56	2.81	456	18.6	28.75	0.9395

MVMA Correlation - Ford

Vehicle Maverick 33Q55D Test Lab. Ford

	Test No.	HC	CO	NO_x	CO_2	Fuel Consumption (mpg)	Barometric Pressure (in. Hg)	K-Factor
Cold Transient (g)	1	1.24	14.0	5.77	3154.25	-		
	2	1.18	14.0	5.73	3242.22	-		
	3	1.64	15.8	5.60	3234.24	-		
Cold Stabilized (g)	1	0.64	0.79	5.46	3419.56	-		
	2	0.52	8.46	4.85	3349.10	-		
	3	0.26	0.20	5.42	3310.30	-		
Hot Transient (g)	1	0.80	2.62	5.54	2739.19	-		
	2	0.98	9.14	5.59	2893.43	-		
	3	0.65	3.30	6.01	2787.60	-		
Total (g/mile)	1	0.22	1.11	1.48	844.96	-	29.31	0.8200
	2	0.21	2.63	1.40	852.33	-	29.25	0.8607
	3	0.18	1.19	1.50	838.66	-	29.42	0.8708