IMS-009/ST-1

Light Duty Vehicle and Light Duty Truck Emission Performance Warranty; Short Tests and Standards

December, 1979

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Inspection/Maintenance Staff
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Office of Air, Noise, and Radiation
U.S. Environmental Protection Agency

Abstract

This report addresses the relationship between short test emission results and emissions as measured on the "complete" or certification test (hydrocarbons and carbon monoxide) for 1981 and later model year light duty vehicles and light duty trucks. Several jurisdictions are now using idle and loaded mode short tests as methods for evaluating emissions from in-use motor vehicles. As provided in section 207(b) of the Clean Air Act, EPA must establish an Emissions Performance Warranty if a short test can be developed which is: 1. available, 2. in accordance with good engineering practice, and 3. reasonably capable of being correlated with the Federal certification test (known as the Federal Test Procedure or FTP). The purpose of this report is to evaluate the correlation of idle and loaded short test emissions to results which will be obtained on the certification test for 1981 model year and later passenger cars and light trucks.

In proceeding with this work, a less common definition of correlation was adopted. While it is not possible for the short tests to predict on-road mass emissions with mathematical certainty, they can detect malfunctioning vehicles with their attendant high emissions. This functional definition of correlation is advanced in this paper as the only practicable approach which satisfies the statutory requirement.

This report addresses the issue of correlation for 1981 and later model year vehicles. For this purpose, data from 1975-77 model year federal cars was examined. This group represents the most advanced automotive emission control technology in service for which adequate data is available. (California cars would be more appropriate for some purposes but, unfortunately, sufficient data does not exist.)

Three short tests are recommended: idle, two speed idle and two mode loaded. These procedures, necessary equipment and short test standards are all described in Section XI of this report. These short tests and associated standards give approximately the same error of commission rate as the FTP (comparing single test results to average emission levels) while identifying a substantial part of the excess emissions. This result is obtained because the short test tends to ignore marginal failures, i.e. those vehicles only slightly above FTP standards.

Further information regarding 207(b) short tests may be obtained from United States Environmental Protection Agency, Inspection/Maintenance Staff, 2565 Plymouth Road, Ann Arbor, MI 48105, (313)668-4367.

Table of Contents

I. Background, Statutory Requirements

The purpose of this paper is to examine the relationship between short test emissions and actual emissions observed on the EPA certification test procedure. (The EPA certification test, or Federal Test Procedure, is commonly referred to as the FTP). Many states will be inspecting motor vehicles for exhaust emissions using various short tests; repairs will be required if emissions exceed limits established by the states. These Inspection/ Maintenance (I/M) programs are mandated by the Clean Air Act for areas with severe air quality problems.

As an element of consumer protection, the Congress provided for an emission control performance warranty, Section 207(b) of the Clean Air Act. Under certain conditions, the manufacturer will be required to remedy emission failures. However, before this warranty can become effective, EPA must promulgate an "approved" short test;

> If the Administrator determines that
>
> > (i) there are available testing methods and procedures to ascertain whether, when in actual use...each vehicle...complies with emission standards,
> >
> > (ii) such methods and procedures are in accordance with good engineering practices, and
> >
> > (iii) such methods and procedures are reasonable capable of being correlated with...(certification tests)...then
>
> he shall establish such methods and procedures by regulation. (Clean Air Act Section 207(b).)

The first two requirements have already been satisfied. As several jurisdictions are currently using idle and/or loaded testing for inspection purposes, these tests are certainly "available". (The last half of the first requirement, ability to ascertain compliance with emission standards, is shown by satisfying the third requirement, correlation with the certification test.) The criterion of good engineering practice is met because these tests can be conducted with reasonable demands of test personnel and equipment, and they yield reasonably accurate and reproducible results.

The term "reasonably capable of being correlated" is not defined in the Clean Air Act. Correlation implies a mutual relationship; two quantitites which can be mathematically related are said to be correlated. Also, two methods of ranking objects are correlated if they put the objects in the same order or class. For example, if eggs are normally graded by weight, a method of measuring the length and width which achieves the same result can be said to be "correlated." The degree of error which can be tolerated before "correlation" is lost is subjective.

Correlation is the most difficult, and consequently the most crucial, element in establishing an approved short test. Before they can be sold, car and light truck exhaust emissions are measured (using prototype vehicles) on the Federal Test Procedure (FTP). It is an expensive, time consuming and complicated method designed to duplicate urban driving. This test takes a minimum of 12 hours, has a specific preconditioning sequence and requires sophisticated gas metering and analytical equipment. If emission standards are met, a certificate of conformity is issued by EPA and sales can begin. While the FTP is totally unsuited for inspection purposes, its intended functions, prototype vehicle certification, selective enforcement audit and recall, are served well. The test begins with a cold start after a simulated overnight "soak"; many different driving modes are tested, including some highway operation. All of this is performed under controlled laboratory conditions using a chassis dynamometer to duplicate vehicle inertia, wind resistance and tire losses.

It should be obvious that correlating a short, simple inspection test to the FTP is a significant task. Compounding this problem is the FTP's cold start which yields a substantial part of the total hydrocarbon (HC) and carbon monoxide (CO) emissions. The cold start also tends to be quite variable. During cold starts, a gasoline engine requires a significantly richer fuel/air mixture to insure that enough fuel is vaporized. For most vehicles this is provided by a "choke" on the air supply. It is this rich mixture and choke operation which cause the increased cold start emissions. (Without enough air for complete combustion high emissions are inevitable) For warm starts and normal operation a choke is not needed. Practical considerations prevent any I/M short test from including a cold start; therefore, it is impossible to fully characterize a vehicle's true FTP emissions. (A car with a faulty choke might have very high FTP emissions and still be "clean" on any short test.) Since classical correlation requires some sort of mathematical relationship, [e.g. FTP emissions = function(Short Test)] no short test can ever achieve classical correlation. However, the short test can be used to correctly identify a substantial number of the high emitting vehicles; this will be developed below.

The position taken in this report is that a short test which accurately predicts FTP failure satisfies the correlation requirement of the Clean Air Act; strict mathematical correlation is not necessary.

A short test should be acceptable if it satisfies two goals. First, it should identify a substantial portion of "excess" emissions, i.e. emission above the appropriate standard. Second, the number of false short test failures, (called errors of commission on Ec's), should be as low as possible. This is necessary so that manufacturers (and owners whose vehicles don't meet warranty requirements) will not be burdened by having to make unnecessary repairs. It is unfortunate, but not pertinent, that a short test will not identify all non-complying vehicles. These errors of omission (Eo's) have no impact on the manufacturers' warranty claims. In addition, the omitted vehicles tend to exceed standards only by a moderate amount; the potential for air quality improvement is not as large as with the correctly failed vehicles.

II. Rulemaking Activities, Direction of Program

On 25 May 1977 the Environmental Protection Agency issued a Notice of Proposed Rulemaking (NPRM) on the Emission Performance Warranty, 42 Federal

Register 26742 and 26747. This rulemaking consisted of two parts: proposed alternate short tests (and associated standard setting methods) and regulations to actually implement the warranty. For various reasons, the implementation regulations were withdrawn and were reproposed on 20 April 1979, 44 Federal Register 23784. Before the Emission Performance Warranty can become effective, both sets of rules must be promulgated in final form.

Originally, five alternative short tests were proposed. These tests fell into three classes; unloaded, steady state loaded (constant speed) and transient (varying speed). Unloaded testing includes the high and low speed idle modes, with exhaust concentrations measured by simple "garage" analyzers. Oxides of nitrogen (NOx) cannot be determined by the unloaded tests. For steady state testing, a chassis dynamometer is employed to impose a power requirement on the engine ("load") for specific vehicle speeds; garage analyzers are also used for determining exhaust concentrations. As proposed, neither the unloaded or steady state loaded procedures would determine the actual mass of emissions produced, only the concentration of exhaust pollutants would be measured. However, the transient tests proposed in the NPRM do determine true mass emissions at the price of using equipment very similar to the FTP. The three types of tests represent increasing levels of sophistication with corresponding cost and complexity.

Along with the various short tests, several methods were proposed for selecting short test standards. These methods applied various statistical tools to determine appropriate standards. At the beginning of each model year, the new vehicle population was to be divided into groups by make, engine size, vehicle size and technology. Vehicles from each group would be tested to establish correlation between the FTP and the various approved short tests. Use of many specific groups was promoted to maximize the correlation obtained. (If sufficient commonality existed, groups of vehicles would be combined to minimize testing.) One of the proposed methodologies would be applied to the data from each group to obtain standards. It would require testing many cars each year at considerable expense; short test standards would not be available until many months after the start of the model year.

In response to comments received, new data, a revision to the Clean Air Act which shortened the warranty, and internal policy decisions, EPA's position has been revised. Initially, only three tests are recommended for promulgation (idle, two speed idle, two mode loaded). This results because, subsequent to the NPRM, EPA acquired data revealing that the idle tests have higher than anticipated correlation for the latest technology vehicles. Also, the idle tests are much more widely accepted and "available". For those jurisdictions which wish to use loaded testing, a simplified version of the Federal Three Mode has been developed. For each test, a single set of standards will apply to the entire vehicle population. This approach will sacrifice some potential accuracy while significantly simplifying the program. As will be shown later, a relatively small number of "gross emitting" vehicles contribute the majority of all excess emissions. These vehicles are detected by the short tests and standards in this report. So, even if a more sophisticated procedure will detect a larger number of excess emitters, its additional air quality impact will not be substantially greater.

In this report, loaded mode testing of NOx emissions will not be addressed.

III. Approach

By statute, the emission performance warranty is tied to state (or local) vehicle inspection programs. Only when a car or truck fails inspection (and some sanction will be imposed) can the warranty be invoked. Even then, certain mileage and maintenance restrictions apply. It is anticipated that many states will use the emission performance warranty standards as a lower limit for their inspection standards; this will achieve the greatest possible air quality improvement without failing vehicles for which the warranty is not available. Actual I/M standards must be set after considering the amount of air quality improvement needed, alternate approaches, etc.

It would be possible to develop short test warranty standards by evaluating vehicles which meet all the warranty requirements (i.e., age and mileage limits, proper maintenance). Unfortunately, such a data set does not exist. Further, since these standards may have wider application, a group of as-received in-use light duty vehicles will be the basis for setting standards.

It should be noted that a portion of those vehicles failing the state I/M short test will not qualify for warranty coverage because of tampering, high mileage and lack of required maintenance.

EPA plans to have the emission performance warranty effective beginning with the 1981 model year. Promulgation of the warranty regulations, short tests and standards (or procedures to set standards) must occur prior to the start of that model year; this is a specific requirement of The Clean Air Act. Quite obviously, it is impossible to test in-use vehicles before their introduction. Instead, the standards will be derived by testing the highest technology vehicles for which data is available. Under the NPRM, this dilemma was to be solved by collecting data on early production vehicles. But, with the enactment of the 1977 Clean Air Act amendments, the warranty period was significantly reduced making the proposed approach less attractive; data gathering would consume a major part of the time available for warranty coverage.

A comparison reveals that 1975 through 1977 California vehicles have the closest emission standards to the forthcoming 1981 and later Federal limits.

Emission Standards (FTP) - g/miles

	HC	CO	NOx
California - car			
1975-6	0.9	9.0	2.0
1977	0.41	9.0	1.5
Federal - car			
1975-6	1.5	15	3.1
1977-9	1.5	15	2.0
1980	0.41	7.0	2.0
1981 and later	0.41	3.4*	1.0

* Possible waiver to 7.0 for 1981 and 1982.

Unfortunately, 1975-7 California vehicles have not been tested in adequate numbers and under appropriate conditions to establish nationwide short test standards. Instead, this paper will use EPA's Portland, Oregon data base. Over 2200 (1975 through 1977) cars have been tested at an actual I/M lane. Subsequent FTP's and short tests were performed by EPA's contractor. An evaluation of these results will produce short test standards for which correlation with the FTP can be established.

Future Federal standards are more stringent than current levels. With the lower emission standards in the future, one can reasonably expect lower short test emissions. Therefore, short test standards developed using 1975-7 Federal vehicles can be applied to 1981 and later model year vehicles without prejudicing the manufacturers rights. However, if unforseen technology is developed for which the standards are not appropriate, the manufacturer could be allowed to apply for a separate short test standard for the effected vehicles.

Short test standards developed in this paper will apply to light duty trucks (LDT) as well as passenger cars. Certification standards for light duty trucks for 1979 and later models were derived from the 1977 passenger car levels. Adjustments were made to account for the higher weights and larger frontal areas; the same degree of emission control is required from 1979 light duty trucks as from 1977 light duty vehicles (passenger cars).

Emission Standards (FTP) - g/mile

	HC	CO	NOx
1977 LDV	1.5	15	2.0
1979 LDT	1.7	18	2.3

Light trucks have used, and will continue to use, the same emission control technology as passenger cars. Most light trucks also use engines derived from passenger cars. The same certification test (FTP) is also used for light trucks. For these reasons, light trucks will respond to the short tests in a manner similar to light duty vehicles. Therefore, short test standards derived from 1975-7 cars can be directly applied to 1980 and later light trucks.

For a full discussion of the light truck standards, test procedure, emission control equipment and related issues, see the rulemaking docket for the 1979 light truck regulations.

IV. Data

Information for this paper came from EPA's Portland study. Results from over two thousand 1975 through 1977 in-use passenger cars were evaluated. These particular vehicles were tested from September 1977 through January 1979 and were selected to represent various types of emission control technology and not the general vehicle population. For purposes of 207(b) this is rather fortunate; any lack of correlation for a low sales group will be more evident than if the sample were sales weighted. All testing was carried out at an elevation of approximately 50 feet.

No effort was made to screen out maladjusted or tampered vehicles. The sample represents vehicles as they would be presented to an inspection station. As it is expected that some jurisdictions may use the warranty standards as limits to their I/M cutpoints, this approach will give an estimate of the potential benefits of an I/M program.

Each vehicle received an idle test by the Oregon Department of Environmental Quality (DEQ). It was then taken to Hamilton Test Systems (HTS), EPA's contractor, where it received a second idle test, a Federal Three Mode (F3M) and a Federal Test Procedure (FTP). DEQ uses a three-step idle procedure; idle - 2500 rpm - idle; the lowest of the two idle readings is used to determine compliance with Oregon's standards. The Federal Three Mode is a loaded test simulating steady state driving; it has high and low speed cruises followed by an idle. In order to determine compliance with Federal Emission standards, an FTP was also run. A summary of the data set appears in Figure 1.

Figure 1

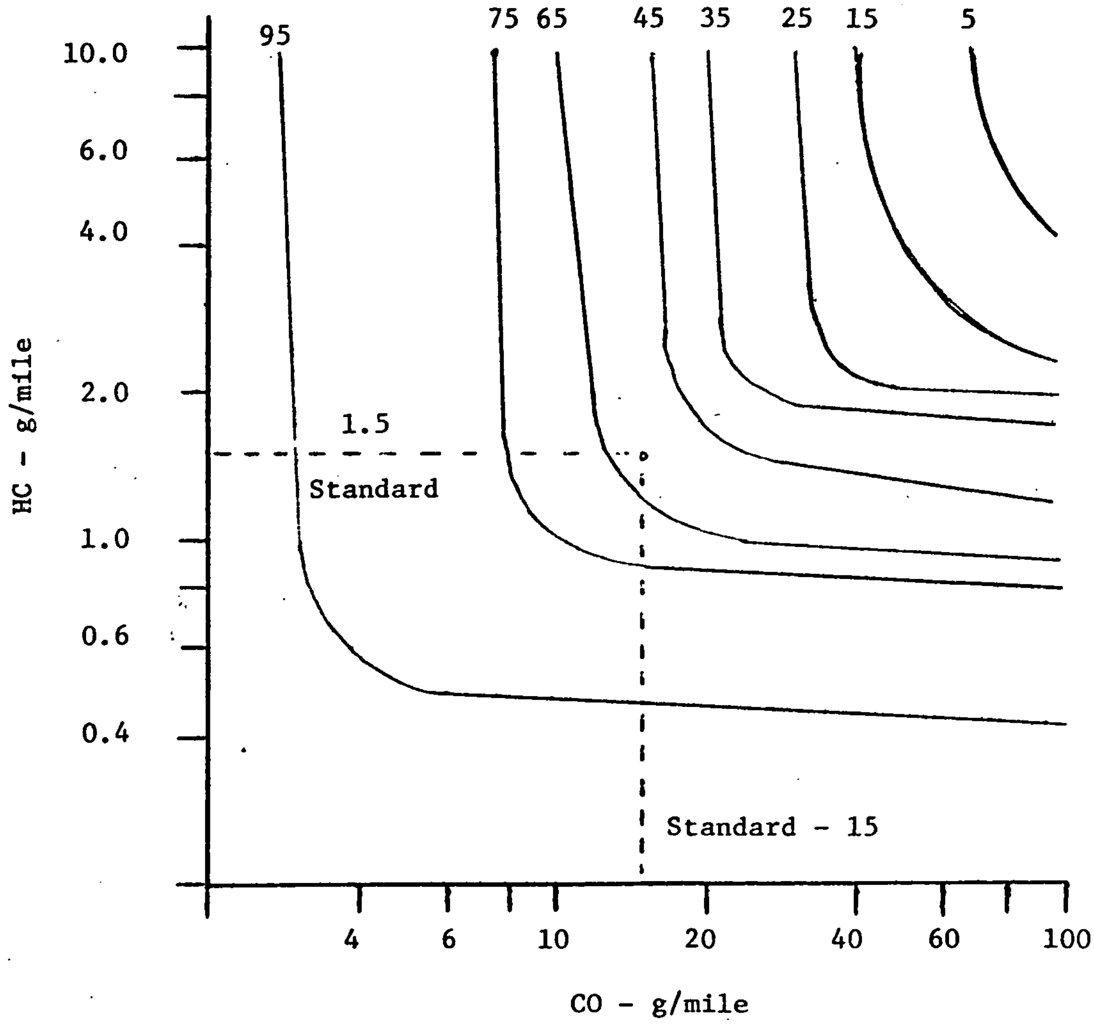
Data Summary

Model Year	No.	Mean Mileage	Mean FTP (g/mile) HC	CO	NOx
1975	636	39174	1.96	25.30	2.59
1976	828	28663	1.64	20.30	2.62
1977	734	17787.	1.61	22.06	1.93
Overall	2207	28030.	1.72	22.33	2.38

Presented in Figure 2 is the distribution of FTP emission values for HC and CO. Each "contour" line on the graph indicates the percent of vehicles which would fail the FTP at any combination of HC and CO standards on the

Figure 2

FTP Failure Rate-(%)



line. For example, 53% of the sample exceed the emission standards of 1.5 g/mile HC and 15 g/mile CO. This is indicated by the 45% and 65% "contours" which bracket the point representing these standards. While a large number of vehicles exceed new car certification levels, many of these are fairly close to the standards. Only 35% are over 1.5 times either standard; at twice either standard this falls to 26%. But these 26% of all vehicles account for over 85% of all excess HC and CO emissions, i.e. emissions over the standards. Fortunately these vehicles are easiest to detect using the short test.

V. "Reasonable" Correlation

Any emission performance warranty short test must be "reasonably capable of being correlated" with the Federal Test Procedure as required by section 207(b). But what is "reasonable"? Certainly, the best possible short test could do no better than the FTP. Since any test has some inherent variability, even the FTP will occasionally fail a vehicle incorrectly. Such errors of commission (Ec's) are unavoidable. The purpose of this section is to investigate the correlation of FTP results to subsequent FTP tests. By this means, we will be able to estimate the number of Ecs which an "ideally" correlating test will yield. Intuitively a "reasonably" correlating short test will be permitted a greater number of Ecs. Compliance with the statutory correlation requirement will be made on this basis.

FTP variability has been characterized in "Survey of Sources of Test Variability in the 1975 Federal Test Procedure," August, 1978, by Douglas Berg of EPA's Motor Vehicle Emissions Laboratory. In Table B, Mr. Berg makes the following estimates for total FTP variability on the same vehicle:

Percent Coefficients of Variation*

HC: 10-25%
CO: 15-30%

*Sample standard deviation/sample mean.

These coefficients of variation can be used to estimate the percentage of error of commissions if the FTP were used as a short test.

In order to evaluate these errors of commission, two assumptions must be made. First, it is assumed that test variability follows the normal (or bell shaped) distribution curve. Second, the Portland data (FTP results) is assumed to be representative of the true emissions of the general population. It is acknowledged that these assumptions are not precisely correct. However, their whole function is to help estimate how well the FTP would function as a short test. Given the range of the estimated coefficients of variation, these assumptions are adequate.

Cars from the Portland data base were segregated into groups which passed FTP standards. All of these vehicles were assumed to have "true" FTP valves equal to the test results observed. For any given car this would not be

Figure 3

FTP Errors of Commission

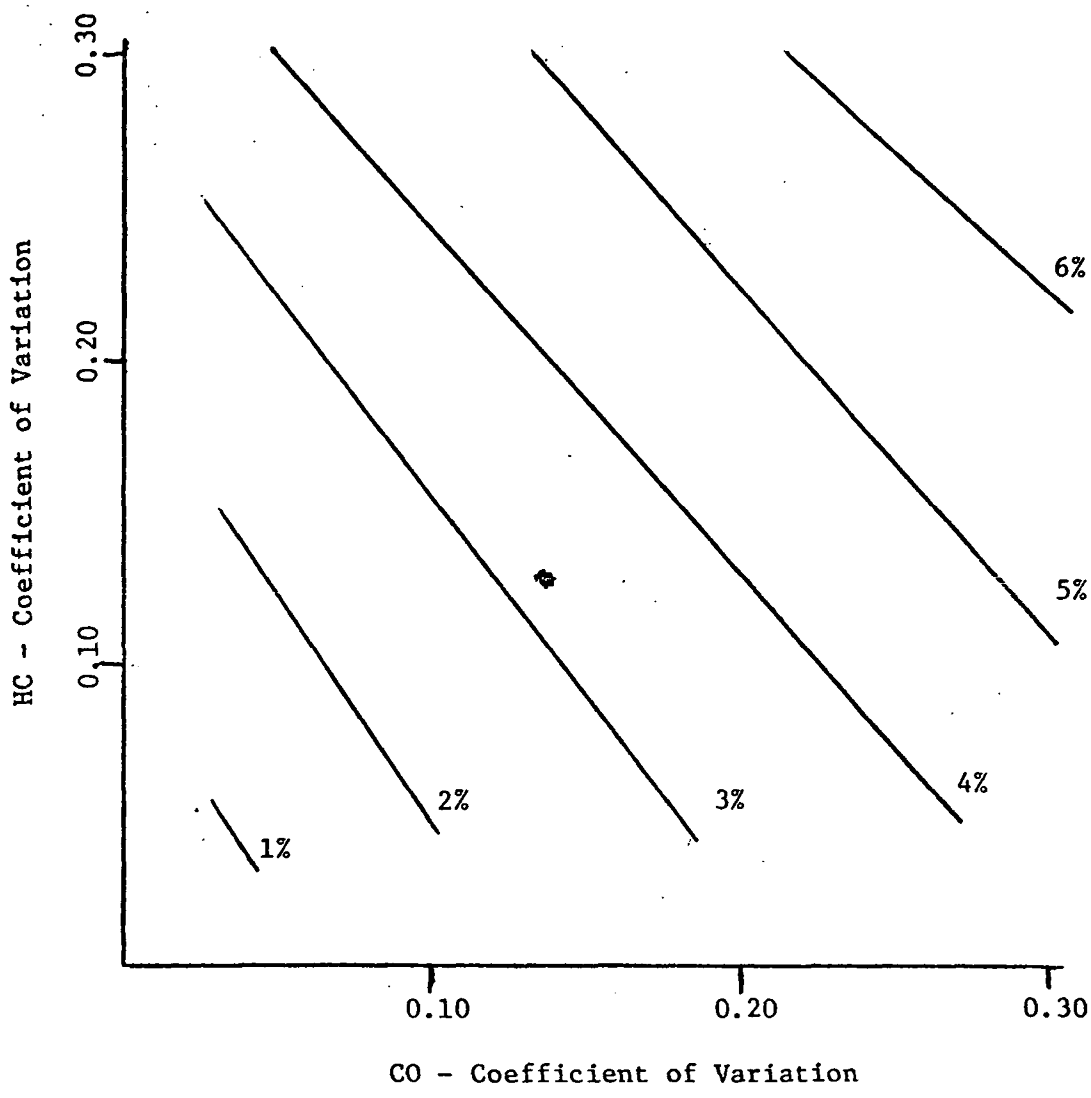
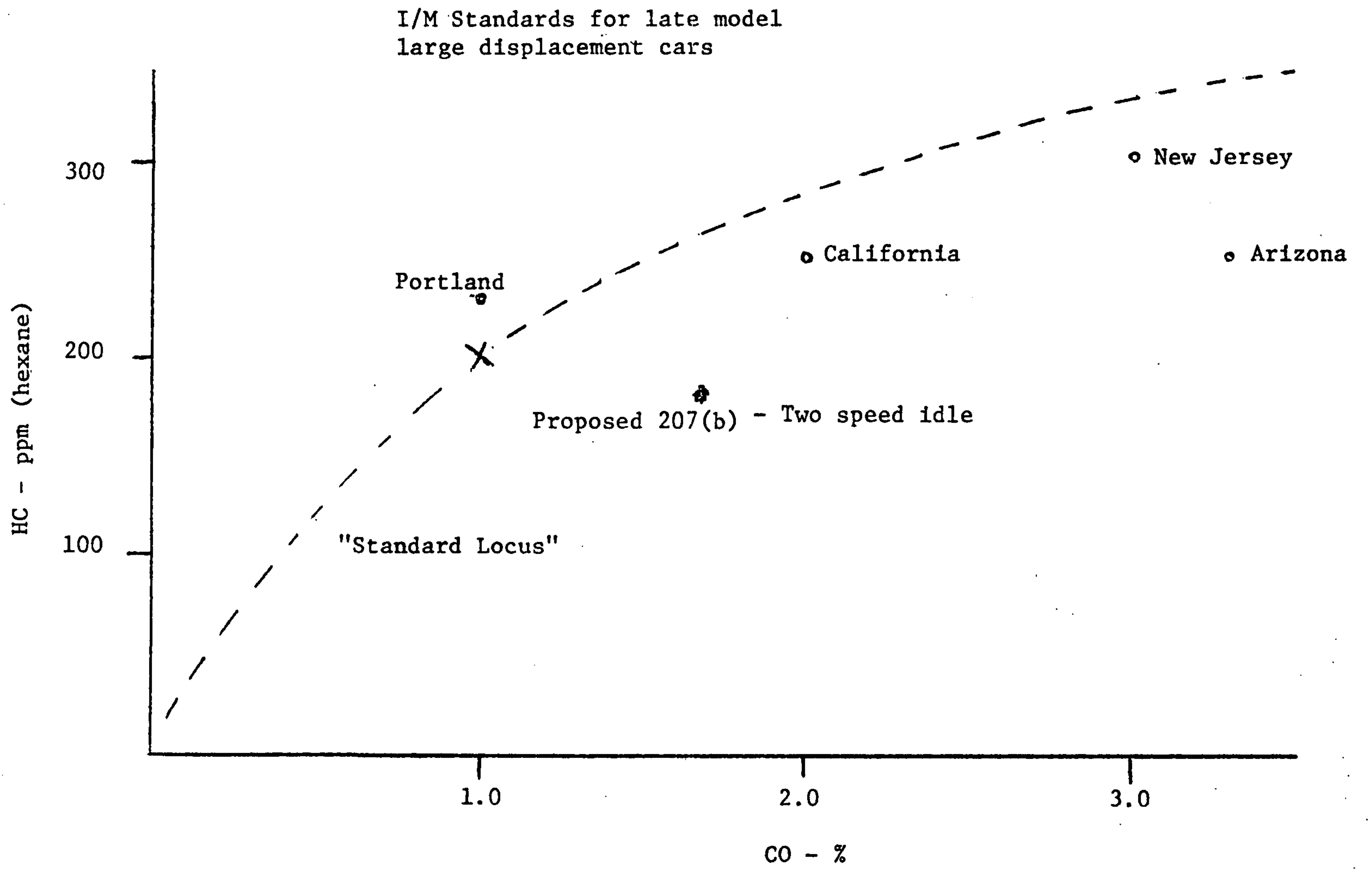


Figure 4

Comparison of I/M Idle Standards



correct; however, for the entire population this assumption should be reasonable. It is expected that if a subsequent FTP were administered, the results observed would be similar to the first set; variations for individual vehicles would average out.

To determine the FTP's error of commission rate, coefficients of variation for HC and CO were assumed. For each vehicle passing the FTP a probability of failing was calculated. This probability is a function of how close the FTP results were to be standards. Various coefficients of variation for HC and CO were assumed. (Probability of failure was calculated by determining how many standard deviations a particular vehicle was below the standards and looking up the probability in a normal distribution table. For example; at an assumed HC coefficient of variation of 0.20, a vehicle whose emissions are 1.25 g/mile would be 1.0 standard deviation below the 1.5 g/mile standard: 1.5 g/mile - 1.25 g/mile = 0.25 which is 0.20 of that vehicles emissions of 1.25 g/mile; or one standardized deviation. At 1.0 standard deviation below the standard the vehicle would have a 16% chance of failing a subsequent FTP. This process was then performed for CO, and a total Ec probability determined). This process was repeated for each passing vehicle to determine its probability of being an error of commission (Ec) on a subsequent FTP. The sum of these probabilities divided by the <u>total</u> number of vehicles is the estimated FTP Ec rate. Results are indicated in Figure 3 for a range of HC and CO coefficients of variation.

Assuming coefficients of variation of 20% and 25% for HC and CO, the FTP will give approximately 5.3% errors of commission. (Using the range of estimates for coefficients of variation, Ec's will be between 3 and 6%). This statement is derived from the Portland data sample where only 47% of the vehicles pass FTP HC and CO standards. If a "cleaner" population (more passing cars) were tested, errors of commission would increase because more cars would be subject to the random test variability. (As a convention, errors of commission are expressed as a percent of the entire population, not just those below emission standards.)

Since the FTP, used as a "short" test, yields approximately 5% errors of commission, this is a criteria against which the short tests can be evaluated.

VI. <u>Standard Selection</u>

Figure 4 indicates idle HC and CO I/M standards for late model, large displacement cars in several jurisdictions. Also shown is a general relationship between the two constituents, developed from earlier work. This relationship, or "standard locus", represents EPA's best judgment (as of September, 1979) of the best relationship between HC and CO standards for typical I/M programs. In developing this relationship, test results from approximately 300 1975-77 California cars were briefly evaluated. Items investigated were failure rate, errors of commission and excess emissions identified. Results of this investigation indicate that the "standard locus" is the center of a region where errors of commission and excess emissions identified are constant <u>for a given failure rate</u>. Farther away from the standard locus, the test loses some effectiveness and errors of commission increase. For these reasons, short test standards will be developed from this relationship. (A more thorough study on the topic of I/M standards is now underway; results should be available in early 1980).

As of September, 1979 the most stringent I/M program had idle standards of 1.0% CO and 225 ppm HC (Portland, Oregon for catalyst vehicles). The corresponding standard on the locus is 1.0% CO and 200 ppm HC. If errors of commission are low enough, such a standard for the emission performance warranty would be desireable.

It is expected that many future vehicles will be designed for low idle emissions, even after some key parts of the control system have failed. For these types of failures an additional short test will be needed. To be effective, such a short test must exercise the fuel and emission control systems so as to detect component failures. Either a high speed idle or loaded mode should accomplish this end.

Standards will be developed for three separate, but related, short tests. All tests include an idle mode. Different standards are necessary because of the way results are calculated and because of potential preconditioning differences. The three tests are briefly described below; all modes except the 30 mph cruise are performed with transmissions in neutral.

Idle	- ° Idle
Two Speed Idle	- ° Idle - ° 2500 rpm idle - ° Idle
Two Mode Loaded	- ° 30 mph cruise - ° Idle

The two speed idle will be addressed first. This test is used in the Portland I/M program. Standards of approximately equal stringency will then be developed for the other procedures.

VII. Two Speed Idle Test

An analysis was performed on the Portland data using an idle standard of 1.0% CO and 200 ppm HC. The two speed idle test consists of two idle portions separated by a high speed segment (idle - 2500 rpm - idle); the lowest HC and CO levels of the two low speed idles is used to compare with the standards. This is the procedure used in Portland.

Idle Portion only

Failures	- 37%
Ec's	- 4.0%
Excess HC identified	- 81%
Excess CO identified	- 83%

This test satisfies the requirement of reasonable correlation and is an acceptable emission performance warranty standard. Effects of other possible standards are shown in Figure 5. Comparison of the two speed idle test (idle portion only) to the FTP is shown in Figure 6.

However, as with any sampling process, predicting the number of Ecs (like an election result) is not an exact process. For idle standards of 1.0% CO and 200 ppm HC an estimate taking into account the impact of test variability was made. The sample of 2207 vehicles was randomly divided into 22 subsamples of 100 cars each. For each subsample the number of Ecs was computed. Considering this to be a sample of 22 programs, nonparametric tolerance intervals based upon the distribution of order statistics were derived to estimate expected programmatic effects. The following statements can be made with 90% confidence:

- 89% of the I/M programs will have Ec's less than 5%

- 92% of the I/M program will have Ec's less than 6%

Of course, these error of commission rates were derived by an analysis of the idle standard applied to groups of 1975 to 1977 model cars. The emission performance warranty will apply to 1981 and later vehicles. For passenger cars, idle emissions and errors of commission should be much lower since the newer vehicles will be certified to lower emission standards. Light trucks will experience about the same Ec rate, they use the same emission control systems as the earlier cars.

The emission performance warranty can also be applied to the high speed (2500 rpm) segment. For 1975 through 1977 model cars the low speed idle is an effective test. But, with changing technology the high speed segment (2500 rpm) may be needed to identify high emitters. (EPA has obtained test results verifying this occurance. For some future technology cars, the 2500 rpm segment identifies certain failure modes where the normal idle does not.) Results of the idle test are summarized below, standards of 1.0% CO/200 ppm HC were used. A summary of these results is as follows; they all meet the statutory requirement of reasonable correlation:

Two Speed Idle Test Summary

	Failure Rate	Excess Emissions Identified Ecs	HC	CO
Idle (minimum of two idles)	37%	4.0%	81%	83%
2500 rpm	22%	2.8%	60%	59%
Combined	42%	6.0%	87%	90%

Note: Test sequence is: idle - 2500 rpm - idle. Idle results are the lowest of the two HC and two CO values observed. Standards of 1.0% CO/200ppm HC were used for both idle and 2500 rpm.

Figure 5

Impacts of Possible Standards
(Two Speed Idle Test — Idle portion only)

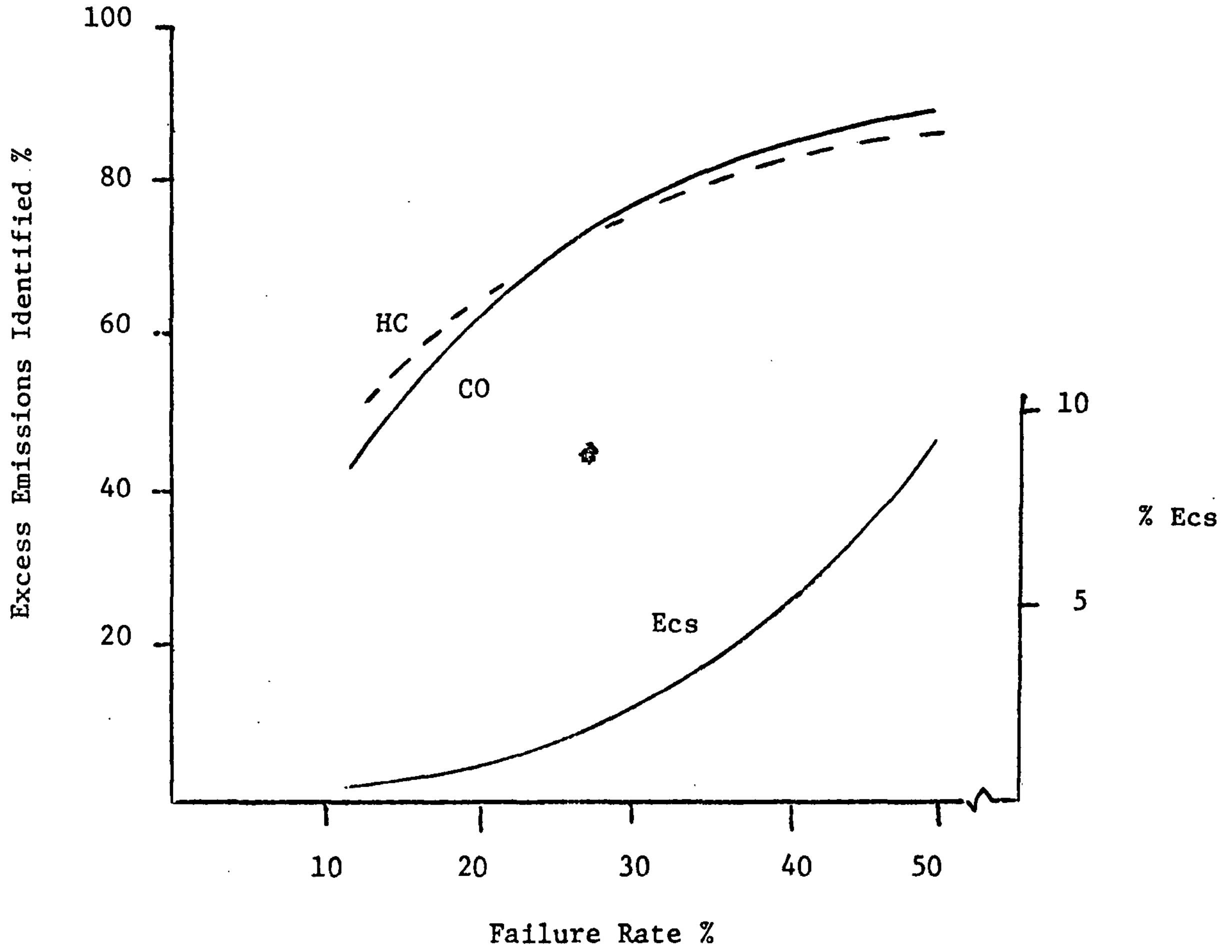
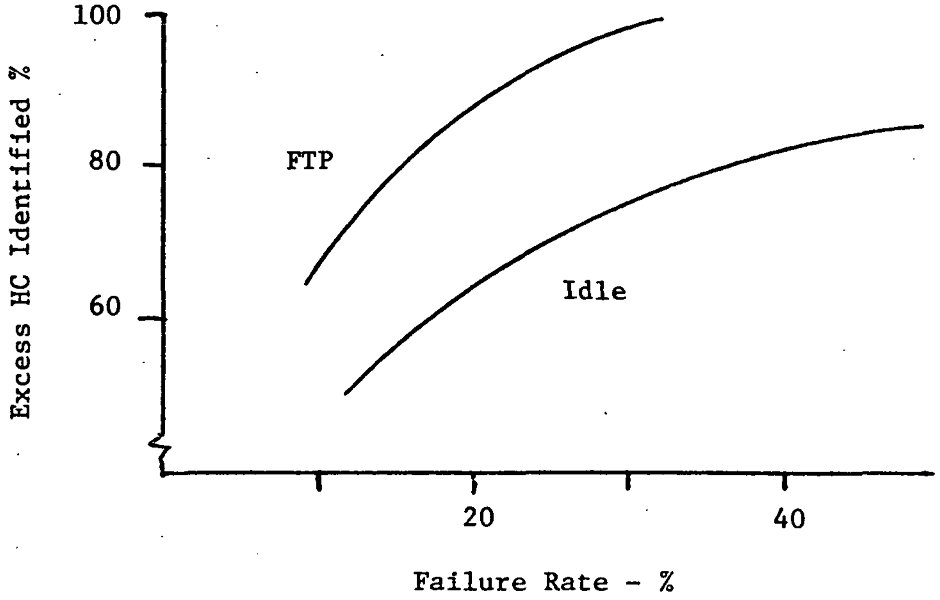
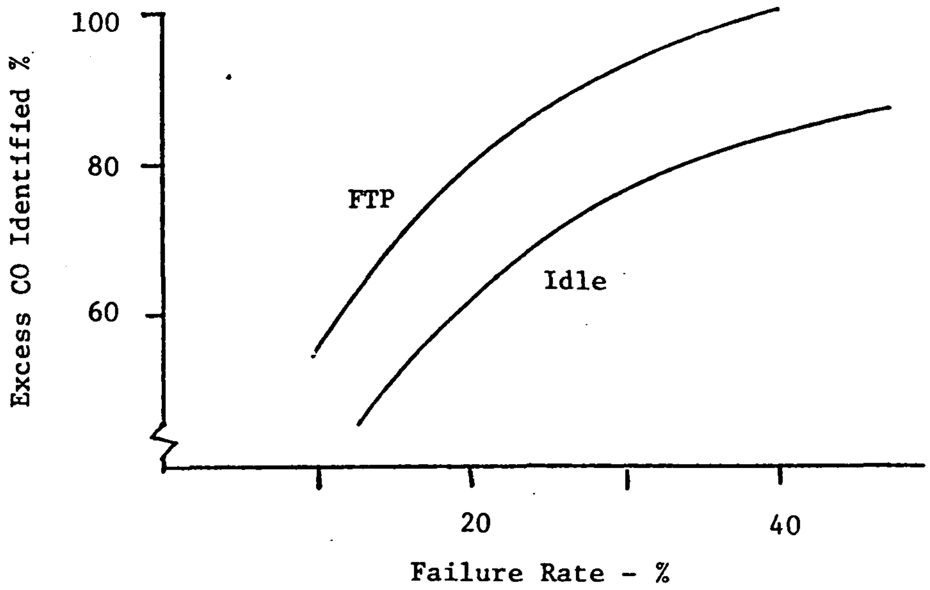


Figure 6

Comparison of Two Speed Idle Test to FTP
(Idle portion only)





While the two speed idle test is a specified sequence (idle - 2500 rpm - idle), three ways exist to take emission results. (See Section XI for a full test description). These methods are as follows:

1. Idle mode only. Emissions from the two idle sequences are measured. The lowest HC and CO readings observed are compared against the standards. Emissions from the 2500 rpm mode are either not measured or their results are disregarded. (This mode is preconditioning for the second idle). Of course, if the vehicle passes on the first idle sequence, the remainder of the test need not be run. (The standard is 1.0% CO/200 ppm HC).

2. 2500 rpm mode only. The vehicle is briefly idled prior to the 2500 rpm mode. Emission measurements need only be taken at 2500 rpm, the second idle is deleted. (The standard is 1.0% CO/200 ppm HC).

3. Combination of idle and 2500 rpm. The full test sequence, idle-2500 rpm-idle, is run with emissions measured under all modes. To pass, a vehicle must be under the standards at both idle and 2500 rpm. As with the "Idle mode only" procedure described above, the lowest HC and CO readings from the two idle sequences are compared against the standard. If the vehicle passes the first idle, the second idle sequence may be deleted. (Standards for both modes are 1.0% CO/200 ppm in HC).

VIII. Idle Test

This is the simplest short test; exhaust concentrations are measured with the vehicle idling in neutral. (This procedure is followed in New Jersey and other locations.) To achieve the same level of stringency as the two speed idle (idle mode only), slightly higher standards will be necessary. (The two speed idle uses the lowest of two observed idle measurements, any single measurement procedure will require higher numerical standards at the same level of stringency).

For standards of 1.2% CO and 220 ppm HC (hexane) the idle test yields the following results:

Idle Test Summary

Failure Rate	Ecs	Excess Emissions Identified HC	CO
39.4%	5.6%	82%	84%

These compare quite closely with those for the idle mode of the two speed idle. This test meets the statutory requirement of reasonable correlation, i.e. it results in low Ecs and a high fraction of excess emissions identified.

IX. Two Mode Loaded Test

This paper presents a simplfied loaded test for use with the emission performance warranty. Derived from the Federal 3 Mode, the simplified two mode test has identical test conditions for all vehicles: 30 mph cruise at 9.0 hp load followed by an idle in neutral. Following is a history of its derivation and an estimate of its effectiveness.

As an alternative to the idle test, I/M jurisdictions may employ loaded mode testing. Currently, Arizona uses a loaded mode preconditioning for its idle test, other states and localities are considering loaded tests. To the extent possible, the emission performance warranty should accomodate these procedures.

Unfortunately, previously there was no standard loaded mode test in which the test parameters are the same for all cars.

In the NPRM, EPA proposed the "Federal 3 Mode" (F3M), consisting of 50 and 30 mph cruises followed by an idle in neutral. Vehicles were divided into four weight categories for the purpose of setting dynamometer load. This test was subsequently modified before the Portland program to provide many more categories of dynamometer adjustment as well as an idle in Drive for automatic transmission cars. EPA's experience with this test revealed the virtues of a procedure with fixed test conditions. In performing a procedure with multiple test conditions, much time is spent determining the proper classifications for a particular vehicle; errors can occur. Any possible increase in correlation from the multiple classification will not be great enough to offset the extra complexity.

For this reason a simplified loaded procedure with one test condition will be evaluated.

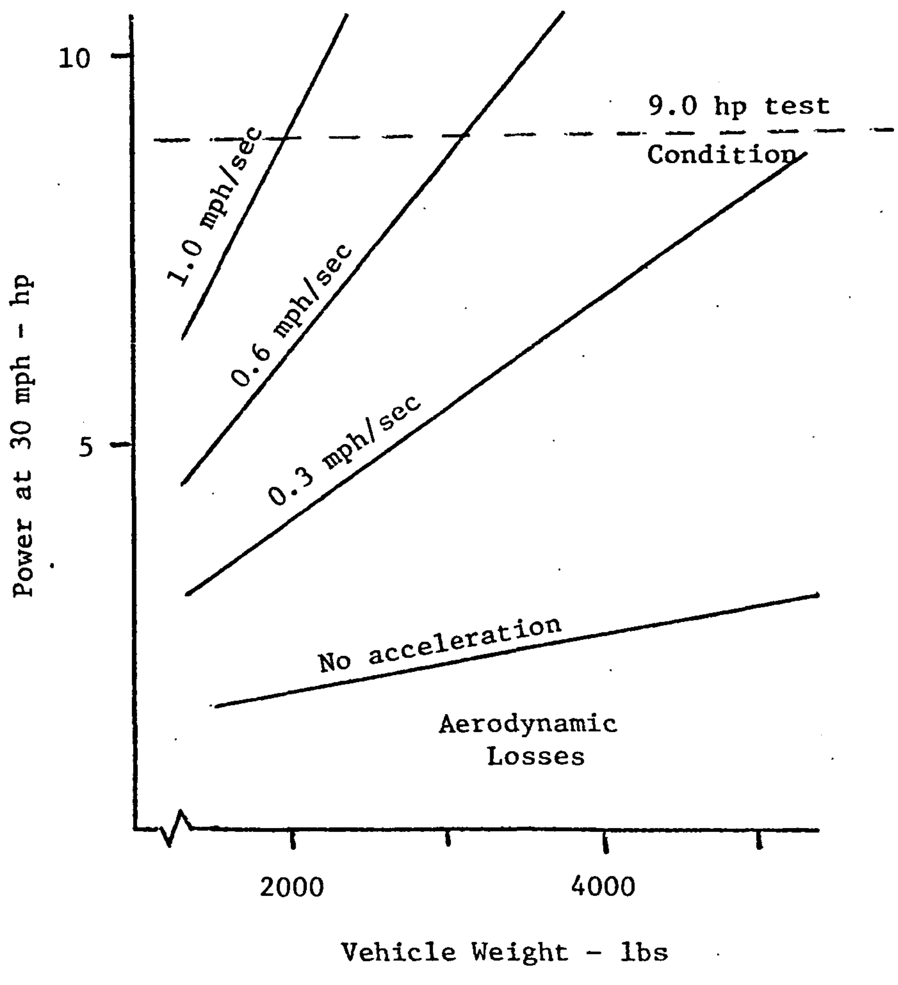
As specified in the NPRM, the Federal 3 Mode low speed cruise for vehicles up to 2500 pounds was 30 mph with a 9.0 hp load. This will be adopted for all vehicles. The high speed cruise will be deleted to reduce test length. (An optional high speed cruise will be permitted, but warranty standards will not apply). For safety reasons, the idle mode will be run in neutral instead of Drive for automatic transmission vehicles.

For heavier vehicles, this test condition is less severe than the original F3M. This power level is equivalent to a modest acceleration for small vehicles and a very low acceleration for a larger car, see Figure 7. (During the FTP, a vehicle will see acceleration rates of up to 3 mph/sec.)

In order to achieve the same general level of stringency it is necessary that slightly higher standards be employed for the idle portion of the simplified loaded test than for the idle test. During the Portland program, idle exhaust emissions averaged approximately 0.2% CO and 25 ppm higher on the F3M than the idle test (idle portion of two speed idle). These results were obtained from manual transmission cars, thus avoiding any increase due

Figure 7

Loaded Mode Power Settings



to automatic transmissions being idled in "Drive" (F3M) as opposed to neutral (idle test). This offset is probably caused in part by the loaded-mode "preconditioning" under the F3M procedure and, in part, by the use of the lower of the two idles in the two speed idle test. Consequently, idle standards for the loaded test will be set at 1.2% CO and 220 ppm HC.

To set standards for the loaded mode it is necessary to calculate a theoretical exhaust concentration. One must assume both an exhaust emission level (grams/mile) and fuel economy (miles/gallon). (Several additional facts and assumptions enter in the calculation; fuel density, fuel composition, stoichiometric combustion, standard temperatures and pressures, etc. Minor discrepancies in these ancillary facts will not upset the approximate outcome). From this point one can apply the standard combustion equations to predict an exhaust concentration. For example, a car traveling 30 mph, emitting 7.0 g/mile CO and 0.41 g/mile HC (1980 standards), and getting 50 miles/gallon will have exhaust concentrations of approximately 1.0% CO and 180 ppm HC. Vehicles with fuel economies less than 50 miles/gallon will consume more fuel and have corresponding higher exhaust flows. For the same mass emissions (g/mile), exhaust concentrations (%, ppm) will have to be lower. Air pumps, employed on some vehicles, will increase exhaust flow with the same effect on concentration.

A very conservative example was used in the paragraph above; a vehicle getting 50 miles/gallon at 30 mph while its engine produces over 9.0 horsepower. (Tire and drive train losses are not considered in setting the dynamometer to 9.0 hp.) Such a vehicle would have to have a very efficient engine, less than 0.4 lb fuel/horsepower - hr. It is doubtful that any real vehicle would consume less fuel and have a lower exhaust flow. Also, it was assumed that HC and CO were being emitted at the level of the standards. Again, this is very conservative; a vehicle which meets emission standards will be very clean at a steady cruise under low power levels when fully warmed up. (These conditions describe the loaded mode test condition.) To pass the FTP, such clean operation is essential to balance inherently high cold start emissions. The same standards used for the idle portion, 1.2% CO/220 ppm HC, will pass the hypothetical example in the previous paragraph; this is a conservative standard and will have very few errors of commission when applied to 1981 and later passenger cars.

These same standards can also be used for light trucks even though their 1980 standards are significantly higher, (1.7 g/mile HC; 18 g/mile CO). However, light trucks consume significantly more fuel with resulting larger exhaust flows. The appropriateness of these standards for light trucks can be verified by examining how 1975-7 cars in the Portland data base respond. As explained previously, these vehicles are technologically similar to 1981 and later model light trucks and should respond similarly to the same short tests. This comparison will also serve as an "upper limit" for 1981 and later passenger cars; their cleaner emissions will give lower Ecs with expected decreases in failure rate and excess emissions identified. Results are stated below (Test conditions were the same or more severe than the two mode test recommended. Results here are estimates only for the loaded mode).

Loaded Test Summary

	Failure Rate	Excess Emissions Identified Ecs	HC	CO
Loaded (Estimates)	24%	4.3%	59%	54%
Idle	40%	5.2%	83%	85%
Combined	46%	7.0%	93%	93%

Note: Test sequence is 30 mph at 9.0 hp load followed by an idle in neutral; standards are 1.2% CO/220 ppm HC for each mode.

The two mode loaded test is a specified sequence. However, as with the two speed idle test, three ways exist to take emission measurements.

1. Loaded Mode only. Standards of 1.2% CO/220 ppm HC are used for the loaded mode, the concluding idle may be disregarded.

2. Idle Mode only. The vehicle undergoes the 30 mph cruise for a brief period, 10-30 seconds. An emission measurement need only be taken for the idle mode. Standards are 1.2% CO/220 ppm HC.

3. Combination of Loaded and Idle. The full test sequence is run with standards of 1.2% CO/220 ppm HC applied to both modes. If these standards are exceeded on either mode, the vehicle fails.

As indicated above, the loaded test and associated standards comply with the requirements of Section 207(b). Errors of commission are within acceptable limits and a substantial part of the excess emissions are identified. Light trucks (1981 model year) should respond in a similar manner to the above table. Actual Ec's for 1981 passenger cars will be lower due to more stringent Federal Standards.

X. Geographical Effects, Light Duty Trucks

To gain additional confidence in the application of the short test standard to other geographic areas, a similar analysis using EPA emission factor data was performed. All currently available EPA emission factors and restorative maintenance test data on 1975 through 1979 models was used. (Analysis was done in October 1979, test results on 3706 cars and light trucks were available). This data has been collected over a number of years in 8 different cities; it represents the best cross section available. For this analysis, results from the idle test (using the recommended standards, 1.2% CO/220 ppm C_6) were compared with FTP emissions; failure rates and percent errors of commission were calculated. As can be seen in Figure 8, the results compare closely to those observed in Portland. It is also evident that light trucks are treated slightly less stringently than automobiles.

XI. Optional Standards

The short test standards developed above are appropriate for anticipated future vehicles. It is possible, but unlikely, that control technology will be developed for which these standards are not appropriate. Under these circumstances specific standards or modified procedures should be established for the effected vehicles.

XII. Recommendations Summary

Three short tests can be used for the Emission Performance Warranty; idle, two-speed idle and two-mode loaded. Initial standards for 1981 and later model light trucks and passenger cars should be as set forth in Figure 9.

Figure 9
Short Test Summary

Name	Idle	Two Speed Idle	Two Mode Loaded
Description (test modes)	Idle	1. Idle 2. 2500 RPM 3. Idle	1. 30 mph/9.0 hp 2. Idle
Standards	1.2% CO 220 ppm HC	1.0% CO* 200 ppm HC*	1.2% CO** 220 ppm HC**
Equipment	Garage Analyzer	Garage Analyzer Tachometer	Garage Analyzer Dynamometer

* Standards apply to the lowest HC and lowest CO emissions observed during the two idle portions of the test. Standards also apply to the 2500 rpm mode either independently or in conjunction with the idle portions.

** Standards apply to the loaded mode and idle, either in combination or independently.

Note: All idles are in neutral

As experience is gained with both the warranty program and the later technology vehicles, data can be collected and more stringent standards, if appropriate, proposed in future rulemakings.

Standards have been set so that the error of commission rate is approximately the same as for the FTP. As a result, the short test concentrates on vehicles with very high emissions. Failure rates are much lower than for the FTP. Because of the heavy contributions from these "gross emitters", a substantial portion of the total excess emissions is identified.

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Figure 8

Idle Test Comparison For Various Cities

City	Type	Number Vehicles	Number Failures	Number Ec	Percent Fail	Percent Ec
Chicago	LDV	792	332	42	42	5.3
	LDT	27	3	1	11	3.7
	Total	819	335	43	41	5.3
Denver	LDV	416	207	8	50	2.0
	LDT	27	13	1	48	3.7
	Total	443	220	9	50	2.0
Houston	LDV	321	168	23	52	7.2
	LDT	27	13	0	48	0.0
	Total	348	181	23	52	6.6
Los Angeles	LDV	371	115	23	31	6.2
	LDT	27	8	2	30	7.4
	Total	398	123	25	31	6.3
St. Louis	LDV	625	199	27	32	4.3
	LDT	23	7	1	30	4.3
	Total	648	206	28	32	4.3
Washington	LDV	339	136	22	40	6.5
	LDT	27	5	1	19	3.7
	Total	366	141	23	34	6.3
Detroit*	LDV	100	35	5	35	5.0
Phoenix	LDV	574	202	42	35	7.3
	LDT	10	3	0	30	0.0
	Total	584	205	42	35	7.2
Composite	LDV	3538	1394	192	39	5.4
	LDT	168	52	6	31	3.6
	Total	3706	1446	198	39	5.4
Portland *	LDV				39	5.6

LDV = Passenger car (Light duty vehicle)
LDT = Light duty truck

* No LDT's tested
Source: EPA test programs through October 1979 for 1975-79 model vehicles.