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An Analysis of Test Procedure Changes Made During 1975-1979 With Respect to Measured Fuel Economy Effects

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Introduction

This paper presents an analysis of each of the changes in EPA test procedure since 1975 which have been identified as potential areas where it may be argued that changes in EPA regulations have resulted in a decrease in measured vehicle fuel economy. These areas are:

A. Changes in the EPA prediction of the dynamometer power absorption.

B. Changes in allowable practices for determining and requesting alternate dynamometer power absorptions.

C. Changes in the dynamometer inertia simulation increments.

D. Changes in allowed alternate shift point schedules.

E. Changes in dynamometer calibrations.

F. Changes in vehicle selection.

G. Changes in laboratory humidity levels.

H. Use of the actual simulated distance traveled by the vehicle versus the nominal test distance.

I. Changes of the value used for the density of CO_2 in the EPA calculations.

In many cases these changes were technical improvements which increased the accuracy of the test procedure or provided for improved fuel economy recognition of technical improvements. In other instances these changes were considered necessary to prevent or restrict abuses of various aspects of the EPA fuel economy measurement procedures. In the first category, these changes either increased measured fuel economy or had no net directional effect. The second type of change generally reduced measured fuel economy; however, these changes were introduced only as the need arose. Consequently, they generally corrected abuses which did not exist in 1975, since there was little pressure for fuel economy improvements in that model year. The changes would not have affected the 1975 results, but were necessary to insure that the results of future model years were comparable to those of 1975.

In general, it is easy to demonstrate that under specific circumstances a given vehicle might show a degradation in fuel economy between the 1975 and the 1979 model year test procedure. Therefore, if the true net fuel economy difference between the test procedures of these years is to be evaluated the following questions must be asked:

Did the change have an effect on all vehicles or what percentage of the total population of vehicles were affected?

Was the change systematic for all vehicles affected or what was the net effects of this change?

Would the change have had an effect on the 1975 test results?

What was the net effect of all changes?

It is intended that this paper provide the background information and the direction for indepth questioning of premises that changes in EPA regulations since 1975 have reduced measured fuel economies.

Analysis of the Changes in EPA Procedures

The following sections address each of the previously identified changes in EPA test procedures or test conditions. In those instances where EPA Technical Support Reports, Analyses of Comments in response to NPRMs, or other supporting material is available, this material is provided as attachments or referenced.

A. Changes in the EPA Prediction of the Dynamometer Power Absorption.

For the 1979 model year, EPA revised the equation used to predict the dynamometer adjustment for LDV testing. The revision replaced the existing table based on the vehicle inertia weight with an equation primarily based on the vehicle reference area, but also including the effect of vehicle protuberances and tire type.

This change was developed, at least partially, in response to requests by the automotive industry for a change in EPA practices to better represent the fuel economy advantages of radial tires which were not directly reflected in the twin roll dynamometer tests.

The potential effect of the change to the area based equation can be seen from the attached plot. This graph indicates that the dynamometer adjustments obtained by EPA were, on the average, in good agreement with the existing weight-based table for vehicles with bias or bias belted tires. For vehicles with radial ply tires, the data indicated that the current table was approximately 8% higher than appropriate for a median vehicle. This result is reflected in the frontal area equation which was subsequently developed by regressing these data against frontal area data supplied by the vehicle manufacturers.

Approximately 80% of the 1979 OEM tires were radials; therefore, the majority of all light-duty vehicles currently tested would be expected to have slightly lower predicted dynamometer power absorption than would have occurred if this change had not been made. This effect is estimated to be about 1.5 percent increase in measured fuel economy or about 0.3 mpg for a 20 mpg vehicle.

The previous analysis assumes that the vehicle weight-area relationships remain the same as observed in 1975, the model year most predominant in the EPA vehicle sample used to develop the reference area based prediction equation. To some extent this has changed, since some vehicle weight reductions may have occurred without reduction in vehicle reference area. To the extent that this has occurred, a vehicle tested with a dynamometer adjustment based on the reference area formula might show reduced fuel economy compared with test results using the previous weight based table. However, since the area based formula more accurately predicts the aerodynamic drag of the vehicle, which is the predominant force simulated by the dynamometer, the use of this equation should more accurately simulate the road experience of the vehicle. That is, the previous weight-based table would have provided a larger predicted fuel economy reward for changes in vehicle weight, without changes in vehicle reference area, than would have occurred in consumer use of the vehicle.

EPA technical support reports have discussed the development of the area-based equation in detail.(1,2) This material was also presented to the technical community in the form of an SAE paper.(3) The analysis of comments received in response to the proposed change from the weight-based equation is also available in the public docket.(4) When reviewing these comments, it should be noted that they were received in response to an originally proposed equation which was considerably more complex and which, in general, predicted higher dynamometer power absorptions. As a result of these comments the equation was revised to its present simpler form.

B. Changes in Allowable Practices for Determining and Requesting Alternate Dynamometer Power Absorptions.

EPA has always provided the option that a manufacturer may request, for specific vehicles, dynamometer adjustments which are different from the values predicted by EPA. A request for such alternate dynamometer power absorptions must be supported by road test data demonstrating the appropriateness of the request. In 1975, the regulations implied that manifold pressure measurements were the required method of generating acceptable road data. Later the manifold pressure approach was deleted, and subsequently the coastdown technique has become the prevalent method of generating supporting data for alternate dynamometer power absorption requests. An acceptable coastdown procedure has been provided to the industry as an EPA Recommended Practice which has been distributed as an attachment to Advisory Circular 55.

Advisory Circular 55 has been revised several times to clarify the requirements of similarity between the road test vehicles, the production vehicles represented and the exhaust emission certification vehicles. Technical changes have also been made to the Recommended Practice to improve precision and to make the standard test conditions more representative of typical vehicle use. While many of the revisions to AC-55 may appear to increase the resulting dynamometer power absorption slightly, these changes were introduced to eliminate abuses which became prevalent after 1975.

In general, compared with the practices of 1975, the entire area of alternate dynamometer power absorption should result in reduced loadings of the test vehicles. This has occurred because very few alternate dynamometer adjustments were requested in 1975, while the use of alternate dynamometer power absorptions is prevalent today. Since an alternate dynamometer power absorption is generally only requested when it is beneficial to the manufacturer, much of the current testing is conducted at vehicle loadings lower than those which would have been used if the same vehicles had been tested in 1975. EPA is currently investigating in detail the average dynamometer adjustments used in the 1979 model year versus the inertia weight table values of the Federal Register Code of Regulation prior to the 1979 model year.(5)

Even for those vehicles for which alternate dynamometer power absorptions were requested in 1975, the current test procedure is likely to yield slightly lower values. This occurs because the added experience and precision of the current procedure allows correction to more ideal standard conditions. While these corrections were not prohibited in 1975, the procedures actually in use were generally not this sophisticated.

C. Changes in Dynamometer Inertia Simulation Increments.

Beginning with the 1979 model year, EPA reduced the increments of simulated inertia by approximately a factor of two. This change was made because it was becoming apparent that manufacturers were increasingly tending to design vehicles which were at the upper bound of the older, larger inertia weight increments.

This decrease in the inertia weight increments improves the precision of the emissions and fuel economy measurements from any given test vehicle. It will decrease the fuel economy results only if the vehicle would otherwise have been tested at a lower, less appropriate inertia weight class.(6)

When the reduction of the inertia weight increments was proposed, none of the manufacturers argued that this change would have reduced the fuel economy results of the 1975 model year. Comments were received that this change would reduce some of the fuel economy benefits that had been anticipated from vehicle weight reduction programs. These comments supported EPA's concern that vehicle down-sizing programs were directed toward the EPA inertia weight classes. To the extent that this was occurring, EPA measurements would have over-estimated the fuel economy benefits of vehicle down-sizing if the intervals of simulated inertia weights were not reduced.

The full record of the comments received in response to the rulemaking which decreased the inertia weight increments, and the analysis of these comments by EPA can be found in the public docket.(7)

D. Changes in Allowed Alternate Shift Point Schedules.

In 1975, the regulations provided that test vehicles would normally be shifted at 15, 25 and 40 mph. In order to provide for unusual vehicles the regulations also provided for the option of shifting the vehicle at the shift points recommended by the manufacturer. During 1975 model year testing, most vehicles were shifted at the default, 15-25-40 shift points.

On July 16, 1976, the default shift points were deleted from the regulations and the vehicles were to be shifted according to the manufacturer's recommendation to the ultimate purchaser. EPA soon began to receive shift point requests which appeared to be selected primarily to minimize emissions or to maximize fuel economy. For example, different requested shift speeds for hot versus cold vehicle operation and generally very early shift points for the EPA Highway Cycle. The shift point recommendations provided by the manufacturers to the vehicle consumer were generally not nearly as specific as the shift point requests recieved by EPA, but rather were sufficiently vague to encompass the requests made to EPA.

EPA investigated this problem and concluded that many of the shift schedules requested by vehicle manufacturers were unrepresentative of typical vehicle use. This investigation was documented in an EPA technical report. (8)

In order to insure more reasonable future shift schedules EPA restricted acceptable shift schedules with Advisory Circular No. 72. This Advisory Circular provides that allowable may be the 15-25-40 mph schedule originally presented in the regulations, a shift schedule based on a percentage of maximum recommended engine RPM which was developed in the attached report, or any other recommended shift schedule based on typical vehicle use data.

At the present time virtually all manufacturers are using the 15-25-40 shift points schedule, as was the case in 1975. Consequently, the changes in allowed shift schedules eliminated an abuse which occurred primarily after 1975. Consequently, change in allowable shift schedules can account for little or no systematic fuel economy degradation between the 1975 and present model years.

E. Changes in Dynamometer Calibrations.

In 1975, EPA used a manual method of adjusting the dynamometer power absorption prior to each test. In this case a dynamometer warm-up vehicle was used to drive the dynamometer at 50 mph while the vehicle operator adjusted the water level in the hydrokinetic power absorber, by means of a solenoid valve, until the desired torque reading was obtained.

In May 1977, EPA changed to an electronic feedback dynamometer control system which eliminated the need for manual adjustment of the dynamometer prior to each test. This change reduced the laboratory effort required for each test and reduced test variability .

This change, if independently made, could have resulted in a change in the loading experience of the test vehicles. However, at the same time EPA altered the dynamometer calibration procedures, both because this was required to support the automatic control features and to ensure that the change to the automatic dynamometer adjustment would not result in a net change in the dynamometer experience of the test vehicle. The most significant change in the calibration procedure was an allowance for the angular velocity differences between the front and rear dynamometer rollers which were previously observed with the dynamometer adjustment vehicle.

The changes in the operation modes and the dynamometer calibration procedures have been described in detail in the EPA communications.(9)

F. Changes in Vehicle Selections.

It has been suggested that changes in the selection of test vehicles may have resulted in a decrease in the measured vehicle fuel economy. However, when attempting to research this question, few changes could be identified in the vehicle selection process.

The emission test vehicles are selected on a structured basis which provides for several EPA selections of "worst case" vehicles. It is possible that EPA is currently more astute in the selection of "worst case" vehicles; however, this would not reflect any change in the procedure or the intent of the procedure.

In addition to the emission test vehicles which are selected by EPA, the manufacturer can elect to test supplementary fuel economy vehicles. In 1975 the fuel economy program was voluntary, and the manufacturers were consequently given greater latitude in the selection of these optional vehicles and in the use of the resulting data than is presently allowed. Currently the optional fuel economy vehicle selections are constrained so that hopefully the data from these vehicles increases the accuracy with which the EPA sample represents the total vehicle population. These constraints probably reduce the fuel economy advantage obtained by a manufacturer for each optional test vehicle. However, in 1975 few optional vehicles were tested compared with those tested in the 1979 model year. The net effect these optional vehicle selections have had on the corporate average fuel economies between the 1975 and 1979 model years is difficult to accurately assess. Certainly the two major factors, the increase in the number of optional vehicles test data in the 1979 data base, and the EPA constraints on the selection of these vehicles tend to be compensatory.

A vehicle selection process also occurs in the review of fuel economy data and selection of vehicles for confirmatory testing. EPA is currently conducting a greater number of confirmatory tests than were conducted in 1975. If these results are consistently lower than those reported by manufacturers, inclusion of these data into the fuel economy calculations could reduce the computed corporate average fuel economy. If this is affecting fuel economy results, it is a more vigilant maintenance of unbiased results, not a change in the EPA procedure.

G. Changes in Laboratory Humidity Levels.

In April 1976 EPA changed the average laboratory humidity from approximately 55 grains of water per pound of air to 75 grains. This change was made to reduce the magnitude of the effects of the humidity correction factor in the calculation of the NOx emissions. Reducing the correction factor effect was desirable to improve the accuracy of the determination of vehicle NOx emissions.

This change would, in general, be expected to decrease the measured fuel economy of a vehicle since the combustible portion of the incoming fuel-air charge would be reduced and the vehicle would tend toward enriched operation. This is, however, entirely dependent on the calibration of the vehicle. For 1975 through 1978 model vehicles, the theoretically anticipated enrichment effect would probably result in some loss of fuel economy. However, for 1979 and later model year vehicles using fuel system feedback technology, this enrichment condition would be sensed and compensation would be made in the fuel delivery. Therefore, no fuel economy degradation would be anticipated for current or future vehicles using sensor-feedback technologies. In fact, under some conditions the increased humidity might benefit fuel economy and exhaust emissions in the same manner as exhaust gas recirculation can be beneficial. That is, a non-combustible diluent can reduce engine pumping losses and allow optimization of the spark timing without knock or excessive NOx production.

It should also be noted that the higher test humidity conditions were chosen as standard conditions well before 1975. This is evident since the NOx correction factor in the EPA exhaust emissions calculations has used 75 grains of water per pound of air as the standard condition from very early in the regulations. The only change which was made was to make the actual test conditions correspond to the theoretical standard conditions of the calculations. This change was made as soon as the Ann Arbor facility could consistently and accurately maintain the higher humidity.

H. Use of the Actual Simulated Distance Traveled by the Vehicle Versus the Nominal Test Distance.

In 1975 EPA calculated fuel economy based on the nominal, that is theoretical, distance of the test cycles. This was done primarily for convenience in the calculations even though the actual simulated distance traveled by the vehicle might be slightly different from this value.

Deviation from the nominal value can occur for two reasons, normal allowable driver fluctuations about the test speed versus time schedule and the inability of the vehicle to maintain the speed called for by the test schedule. EPA investigated variations in the simulated distance traveled in 1975 and concluded that most of the distance variations occurred because of driver fluctuations. This investigation was presented in an EPA technical report.(10) The largest data base, which considered the results of 170 repeat tests on a single vehicle, was contributed by Ford Motor Company. These data indicated that the coefficient of variability of repeated fuel economy measurements would diminish by about 30% (a decrease from approximately 3.6% to 2.4%) when the actual distance was used in the fuel economy calculations. These same data indicated this change would result in an increase in the harmonic mean fuel economy of 0.16%.

It was concluded that for most vehicles no significant effect on measured fuel economy occurred when the actual simulated distance was used in the fuel economy calculation. Consequently, the change was made in the fuel economy calculation to reduce test variability. For some underpowered vehicles which might not be able to follow the EPA driving schedules, some systematic decrease in vehicle fuel economy would result from this change. Few of these vehicles, however, were present in the 1975 test fleet. If such vehicles are becoming more prevalent it would be illogical to credit these vehicles with greater fuel economies than actually achieved because of an erroneous assumption that they traveled a greater distance than was actually simulated in the fuel economy test.

I. Change of the Value Used for the Density of CO_2 in the EPA Calculations.

On November 14, 1978 EPA changed the value for the density of CO_2 used in the fuel economy calculations from 51.85 gm/ft3 to 51.81 gm/ft3. This change was made so that the value for the density of CO_2 would be the same in all EPA calculations. The current value is considered to be more accurate, and it is believed that the slight discrepancy from the previous value may have been the result of round-off error in calculations of the original density.

This change will have a direct systematic effect on all EPA light-duty vehicle fuel economy calculations. It will increase the measured fuel economy by slightly less than 0.08% or 0.015 mpg for a 20 mpg vehicle. This effect is quite small, however, it is significant because it systematically improves all fuel economy measurements.

Conclusions

It is concluded that none of the identified changes in the EPA test procedures should result in a net systematic decrease in the measured corporate fuel economies. The one possible exception, the change in laboratory humidity, might reduce the fuel economy of some vehicles not using the advanced technologies introduced by some manufacturers in 1979 and widely anticipated in the 1980's.

References

1. G. D. Thompson, "Light-Duty Vehicle Road Load Determination", EPA Technical Report LDTP-76-3, December 1976.

2. G. D. Thompson, "Prediction of Dynamometer Power Absorption to Simulate Light-Duty Vehicle Road Load", EPA Technical Report, April 1977.

3. G. D. Thompson, "Prediction of Dynamometer Power Absorption to Simulate Light-Duty Vehicle Road Load", Society of Automotive Engineers, 780617.

4. Analysis of Comments received in response to the September 10, 1976 EPA NPRM regarding fuel economy and emissions testing.

5. J. D. Murrel, Discussion.

6. T. R. Norman, T. Rarick, "The Effect of Dynamometer Weight Simulation on Fuel Economy Measurements", EPA Technical Report, February 1976.

7. Analysis of Comments op cit.

8. R. A. Rykowski, "Shift Schedules for Emissions and Fuel Economy Testing", EPA Technical Report, November 1977.

9. D. Paulsell, "Analysis of Ford Presentation Regarding Road Load Problems", Memorandum to Michael Walsh, August 28, 1978.

10. T. Rarick, "Dynamometer Distance", EPA Technical Report, July 1975.