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In-use Testing for CO_2 and Fuel Economy in the United States

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Background and objective

China is considering including an after-production conformity test as part of China's Phase 3 passenger car fuel consumption standard implementation and enforcement plan and is looking for experiences from the existing practices in the US for the light-duty vehicle CAFE and GHG emissions standards compliance. The purpose of this short paper is to provide an overview of the US in-use vehicle CO_2 emissions regulation, relevant in-use emissions compliance tests, and to focus on key questions including: 1) What are the criteria for selecting vehicles for the in-use test? 2) What is the ratio (or is there a required ratio) between the number of in-use vehicles selected and the number of vehicles in the test group at the certification? 3) How does EPA perform the tests? 4) How does EPA determine whether an in-use vehicle is in compliance? 5) Is there an allowable error margin (or deterioration level) between the in-use CO_2 test result value and the value at certification? 6) What are the detailed procedures of recruiting vehicles from consumers?

The structure of this paper is as follows: i.) a brief introduction of the US in-use program in the broad context of the overall EPA compliance framework, ii.) a description of the new in-use CO_2 emissions compliance requirement under the US 2012-2016 Model Year Light-duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, iii.) an explanation of the in-use compliance tests performed by manufacturers and by EPA, iv.) a discussion of the additional test burden for the new in-use CO_2 compliance rule compared to testing for in-use criteria pollutants only, v.) a focus on the penalty for not complying with the in-use CO_2 requirement and vi.) useful experiences for China to consider.

Introduction

When the Clean Air Act was passed in 1970, the US vehicle compliance program only covered new vehicle certification. Over the years the program has grown and evolved from one that focused mainly on ensuring prototype and new production vehicles comply with standards, to the current program that places strong emphasis on in-use testing to ensure compliance of emissions standard over the vehicle useful life.

Under the current program, all compliance activities related to new vehicle criteria pollutants (i.e., NMOG, NOx, CO, and PM) include: 1) Pre-production certification, 2) Confirmatory testing, 3) Selective enforcement audit (SEA), 4) In-use surveillance performed by EPA, 5) In-use verification testing performed by manufacturer, 6) Recall, and 7) Warranties and defect reporting. These elements are implemented over a vehicle's life as illustrated in Figure 1. This paper focuses on items four and five mentioned above, the activities highlighted by red boxes in Figure 1.

Effective in 2012, EPA will add an in-use CO_2 emissions requirement to its current in-use testing programs. The new regulations leave it to EPA's discretion and budget constraints to determine how much testing it will do. The GHG regulations do not substantially change the in-use testing requirements placed on manufacturers compared to what had been in place for criteria pollutants, but they do make a minor change. While the requirement for manufacturers to perform in-use testing at their own expense under the in-use verification program (IUVP) was not changed with regard to how many vehicles must be tested or how they will be selected, the new regulations add the requirement for the

Figure 1. Compliance Life of a Light Duty Vehicle. *Source: EPA 2007 Progress Report: Vehicle and Engine Compliance Activities.*
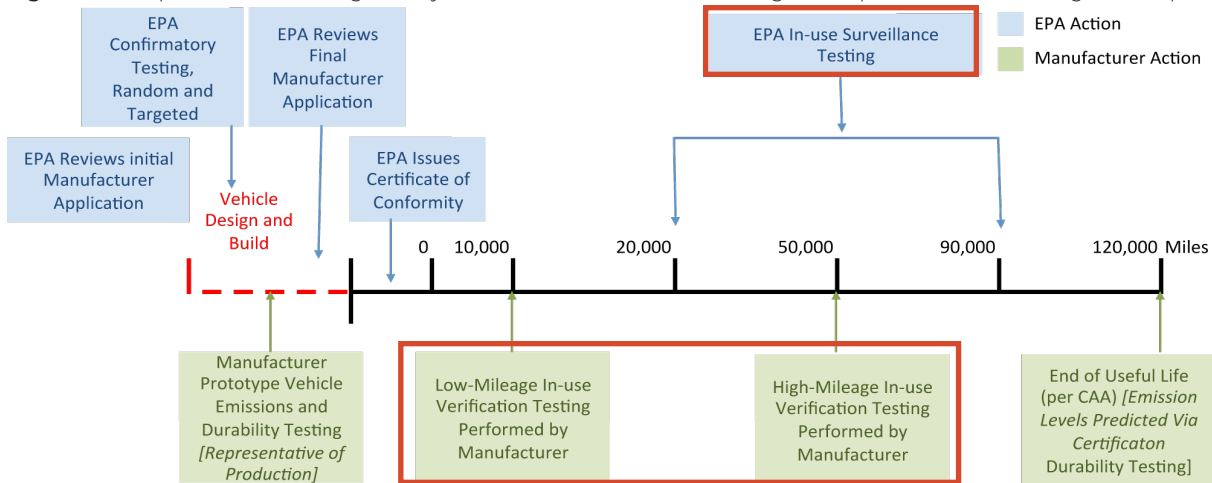
highway test to be run in addition to the FTP. Otherwise, the IUVP program has been unchanged.

Given the above, this short paper mainly addresses how in-use testing is currently handled for criteria pollutants. Through this, in some narrow circumstances, it is possible to comment on how the program might have to change in the future to consider in-use CO_2 levels, although EPA has indicated that they have not yet focused on how they might potentially readjust in-use testing protocols or priorities after vehicles newly being certified to CO_2 standard have been in the field long enough to consider testing them.

The new in-use CO_2 emissions compliance regulation

Starting in 2012, EPA will mandate an in-use vehicle CO_2 standard determined by adding an adjustment factor to the emission results used to calculate manufactures' fleet average CO_2 emissions. The purpose of using an adjustment factor is to address the test-to-test variability or production variability, but not to allow any deterioration of CO_2 emissions performance during the useful life of the vehicles.

EPA does not anticipate notable deterioration in CO_2 performance of a vehicle during its lifetime use, therefore determined a "zero" deterioration factor for CO_2 emissions values at the time of certification, in contrast to the criteria pollutants' deterioration rates. However, EPA may consider technology-specific deterioration factors in the future when supportive data are available.

The new GHG regulations establish the in-use CO_2 standard to be a level ten percent above the value used for each model when the initial corporate fleet average CO_2 was computed for the purposes of determining compliance with the fleet average standard. The ten percent will be applied to emissions test results for the vehicle sub-configuration[1] if

such data existed at the time the fleet average standard was computed, or to the model type[2] emissions level used to calculate the fleet average if the sub-configuration was not available in the original fleet average computation.

This approach for CO_2 differs from what EPA has historically done regarding in-use emissions for criteria pollutants. For the latter, each test group certified has a specific standard applicable to that group. Although EPA has implemented emissions averaging for criteria pollutants, its approach has been to assign standards to specified "bins." A manufacturer can choose to certify its products to any bin, although the average NOx level assigned to each bin must conform to an overall fleet average NOx standard[3]. As a result, every model certified has to conform to a specific standard applicable to its respective bin. This standard applies in-use over the useful life. Hence, for criteria pollutants there is no ten percent margin applied. Every vehicle must comply with its bin standard in-use.

However, EPA has designated a different approach for CO_2. It did this to align its CO_2 standards with the existing corporate average fuel economy (CAFE) enforced by NHTSA. Under this approach there is no equivalent "bin" standard set at the time of certification. The fleet average is based on the sales weighted average of all model types, which in turn are averages of the configurations and sub-configurations within each model type. Given there was no "bin" standard, EPA adopted the approach of setting an in-use standard equal to the level used for the purpose of

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1   Vehicle subconfiguration is most detailed level along the test class hierarchy developed for fuel economy testing. Subconfiguration refers to a group of vehicles that share similar design features that affect vehicle fuel economy. These features include engine displacement, number of cylinders, fuel injection system, air intake system, transmission type and class, inertia

weight class, engine calibration, axle ratio, equivalent test weight and road-load horsepower setting. In ICCT's technical paper "CAFE data collection and verification", we provided more detailed descriptions of subconfiguration and other test levels.

2   Vehicle model type is the roughest level along the test class hierarchy developed for fuel economy testing. A model type refers to a group of vehicles that share similar combination of features including car line, engine displacement, number of cylinders, fuel injection system, air intake system, and catalyst.

3   For the future EPA has indicated that it plans to change this approach under the expected tier 3 emissions standards to base fleet averaging of bin standards on NMHC+NOx instead of just NOx as has been done under the tier 2 standards.

computing the CO_2 fleet average plus ten percent.

EPA selected this value of ten percent as the in-use CO_2 standard adjustment factor based on a review of EPA's fuel economy labeling and CAFE confirmatory test results from the past model years. The EPA data indicate that it's common for test variability to range between three to six percent percent and only on rare occasions to exceed ten percent[4].

In-use compliance tests

There are two major components to the in-use testing program. The vast majority of in-use tests are conducted as part of the manufacturer run IUVP testing. Additionally, EPA may test whatever number of in-use vehicles it chooses based upon budget constraints and any information EPA has that might indicate there is a concern about the compliance status of any test group. EPA tends to use its own test program as a "spot check," to monitor the credibility of testing done by the manufacturers both in certification and in the IUVP.

Manufacturer-Conducted In-Use Verification Program

EPA mainly relies on the manufacturer-run In-Use Verification Program (IUVP) to monitor the performance of vehicles during their useful life since 2004. IUVP tests are required at low mileage (at least 10,000 miles) and high mileage (more than 50,000 miles). The manufacturer must complete low-mileage IUVP testing within one year after the end of production of the test group. High-mileage IUVP testing must commence within four years of the end of production of the test group and must be completed within 5 years of the end of production of the test group. Additionally at least one of the high mileage vehicles must have a minimum odometer mileage of 75 percent of the useful life. Results must be reported to EPA according to set schedules.

The regulations specifically require each manufacturer to perform IUVP testing of each certified test group at their own expense. The regulations specify the number of vehicles that must be tested for each group. This varies between two and six vehicles per test group based upon the overall sales of the test group and whether the low or high mileage test point is involved. For test groups in the 50,001-250,000 annual sales range, three vehicles must be tested at the low mileage point and five at high mileage; and for test groups at over 250,000 annual sales the low and high mileage number of vehicles required are four and six respectively.

Manufacturer's IUVP testing covers significantly more vehicles than EPA's surveillance tests. In 2007, 3,344 high mileage vehicles covering model year 2000-2003 and 1,970 low mileage vehicles covering model year 2004-2007 were tested and reported by manufacturers[5].

Manufacturers recruit IUVP vehicles from private citizens across the United States. The test vehicles must be randomly selected subject to protocols established by EPA. The vehicles are tested "as received," meaning they are not screened for proper maintenance (although there are extreme criteria that allow for elimination of certain problem vehicles).

For criteria pollutants, if the average emissions from a test sample exceed the applicable standard by a factor of 1.3 times the standard and if 50 percent or more of the test vehicles exceeded the standard, the manufacturer must run an in-use confirmatory program (IUCP) test for that model type. For this at least 10 vehicles must be procured, again randomly, but this time the vehicles are screened for proper maintenance[6]. Failure of a substantial number of these vehicles to meet the actual standards (i.e., not 1.3X but 1.0X) can then lead to a requirement to recall and repair vehicles.

The new GHG regulations effective for MY 2012 only slightly modified the requirements for the IUVP program. They require manufacturers to now run the highway test on each vehicle whereas the prior program only required the FTP to be run on each vehicle[7]. The highway cycle was added to now check compliance with the in-use CO_2 standard which is based upon the weighted 55/45 average of both the city (i.e., FTP) and highway tests. If IUVP testing indicated a potential CO_2 compliance problem, EPA would use this to target its own investigations and potentially to run its own in-use testing. Depending on the results of the IUCP testing, manufacturers might need to recall or implement other remedies for the failing test groups.

In-Use Testing Conducted by EPA

EPA conducts a surveillance program at its Ann Arbor laboratory. EPA typically recruits two- or three-year old vehicles from vehicle owners in southeast Michigan based on random selection, EPA certification data, manufacturer In-Use Verification data (described in the next section), and public complaints and inquiries. Special attention will be paid on vehicles with issues of past emissions performance, or vehicle that adopted new technologies to gain a better understanding of how new technologies are working.

For EPA's own in-house, in-use testing, it currently determines what test groups to test and how many vehicle within the group to test based on budget limitations and any available intelligence that might indicate there is a problem test group. This number has been set in recent years at roughly 144 vehicles per year (i.e. 12 vehicles per month).

The number of test groups tested will then be set by how many vehicles are selected for given test groups based upon what is observed from the minimum testing levels. EPA typically selects three vehicles per targeted test

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4   Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule for model year 2012-2016

5   EPA 2007 Progress Report: Vehicle and Engine Compliance Activities.

6   The new regulations did not establish any requirement for the manufacturer to move onto an IUCP program if the CO_2 levels exceeded the standards.

7   Additionally one vehicle for each test group would need to be tested on the US06 test and one on the evaporative emissions test. For conventional pollutants, there is no need to test on the highway cycle.

group[8]. Hence, the number of test groups tested per year is typically slightly less than 50. To place this in perspective, consider that there are approximately 425 to 450 LDV/LDT test groups certified each year. Since so few groups can be tested each year, they choose test groups over a period of years to attempt over time to look at all manufacturers and most broad vehicle classes and technology types if not every individual test group.

In 2007, EPA tested 142 vehicles, representing 47 test classes[9]. Compared to the number of vehicles tested by the manufacturers (described in the previous section), EPA only tests a small portion of the vehicles. EPA tends to rely mainly on the manufacturer-performed in-use tests to discover issues.

EPA can and occasionally does deviate from this plan to focus on a specific expected problem test group if it has intelligence information leading to a concern about that test group (e.g., intelligence could be information from the mandatory defect reporting regulations, information from the IUVP testing, pattern problems perhaps observed in state inspection and maintenance programs, and other sources). If their limited three vehicle per test group testing indicates a compliance concern and if testing from the IUVP program or other information has not lead the manufacturer to agree to voluntarily recall vehicles, EPA might then conduct its own "confirmatory test," and may sometimes procure additional vehicles, including if necessary, going to a full confirmatory test of ten vehicles[10]. Just as was described above for the IUVP/IUCP programs, vehicles routinely procured for EPA's normal surveillance testing are tested "as received," but confirmatory test vehicles are screened for proper maintenance.

Test vehicles are randomly procured in both EPA in-house testing and in IUVP testing. EPA has a procurement contractor who obtains state registration lists of owners of vehicles in the selected test group. They typically consider lists from counties located approximately within a 70-mile radius[11] of the EPA laboratory. The contractor mails a solicitation letter out in batches of 50 to randomly selected owners and then procures the target number of vehicles (typically three) in the order in which acceptances are received. Additional batches of 50 mail-outs are done as necessary to obtain the target vehicles; however, before going to a third batch, the contract usually reviews the case with EPA to make sure the agency wants to continue to seek additional vehicles from that group. Presently EPA has no plans to alter this process once it begins to also follow up on CO_2 compliance issues[12].

Owner incentives are fixed under the procurement contract. Current terms involve paying the owner $20/day if they choose to take a loaner vehicle or $50/day with no loaner vehicle. Additionally the car is returned with a full tank of gas and a car wash.

Additional test burden for the new in-use CO_2 compliance rule compared to testing for in-use criteria pollutants only

EPA designed the new CO_2 compliance program to have a minimal incremental impact beyond what was already being done for criteria pollutants. The only added burden in the IUVP program is the addition of the need to run the highway test on each vehicle. Otherwise, there is no change to test vehicle procurement numbers or requirements. For EPA in-house testing, it has historically run both the FTP and highway test anyway, so there is no change to testing requirement there.

However perhaps there will be a more subtle potential impact associated with CO_2 in-use compliance testing that is hard to quantify without more some experience with the program. In recent years, EPA has rarely had to deal with criteria pollutant compliance issues. When they have occurred, they have typically been clear-cut cases of a broken, deteriorated, or malfunctioning parts or calibrations which have had relatively easily identifiable fixes. More often than not, manufacturers have agreed to conduct voluntary recalls or some cases have agreed to provide extended warranties for failures that do not necessarily occur on every vehicle. This has occurred without the need for official confirmatory testing being needed.

This could change with CO_2. For CO_2, deterioration of emissions is not expected. In-use failures are more likely to fit into two categories. One category might be an actually failed component. However, for such cases, it seems probable the failure would also affect criteria pollutants and therefore might actually be caught and be handled as a normal criteria pollutant case. The other category would be a case where a manufacturer failed to accurately determine the correct CO_2 and fuel economy level for the vehicle when it was originally tested. This could have occurred either because the original test vehicle was not representative of actual production or because the manufacturer was "gaming" the system during certification and CAFE testing.

Such cases may not involve any deteriorated or defective components; hence these most likely will not have any fix or remedy available. Such cases could become more adversarial in nature and might need more extensive confirmatory testing to clearly sort out the level of non-compliance to form a basis for some sort of enforcement penalty. However, EPA does not seem to think the latter problem will be a significant issue because EPA believes the ten percent margin it has built into the standard should be sufficient to cover normal test variability (i.e., in the three to six percent

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8   EPA routinely selects 3 vehicles per test group regardless of the size of the test group as this is what they have determined to be the minimum number of vehicles that can yield a meaningful result. They have experimented with as few as 2 vehicles per group but found this to be too limited to draw conclusions.

9   A test class is a group of vehicles with very similar design characteristics from an emissions standpoint.

10   In recent years EPA has rarely had to get into running full confirmatory tests, both because compliance rates have been very good and because the combined IUVP/IUCP program has tended to result in voluntary recalls of the few compliance cases that have been observed.

11   This might be expanded for difficult to find vehicles.

12   The protocols required of manufacturers in the IUVP program involve random procurement much the same as is done by EPA.

range) with compliance margin leftover. EPA believes the threat of in-use enforcement will cause manufacturers to avoid blatant gaming of the system when the original fleet average computation is performed.

Non-compliance penalty

According to the 2012-2016 model year regulation, failure to meet the in-use CO_2 standard may result in recall liability, under the Clean Air Act. But the CAA also states that recall can only be used in cases where the problem is repairable. EPA recognized that there might not be a practical in-use repair available to be able to require in a recall given CO_2 levels (i.e. fuel economy) would be largely determined by fundamental designs and vehicle characteristics that do not change over time (e.g., weight, aerodynamics, engine selections, etc.) and not by the addition of emissions control devices. However, EPA argued the CAA requires enforcement over the useful life on an in-use basis and the first order of remedy is to be recall and repair. And, EPA insists that the recall liability should apply to CO_2 standard as well, since it considers repairable problems such as issues related to components, systems, software, and calibration.

If EPA determines that a test group is failing the in-use standard, its first course of action would be to determine if a recall to repair or apply design changes is feasible. If the cause is a defective or broken component, EPA would resort to the normal use of its authority to require a recall. In fact, as discussed above, it could be possible that a defective or broken component might also affect criteria pollutants and hence the problem might end up being dealt with under the normal criteria pollutant recall/remedy process.

However, if there are no defective parts and hence no obvious repairs which rules out conducting a recall, EPA can fall back then on assessing a compliance penalty. EPA left this vague as to how such a penalty would be computed. At least one of the criteria to be considered would be that the penalty would need to be punitive in nature, meaning the manufacturer may not simply "pay to pollute." The penalty would have to exceed the potential cost benefits the manufacturer might have achieved by producing non-complying vehicles. In general, previous EPA guidance has suggested that it would also consider gravity of the noncompliance situation and what the potential cost savings benefits might have been derived by the manufacturer as a result of the non-compliance.

Useful lessons for China

- In-use compliance program and tests are a very important component of vehicle emissions/fuel economy/fuel consumption compliance system. The U.S. in-use tests for the criteria pollutants have helped identify many compliance issues in the past and have proved to be an effective measure.

- An in-use compliance program should be as comprehensive as possible within the regulatory agency's budget constraint. If budget is limited, special attention should be focused on vehicles with issues of past emissions performance and vehicles that adopt new technologies. Regulatory agencies can also mandate manufacturers to conduct larger-scale in-use tests at their own costs, while the official tests only serve as a "spot check".

- EPA adopted a relatively large compliance margin – ten percent -- for the in-use vehicle CO_2 emissions standard. This is partially because that vehicle CO_2 emissions level is an averaged value of sub-configurations of a certain model type. An in-use vehicle's CO_2 emissions level thus may be actually higher or lower than that averaged value. In China, however, each model and its variants have their own certified fuel consumption value. In turn, at the in-use stage, there is no need to grant such a big margin (ten percent) for in-use compliance. The major factor to be considered in the Chinese situation should be test variation, which is normally within a five percent difference.

- Given that CO_2 emissions rarely deteriorate during vehicle lifetime, there is no need to consider a deterioration factor when projecting full useful life emissions for certification purposes. EPA currently uses a zero deterioration factor for CO_2 emissions.[13]

- Stringent enforcement is also crucial for an effective in-use compliance program. Regulatory agency may consider fiscal and non-fiscal penalties (such as recall, void of certificate) for non-compliance.

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13 The assumption of no deterioration is based upon experience with conventional gasoline and diesel vehicles. However, this could potentially change with the evolution of technology. For example, it might be possible for a gasoline-electric hybrid vehicle to experience deterioration in fuel economy (hence, increase in CO_2) if deterioration of the battery were to result in a reduction in the percentage of operation that might occur in battery-electric operation. EPA has said it will re-evaluate the no deterioration assumed as in-use experience is gained with new technologies.