UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NATIONAL VEHICLE AND FUEL EMISSIONS LABORATORY
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OFFICE OF
AIR AND RADIATION

October 15, 1998

VPCD-98-13 (HD Engine)

Dear Manufacturer:

Subject: Heavy-duty Diesel Engines Controlled by Onboard Computers: Guidance on Reporting and Evaluating Auxiliary Emission Control Devices and the Defeat Device Prohibition of the Clean Air Act

Enclosed with this letter is a guidance document which addresses the identification and reporting of certain on-board computer controlled systems on electronically controlled diesel engines used in heavy-duty motor vehicles and nonroad equipment for purposes of certification under Title II of the Clean Air Act. This document also confirms and clarifies prior EPA interpretation of the Clean Air Act's prohibition against defeat devices as applied to engines with these types of onboard computer controls. Finally, this document provides objective screening tools to assist manufacturers and EPA in evaluating Auxiliary Emission Control Devices as they relate to the prohibition against defeat devices and the certification of on-highway diesel engines that utilize them. EPA intends to develop similar screening tools for other classes in the future.

This guidance is being issued jointly by EPA's Office of Mobile Sources and Office of Regulatory Enforcement, because these offices are responsible for the certification that engines meet emission standards for their useful lives, and for the enforcement of the Clean Air Act prohibition against strategies which reduce the effectiveness of emission control systems respectively

If you have any questions about this guidance, please contact your certification team representative.

Sincerely,

Jane Armstrong, Director
Vehicle Programs and Compliance Division
Office of Mobile Sources

Bruce C. Buckheit, Director
Air Enforcement Division
Office of Regulatory Enforcement

Enc.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

October 15, 1998

Heavy-duty Diesel Engines Controlled by Onboard Computers: Guidance on Reporting and Evaluating Auxiliary Emission Control Devices and the Defeat Device Prohibition of the Clean Air Act

I. Purpose

This guidance addresses the identification and reporting of certain onboard computer controlled systems on electronically controlled diesel engines used in heavy-duty motor vehicles and nonroad equipment, for purposes of certification under Title II of the Clean Air Act. This document also confirms and clarifies prior EPA interpretation of the Clean Air Act's prohibition against defeat devices as applied to engines with these types of onboard computer controls. Finally, this document provides objective screening tools to assist manufacturers and EPA in evaluating these Auxiliary Emissions Control Devices (AECDs) as they relate to the prohibition against defeat devices and the certification of engines that utilize these AECDs. Unless otherwise noted, the term "heavy-duty diesel engines" in this guidance refers to both on-highway heavy-duty diesel engines and nonroad diesel engines.

EPA is issuing this guidance at this time because (1) in the near future almost all on-highway heavy-duty diesel engines and many non-road diesel engines will have onboard computers controlling the operation of the engine and its emissions control system; (2) the increased complexity of computer controlled engine management systems, including the various sensors and software associated with these systems, has led to an increase in the number and types of AECDs; and (3) recent investigations and enforcement actions by the Agency and the State of California have revealed that the manufacturers of the majority of the on-highway heavy duty diesel engines sold in this country have employed onboard computer strategies that are defeat devices.

II. Background

The Clean Air Act's federal mobile source program has three basic elements. First, Congress authorized EPA to promulgate emission standards to control emissions that lead to harmful air pollution. This includes setting specific emission limits that vehicles and engines must meet when tested in accordance with established test procedures. Second, Congress also prohibited manufacturers from using devices that "defeat" the pollution control system used during the emission standards testing. This second element, known as the statutory "defeat device prohibition," is similar to other restrictions under the Clean Air Act that prohibit factory or power plant operators from turning off or disabling their pollution control systems. The third element of the statutory scheme involves compliance related measures, including a certification program, assembly line audits, in-use recall, and authority to assess civil penalties for violations of the Clean Air Act's prohibitions. All three elements reflect that the purpose of the emissions standards, defeat device prohibition, and compliance measures is to achieve the desired emissions reductions during actual operation and not just during operation under laboratory conditions.

EPA's regulations implement these Clean Air Act provisions in several ways. First, EPA has established detailed test procedures that are used to measure compliance with the emissions standards. These are known as the "Federal Test Procedure" or "FTP." EPA has also prohibited the use of defeat devices in these and other engines. Second, a manufacturer is required to obtain a certificate of conformity from EPA prior to introduction of a new heavy-duty diesel engine into commerce. The manufacturer must submit a complete and truthful application to EPA, including any required test information. To implement the defeat device prohibition, manufacturers also must provide a detailed description of the basic pollution control system for the vehicle or engine, and identify and provide a detailed description of each element of design that may change the emission control system compared to its operation during FTP testing to demonstrate compliance with the emission standards. If EPA determines that the vehicle or engine will comply with the emission standards, the defeat device prohibition, and other requirements, for its useful life, then EPA issues a certificate of conformity. Thereafter, EPA may require or conduct assembly line and in-use testing and may suspend production and order the manufacturer to recall vehicles or engines that do not meet emission standards throughout their useful life. EPA also has the authority to seek fines and other sanctions where a manufacturer introduces into commerce a vehicle or engine that differs from that described in the manufacturer's certification application or that contains a defeat device.

III. Prior Agency Guidance

EPA has published prior guidance documents addressing issues relating to the subject of this guidance. For example, Advisory Circular 24 ("A/C 24") (1972) generally defines and discusses defeat devices and AECDs. A/C 24-2 (1978) provides guidance relevant to the use of electronic engine controls. It clarifies that electronic control systems that affect the emissions control system's performance are AECDs.

In addition, EPA has interpreted the AECD and defeat device requirements in the context of several rulemakings. See. e.g., 57 FR 31894 (July 17, 1992), including discussion of emission control system logic, on-board computer software, calibrations and hardware items as AECDs and providing objective criteria to aid in evaluating AECDs that controlled emissions of carbon monoxide; and 59 FR 23418 (May 5, 1994), stating that onboard computer algorithms that improve fuel economy but increase NOx emissions in diesel engines during highway driving by retarding timing during transient engine operating conditions and advancing timing during steady state operating conditions are illegal defeat devices.

Most recently, EPA issued guidance to light-duty vehicle manufacturers emphasizing that all applications for certification must include a detailed description of each AECD. The detailed description of the AECD should include parameters sensed and controlled and the

effect on emissions, both on- and off-cycle. This guidance also reiterated that manufacturers must justify any AECD that results in a reduction in the effectiveness of the emissions control system. (See, Dear Manufacturer Letter dated May 27, 1998.)

IV. Applicability

This guidance is applicable as follows: 1) prior guidance continues to be applicable including A/C 24 and A/C 24-2; 2) guidance related to the specific design information about electronic control AECDs that must be submitted with applications for certification is applicable to all heavy-duty diesel engines which utilize electronic controls beginning with applications for certification submitted to EPA on or after December 1, 1998; 3) guidance related to the manufacturer's use of objective emissions screening tools in certificate applications applies to model year 2000 and later on-highway heavy-duty diesel engines; 4) guidance related to the manufacturer's use of objective design screening criteria in certificate applications applies to model year 2000 and later on-highway heavy-duty diesel engines.

While this guidance specifically addresses issues arising in the context of heavy-duty diesel engines using retarded injection timing for NOx control, manufacturers of other vehicles or engines should use the discussion of AECDs relating to onboard computers and electronic controls during the certification process, and compliance with the prohibition against defeat devices, because the same regulatory and statutory requirements concerning AECDs and defeat devices apply to these manufacturers as to manufacturers of heavy-duty diesel engines.

V. Definitions

For on-highway heavy-duty diesel engines, the following regulatory definitions apply:

1. Auxiliary Emission Control Device (AECD). An AECD is any element of design that senses temperature, vehicle speed, engine rpm, transmission gear, manifold vacuum, or any other parameter for the purpose of activating, deactivating, or modulating the operation of any part of the emission control system. See 40 CFR 86.082-2 and 86.094-2.

2. Defeat Device. A Defeat Device is an AECD that reduces the effectiveness of the emission control system under conditions which may reasonably be expected to be encountered in normal vehicle operation and use, unless (1) such conditions are substantially included in the Federal emission test procedure; (2) the need for the AECD is justified in terms of protecting the vehicle or engine against damage or accident; or (3) the AECD does not go beyond the requirements of engine starting. See 40 CFR 86.094-2.

For nonroad diesel engines, the following regulatory definitions apply:

1. Auxiliary Emission Control Device (AECD) means any element of design that senses temperature, vehicle speed, engine rpm, transmission gear, or any other parameter

for the purpose of activating, modulating, delaying, or deactivating the operation of any part of the emission control system. See 40 CFR 89.2

2. Defeat Device means any device, system or element of design which senses operation outside normal emission test conditions and reduces emission control effectiveness. A defeat device includes any auxiliary emission control device (AECD) that reduces the effectiveness of the emission control system under conditions which may reasonably be expected to be encountered in normal operation and use unless such conditions are included in the test procedure. A defeat device does not include such items that either operate only during engine starting or are necessary to protect the engine (or equipment) against damage or accident during its operation. See 40 CFR 89.107-96.

VI. Auxiliary Emission Control Devices (AECDs)

Recent EPA and CARB investigations have revealed that heavy-duty diesel engine manufacturers are not fully and appropriately reporting AECDs as part of the certification process. This is particularly evident for electronically controlled engines, where numerous sensors, software calibrations, and algorithms may be used to modulate and control multiple aspects of the engine operation, including operation of some or all of the emission control system. Any software or hardware that modulates, activates, or deactivates any part of the emissions control system is an AECD under the Agency's regulations. The following is intended to provide manufacturers with specific examples of the types of design elements that EPA considers to be AECDs, and which must be reported and justified in the application for certification. The following is not intended to be an exhaustive listing of all AECDs, but rather, is intended to provide guidance as to what may constitute an AECD.

1. As set out in A/C 24-2, electronic engine control systems are AECDs, where the computer may receive inputs from various sensors and control multiple actuators that affect the emission control system.

2. Current heavy-duty diesel engines employ retarded fuel injection timing as the primary emissions control device for NOx emissions. In such engines, the basic emission control system includes the software incorporated in the on-board computer that contains the operating parameters for fuel injection timing employed during FTP testing. Any mechanical system or software that alters the fuel injection timing that is employed to control emissions on the FTP is an AECD. Examples of such AECDs include strategies that adjust fuel injection timing based on barometric pressure, intake manifold pressure, engine rpm, fuel rate, average fuel rate, ambient temperature, actual or inferred gear ratio, intake manifold temperature, engine coolant temperature, oil temperature, the derivative(s) of these inputs, use of cruise control, idle periods, power-take-off (PTO) systems, or any similar inputs for the purpose of determining diesel fuel injection timing. A software strategy that is incorporated in the on-board computer, but does not command or change fuel injection timing during the FTP test, is not considered employed during the FTP, or substantially included in the FTP. For example, a strategy that changes fuel injection timing at ambient temperatures below FTP limits is not

employed during the FTP and is not substantially included in the FTP.

3. In order to meet future emission standards it is likely that manufacturers will use technologies such as exhaust gas recirculation (EGR) and/or NOx after treatment devices, perhaps in conjunction with fuel injection timing strategies. These systems will almost certainly require modulation by an engine computer employing software and/or hardware that embodies a control strategy. Mechanical or electronic elements of design that modify the operation of the EGR or after treatment devices are also AECDs.

VII. Reporting AECDs

Manufacturers are required to describe all AECDs and justify any that reduce the effectiveness of the emission control system. The AECD reporting guidelines below are effective for certification applications submitted to EPA on or after December 1, 1998, that relate to heavy-duty diesel engines.[1]

A manufacturer must, in the initial certification application, provide the following information to satisfy its obligation to disclose electronic control AECDs that relate to diesel fuel injection timing.

A technical description of the AECD which explains:

(a) its purpose (for example, turbo charger protection at high operating temperatures, white smoke control on engine start-up),

(b) the parameters sensed or controlled by the AECD (for example, sensing: engine oil temperature, engine rpm, engine fuel rate, barometric pressure; controlling: fuel injection timing),

(c) the conditions under which the AECD is activated to influence fuel injection timing or another part of the emission control system (for example, at cold oil temperatures, under overheat conditions), and

(d) the impact of the AECD on engine emissions (for example, reduction in white smoke with increase in NOx).

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[1] While this specific guidance does not require resubmission of applications submitted before December 1, 1998, this does not relieve manufacturers from the obligation to comply fully with the applicable regulations for reporting and justifying AECDs, consistent with previously issued guidance on these matters.

example, intake manifold air temperature below 10°C), and the extent to which the AECD activates, deactivates, or modulates the operation of any part of the emissions control system, including fuel injection timing (for example, timing increases from 10 degrees BTDC to 15 degrees BTDC).

3. A demonstration that the strategy is the minimum strategy needed to offset the identified reason for the AECD.

4. For nonroad heavy-duty engines, the manufacturer should submit the base timing map (e.g., the base timing over the range of engine and speeds and loads).

Attachment I contains a sample AECD report using these guidelines.

VIII. Screening Tools to Assist in Evaluating AECDs

EPA will use three objective tools to assist in evaluating compliance with the defeat device prohibition. The first two tools are emission performance screening tools called the Supplemental EURO III Limits and Not-to-Exceed Limits, and only apply to on-highway heavy-duty diesel engines. The third tool is a set of design-based screening criteria that apply to all heavy-duty diesel engines (on-highway and nonroad). EPA will also use any other available information relevant to determine compliance with the defeat device prohibition.

1. The Supplemental EURO III is a test based on the European steady-state engine certification test. The test consists of 13 steady-state modes covering a broad range of highway-type operating conditions. The Supplemental EURO III test demonstrates the emissions performance of engines over these highway-type operating conditions. The testing and technical requirements for conducting the Supplemental EURO III test are described in Attachment II.

An engine satisfies the screening criteria of the Supplemental EURO III test if it meets the following emissions limits when tested in accordance with Attachment II:

Pollutant	Weighted Composite Emission Limit
NOx (or NOx + NMHC as appropriate)	1.0X FTP-based numerical standard or 1.0X FEL as applicable
HC (or NOx + NMHC as appropriate)	1.0X FTP-based numerical standard or 1.0X FEL as applicable
CO	1.0X FTP-based numerical standard or 1.0X FEL as applicable

Pollutant	Weighted Composite Emission Limit
PM (cycle composite only, not weighted)	1.0X FTP-based numerical standard or 1.0X FEL as applicable

FEL = Family Emission Limit for engines participating in the Averaging, Banking, and Trading program.

If the manufacturer chooses to submit EURO III data, it should submit test results and other data specified in Section 1.1 of Attachment II in its application for certification, along with a statement that the test results correspond to the maximum NOx producing state that could be encountered for a 30 second or longer period at each test point.

EPA will use the Supplemental EURO III screening test and the emissions limits above to evaluate the performance of post-1999 model year on-highway heavy-duty diesel engines. EPA may use the screening test and emissions limits for prior model years, where appropriate.

2. In addition to EURO III test results, EPA will use a Not-to-Exceed (NTE) tool to screen for a wide variety of potential defeat devices. The NTE defines a broad range of engine speed and load points (called the NTE Control Area), under which engines are expected to emit at reasonable levels in all normal ambient conditions. A technical description of the NTE is also included in Attachment II.

An engine satisfies the screening criteria of the NTE if it meets the following emissions limits when operated within the NTE Control Area:

Pollutant		Maximum Allowable Limit
NOx (or NOx + NMHC, where appropriate)		1.25X FTP-based numerical standard or 1.25X FEL as applicable
Smoke		filter smoke number of 1.0
Alternate Opacity	Steady State Limit	10 second average smoke opacity of 4% for a 5 inch path limit
	Transient Limit	30 second average smoke opacity of 4% for a 5 inch path limit

Note: Either the Smoke or Alternate Opacity Limits apply, but not both.

The manufacturer need not submit test data at the time of certification to satisfy the NTE screening limits. However, the manufacturer should state in the certification application that the engine is designed to meet the NTE limits defined above and in Attachment II, and have a sound technical basis for making such statement.

EPA will use the NTE screening test and the emissions limits above to evaluate the performance of post-1999 model year on-highway heavy-duty diesel engines. EPA may use the screening test and emissions limits for prior model years, where appropriate.

3. Finally, EPA will use objective design-based screening criteria to evaluate specific AECDs with respect to the prohibition against defeat devices. The design screening criteria are described in Attachment III.

A particular engine strategy, as reported in the certification application using the guidelines described in Section VII above, satisfies the objective design-based screening criteria if it is within the criteria described in Attachment III. Any allowance for strategies to protect against white smoke and misfire that increase NOx emissions will only be available until a NOx + NMHC standard or requirement is applicable, as discussed more fully below

EPA will use the design-based screening criteria to evaluate the performance of post-1999 model year on-highway heavy-duty diesel engines. EPA may use the criteria for prior model years, where appropriate.

IX. Evaluating AECDs During the Certification Process

1 For on-highway heavy-duty diesel engines:

Except as noted below, if an engine manufacturer demonstrates to EPA's satisfaction that an engine family satisfies each of the three screening tools described above and in Attachments II and III, including submitting the relevant test results and statements, then absent other information suggesting the existence of a defeat device, EPA does not intend to pursue further investigation of the engine family for the purposes of certification with respect to the prohibition against defeat devices.

If an engine manufacturer does not satisfy each of the three screening tools, EPA will evaluate the appropriateness of engine control strategies on a case-by-case basis. For example, if a particular design is not within the criteria of Attachment III, the manufacturer should demonstrate at the time of certification that the particular strategy is the minimum strategy necessary to protect against engine damage, white smoke or misfire. Any strategies or elements of design not discussed here will be addressed by EPA on a case-by-case basis during the annual certification process.

EPA reserves the right to use the Supplemental EURO III and NTE screening tests and limits described herein to evaluate certification, assembly line, and in-use engines with regard to the prohibition against defeat devices, whether or not the engine manufacturer has submitted the information and test results described above during the certification process. In addition, EPA reserves the right to conduct further investigation of any engine family where appropriate under the circumstances.

2. For nonroad diesel engines:

The Supplemental EURO III and NTE screening tools are not applicable to nonroad diesel engines. However, if an engine manufacturer demonstrates to EPA's satisfaction that an engine family satisfies the design screening thresholds in Attachment III, or the manufacturer has sufficiently demonstrated that the particular strategy is the minimum strategy necessary to protect against engine damage, white smoke, or misfire, then absent other information suggesting the existence of a defeat device EPA does not intend to pursue further investigation of the engine family for the purposes of certification with respect to the prohibition against defeat devices based on the kind of strategies discussed in Attachment III. The allowance for a minimum strategy to protect against white smoke and misfire will only be available until a NOx+NMHC standard or requirement is applicable, as discussed more fully below. Any strategies or elements of design not discussed here will be addressed by EPA on a case-by-case basis during the annual certification process.

EPA reserves the right to conduct further investigation of any engine family where appropriate under the circumstances.

X. Defeat Devices, Normal Operation and Use and the Frail Engine

The agency believes that the manufacturer is obligated to design and install an emissions control system that functions effectively in the real world, i.e., "in normal operation and use." The definition of defeat devices concerns the effectiveness of the emissions control system during such real world operating conditions, and provides an exemption for disclosed AECDs that are justified in terms of protecting the engine or vehicle from damage. Given the myriad of potential operating scenarios, there are occasions when manufacturers are entitled to modulate the pollution control system, where fully disclosed, because it is necessary to protect the vehicle or engine from damage. However, whether an AECD is justified as necessary depends in part on considerations of currently available technology. For example, engine protection would not justify an AECD if the need for engine protection is the result of inadequate design of the engine, when viewed in comparison to currently available technology.

Some manufacturers have employed strategies that advance timing when the vehicle is operated at altitudes above a specified threshold, in some cases as low as several hundred feet. Significant parts of this country are at altitudes above this threshold. It is the agency's view that driving in these areas is included within normal operation and use. This guidance sets out altitude screening criteria for use in evaluating AECDs, based in part on the Agency's view of the technical capability of currently available technology.

Many manufacturers have over temperature protection strategies that advance timing when coolant or other temperatures reach certain thresholds. While such engine protection strategies are clearly contemplated by the exemption from the defeat device definition, the exemption would not apply where a manufacturer does not specify adequate cooling capacity for vehicles using the engine but relies instead on the over temperature protection strategy to

cool the engine in normal operation and use. In the summer, many areas of the country experience numerous days where the temperature approaches or exceeds 100 degrees F ambient. The adverse health impacts from excess NOx emissions - excessive ozone formation – are most acute on hot days. EPA believes that vehicle operation at 100 degrees F and above is "normal" and that NOx emission controls can and should be designed to work on the hot summer days when they are needed the most. Accordingly, EPA will screen over temperature protection strategies to determine whether the engine has been designed to operate without the need for over temperature protection during normal operation and use, and also whether the emission system degradation that occurs when the strategy is activated is no more than necessary to protect a well-designed engine.

Nearly all manufacturers of heavy duty diesels have installed pollution control systems that control HC at cooler ambient temperatures by advancing fuel injection timing, thereby degrading NOx control efficiency. Operation at cooler temperatures is "normal," except for extreme cold temperatures. However, absent the modification of the NOx control operating parameters, significant quantities of unburned hydrocarbons ("white smoke") could be emitted. EPA understands that current diesel engines may require fuel injection timing modulations under certain such conditions to prevent unwanted white smoke emissions or engine misfire conditions, and that current diesel engines lack the technology needed to adequately control both NOx and HC emissions in these cases. EPA intends to allow such strategies on current technology engines, but only to the extent such strategies are necessary to overcome white smoke or engine misfire and only where such strategies represent the minimum fuel injection timing advance necessary.

XI. Enforcement of the Statutory Prohibition Against Defeat Devices

EPA's Office of Enforcement and Compliance Assurance (OECA) is responsible for enforcing the statutory prohibition against defeat devices found in Section 203(a)(3)(B) of the Clean Air Act. OECA will use the same threshold levels and the same screening tests (i.e., the Supplemental EURO III, NTE, and design criteria) when evaluating whether to investigate potential defeat device and AECD reporting violations. In general, if the engines in question satisfy the design-based criteria in this guidance and the Supplemental EURO III and NTE screening, OECA will consider those engines to be a lower priority for further investigative scrutiny. In addition, OECA intends to promulgate a specific grant of enforcement discretion until the NOx plus NMHC standards become effective and not to seek to enforce the defeat device prohibition as it relates to limited white smoke and black smoke protection schemes for heavy duty diesels that use retarded injection timing as the principal NOx control measure. OECA will do so only where such schemes are fully disclosed in the initial application for certification and approved by the Office of Mobile Sources. However, OECA reserves the right to conduct further investigation and to take enforcement action in any other circumstance where the strategy in question is an attempt to circumvent the threshold levels or the Supplemental EURO III and NTE screens or otherwise constitutes an unreported AECD, defeat device, or other violation of law.

Attachment I - Sample AECD Reporting Guidelines

The following is a sample AECD reporting format intended to show the level of detail EPA expects from engine manufacturers when they report AECDs on heavy-duty diesel engines. The sample format is applicable to all electronically controlled heavy-duty diesel engines. The use of particular parameters or emission values is intended to be illustrative of the nature of the reporting required and not to suggest that EPA would approve or disapprove the particular AECD described. The sample report contains a limited number of examples; EPA expects that a typical heavy-duty diesel engine uses a number of additional AECDs.

[Engine Company] uses the following electronic strategies as AECDs for engine family XSP012.9D6DAAW.

General Overview

[Engine Company] uses the following AECDs on its electronically controlled diesel engines: cold start, altitude, white smoke and misfire prevention, and inlet air temperature white smoke and misfire prevention.

Each AECD determines an injection timing value for the given condition (altitude, temperature, etc.). The timing values from the individual AECDs are compared and the largest value is added to the base timing value. The resulting timing value is the final ECU timing command, for a given load and speed. Each AECD is fully described below.

Coolant Temperature Strategy

Technical description – The coolant temperature strategy is used to prevent misfire and incomplete combustion when the engine itself is cold. A cold engine environment delays the start of the diesel engine combustion process which can cause misfire and allow unburned fuel (HC) to enter the exhaust in the form of white smoke. Furthermore, once combustion is initiated at low engine temperatures, the fuel does not burn completely which produces PM in the form of black smoke. Advanced injection timing compensates for the ignition delay and accelerates the warming of the engine to temperatures which promote complete combustion.

Engine coolant temperature is sensed via a thermistor located in the engine block. Below the calibrated threshold temperature, injection timing is advanced as coolant temperature decreases. The strategy decreases white smoke/HC and increases NOx. Based on test data, we estimate that the NOx increase is less than 10 percent during operation of the strategy and that the strategy is operative less that 2 percent of the annual operating miles of this engine, which is ordinarily used in line haul applications. Because NOx generation is low during cold temperatures, NOx levels remain below the FTP levels. This strategy is fully active and operational during the cold start portion of the FTP.

Calibration description – Injection advance is initiated at coolant temperatures below 80F as described in Figure 1.

[A statement as to whether these levels are within the thresholds provided in this guidance.]

Altitude strategy

Technical description – The altitude strategy is used to prevent engine misfire. Reduced engine cylinder pressures at high altitude delays the start of combustion, which can cause misfire and white smoke (HC) emissions. Timing advance compensates for the ignition delay. A sensor located in the engine compartment measures ambient pressure. At ambient pressures below the calibrated threshold, fuel injection timing advance increases with reduced pressure (increased altitude).

Calibration description – Injection advance is initiated at ambient pressures less than 80 kPa (approximately 6,000 ft.) and increases linearly down to 50 kPa (approximately 12,000 ft.). See Figure 2. Based on field tests conducted in Denver in 1996, the extent of advance is the minimum needed to prevent misfire and white smoke. Review of the 30 point plot for this engine, attached, suggests a linear increase in NOx emissions from 0 at 6,000 feet to an 8 percent increase at 12,000 feet. Other emissions are improved.

[A statement as to whether these levels are within the thresholds provided in this guidance.]

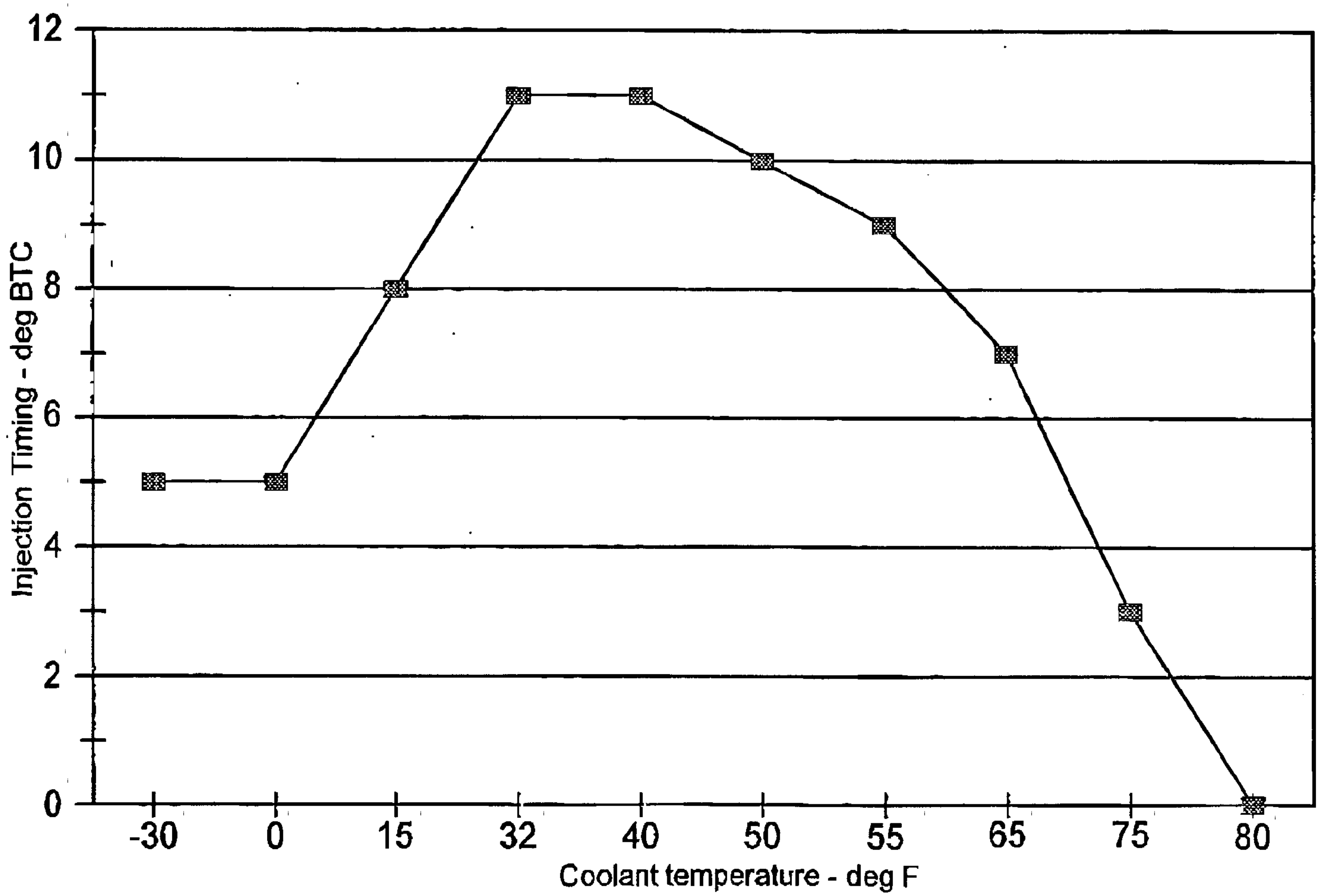
Inlet Air Temperature

Technical Description - The inlet air strategy is used to advance fuel injection timing under cold operating conditions to reduce engine misfire and reduce white smoke. A sensor located in the intake manifold measures the air temperature after the turbo charger and air-to-air intercooler.

Calibration Description - The system is calibrated such that no timing advance is present unless the engine is operating below one-half maximum fueling, and the intake manifold air is below 55F. Based on test data, the extent of advance is the minimum needed to prevent misfire and reduce white smoke. Figure 3 shows the intake manifold temperature versus amount of timing advance.

[A statement as to whether this value is within the thresholds provided in this guidance.]

Coolant Temperature Strategy



FIGURE

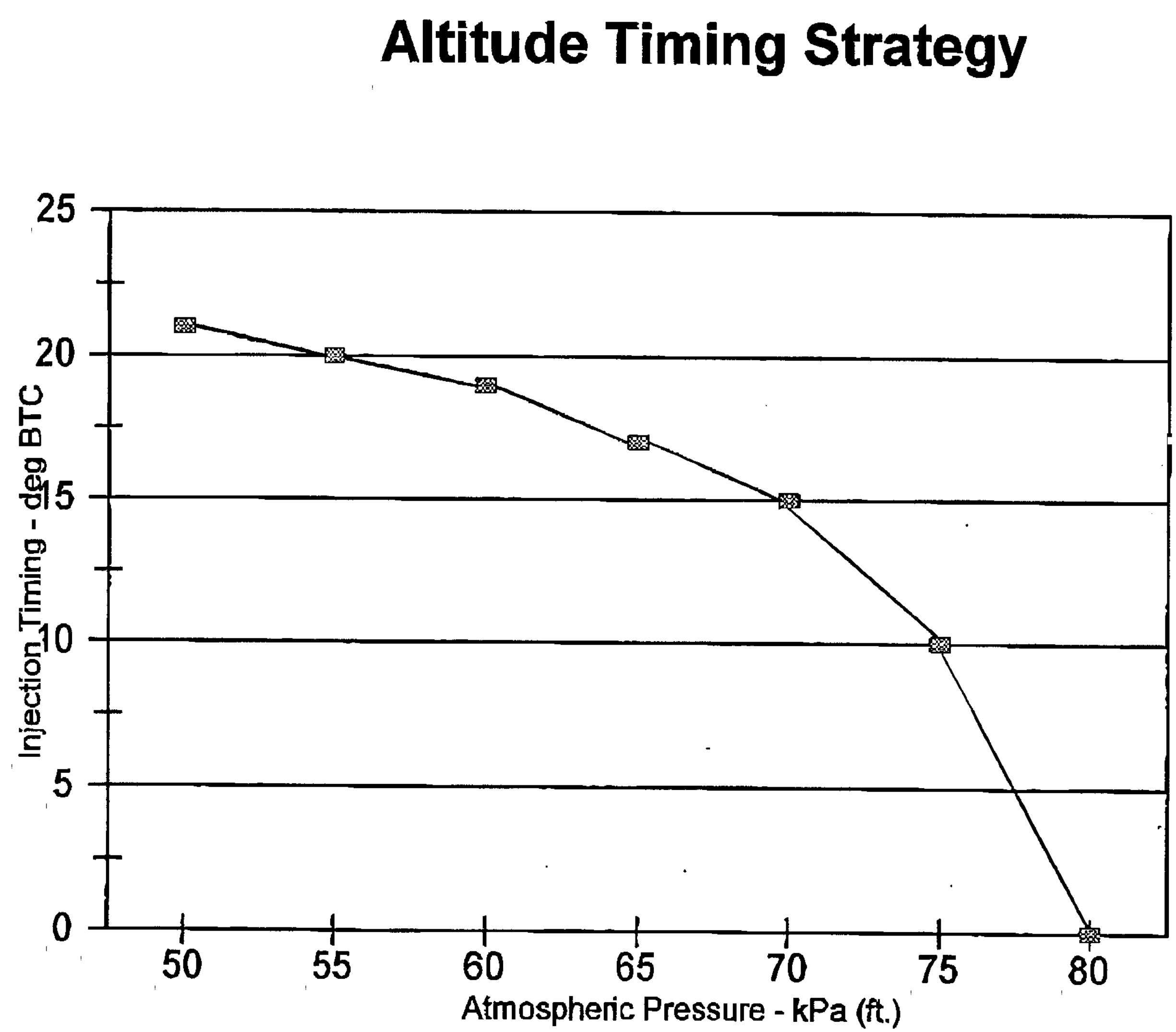

Altitude Timing Strategy
Injection Timing - deg BTC
25
20
15
10
5
0
50
55
60
65
70
75
80
Atmospheric Pressure - kPa (ft.)

FIGURE 2

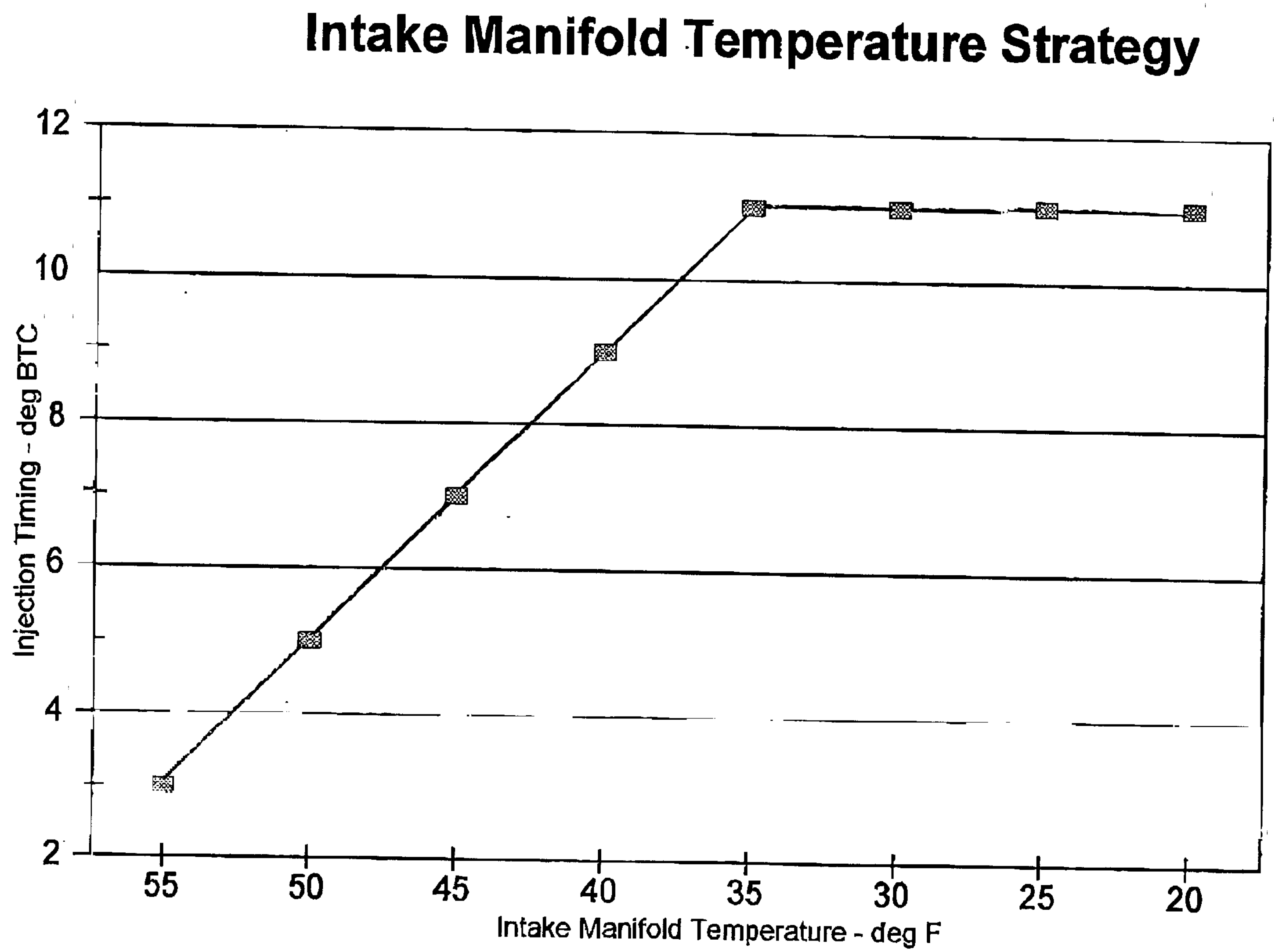

Intake Manifold Temperature Strategy
Injection Timing - deg BTC
12
10
8
6
4
2
55
50
45
40
35
30
25
20
Intake Manifold Temperature - deg F

FIGURE 3

Attachment II - Technical and Testing Requirements for Supplemental EURO III and NTE[2]

1. EURO III Requirements. The weighted average emission limit values applicable to the EURO III test set forth in this guidance apply to engines tested using the EURO III steady state test and emission weighting protocols identified as the "ESC test" in Annex III to the Proposal adopted by the Commission of the European Union on December 3, 1997. [3] The modal test point definition and weighting factors will be taken directly from Annex III. Except as specifically stated in this attachment in all other respects testing shall be conducted in accordance with 40 CFR Part 86, unless the company proposes, and EPA approves, an alternative procedure. The applicable weighted average emission levels and maximum allowable emission levels specified in the guidance apply to engines when new and in-use throughout the Useful Life of the engine and during all normal operation and use. In order to satisfy the Supplemental EURO III screening guidelines, the manufacturer must adhere to the requirements and protocols described in Sections 1.1 through 1.3 below.

1.1. The manufacturer must provide weighted average emission results of all regulated gaseous emissions and cycle composite PM results from the ESC test as part of the certification process. In addition to the weighted average data, the manufacturer must supply brake-specific gaseous emission data for each of the 13 test points in the ESC test. For each of these 13 test points, the manufacturer must provide upon request the concentrations and mass flow rates of all regulated gaseous emissions plus CO_2, as well as exhaust smoke opacity ("k" value) and the values of all emission-related engine

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[2] If the manufacturer has received a waiver for certain emissions pursuant to 40 CFR 86.094-23(c)(2)(i), then that emissions waiver applies to the Supplemental EURO III provisions as well. Except as specifically noted herein, all existing EPA regulations and policies shall apply to any testing conducted under this test protocol. Exceedances of the EURO III and Not to Exceed Limits would be appropriate where the manufacturer demonstrates to EPA's satisfaction during the certification process that the excess emissions are due to the requirements of engine starting, or conditions resulting from the need to protect the engine or vehicle against damage or accident and there are no other reasonable means to protect the engine or vehicle. In addition, during the term of this guidance, exceedances would be appropriate if the manufacturer demonstrates to EPA's satisfaction during the certification process that the excess emissions are due to extreme ambient conditions and that there are no reasonable means of meeting such limits under such ambient conditions. All procedures set forth in this attachment shall be implemented in accordance with sound engineering practice.

[3] Proposal adopted by the Commission of the European Union on 3 December 1997, for presentation to the European Council and Parliament, titled Draft Proposal for a Directive of the European Parliament and the Council Amending Directive 88/77/EEC of 3 December 1987 on the Approximation of the Laws of the Member States Relating to the Measures to be Taken Against the Emission of Gaseous and Particulate Pollutants From Diesel Engines for Use in Vehicles." Fuel meeting the specifications of 40 CFR 86.1313-94(b) for exhaust emissions testing will be substituted for the fuel specified in this Directive.

control variables.

1.1.1 The ESC test shall be conducted with all emission-related engine control variables in the highest brake-specific NO_x emissions state which could be encountered for a 30 second or longer period at the given test point. The manufacturer shall include a statement that the test results correspond to the maximum NO_x producing condition for a 30 second or longer period reasonably expected to be encountered at each test point during normal engine operation and use.

1.1.2 Any regulated gaseous emissions at any of the test points, or any interpolated points in the ESC control area (as defined in Section 1.2 below), shall be at or below the Not-to-Exceed Limits specified in the guidance if within the Not-to-Exceed Region as defined in Section 2 below.

1.1.3 As part of its certification application, the manufacturer shall submit a statement that its engines will meet the applicable EURO III limit values and testing requirements during all normal engine operation and use, including the limits described in sections 1.2 - 1.3.

1.1.4 For the purposes of submission of the certification application, the manufacturer shall conduct the ESC test within the temperature range of 68F to 86F.

1.2 For gaseous emissions, the 13 ESC test point results described in section 1.1, along with the four-point linear interpolation procedure of the ESC test protocol (Annex III, Appendix 1, Sections 4.6, 4.6.1, and 4.6.2) for intermediate conditions, shall define maximum allowable emission limits (See Figure 1). The ESC control area extends from the 25% to the 75% engine speeds, at engine loads of 25% to 100%, as defined in Annex III.

1.2.1 If the weighted composite ESC test result for any gaseous emission is lower

ESC Maximum Allowable Emission Limits
Sample - For Illustration Only

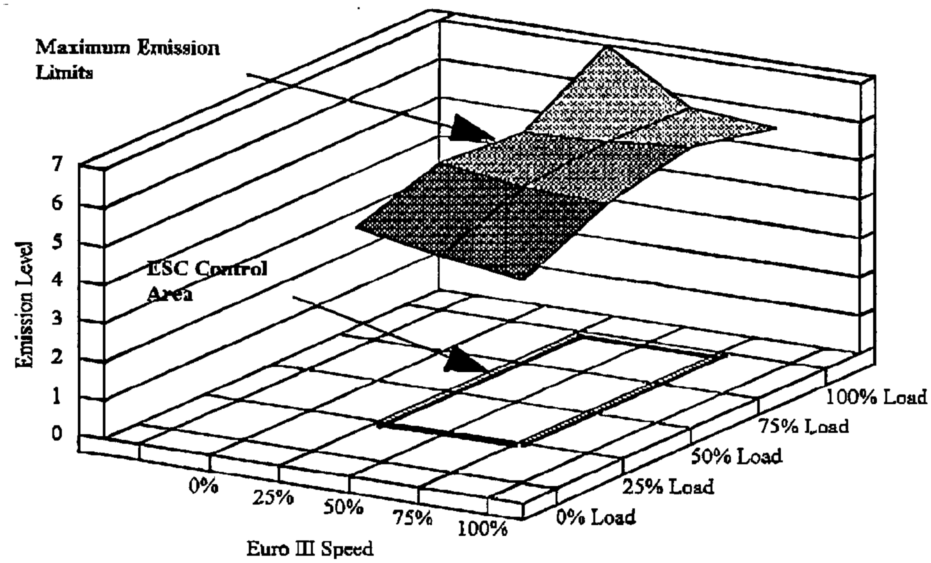

Figure 1

than specified in the guidance, the 13 ESC test values for that pollutant shall first be multiplied by the ratio of the limit value to the composite value and then by 1.05 for interpolation allowance before determining the maximum allowable emission limits of Section 1.2.[4]

1.3 In addition to the steady state testing protocols of the ESC test, engines may be tested under conditions that may reasonably be expected to be encountered in normal vehicle operation and use. The engine may be tested in a vehicle in actual use or on a dynamometer, under steady state or transient conditions and under varying ambient conditions. Test results within the ESC control area shall be compared to the maximum allowable emission limit for the same engine speed and load. The engine, when operated within the ESC control area, must meet with the maximum allowable

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[4] The 10% allowance for NOx at interpolated points found in Section 6.2.3 of Annex 1 of the December 1997 Directive for evaluating compliance within the limit values of the Directive is reduced to 5%.

emissions limits.

1.3.1 Where the test conditions identified in 1.3 require departures from specific provisions of Annex III or 40 CFR Part 86 (e.g., sampling time) testing shall be conducted using good engineering practices.

1.3.2 When engine dynamometer testing is performed by the manufacturer under non-FTP conditions, such testing shall be done on existing equipment, and carried out only within the limits of operation of available test equipment with regard to ambient temperature, humidity and altitude. EPA may conduct its own testing at any ambient temperature, humidity or altitude.

1.3.3 When tested under transient conditions, emission values to be compared to the maximum allowable limits shall represent an average of at least 30 seconds.

1.3.4 Until further guidance is issued, the humidity correction factors found in 40 CFR Part 86 shall be used for NOx. Outside the temperature range of 68-86 degrees F, NOx emissions shall be corrected to 68F if below 68F or to 86F if above 86F.

2. Not To Exceed Limits. The Not-To-Exceed Limits (NOx or NOx + NMHC, Smoke, and/or Alternate Opacity) specified in the guidance apply to engines when tested under conditions which can reasonably be expected to be encountered in normal vehicle operation and use. The applicable Not-to-Exceed Limits specified in the guidance apply to engines when new and in-use throughout the Useful Life of the engine. In order to satisfy the Not-to-Exceed screening guidelines, the manufacturer must adhere to the requirements and protocols described in Sections 2.1, 2.2, and 3 below.

2.1. Except as described in paragraph 2.1.2, the Not To Exceed Control Area includes all operating speeds above the "15% ESC Speed" calculated as in section 2.1.1, and all engine load points at 30% or more of the maximum torque value produced by the engine. In addition, notwithstanding the provisions of section 2.1.2, the Not To Exceed Control Area includes all operating speed and load points with brake specific fuel consumption (BSFC) values within 5% of the minimum BSFC value of the engine, unless during Certification the manufacturer demonstrates to the satisfaction of EPA that the engine is not expected to operate at such points in normal vehicle operation and use. Current engine designs equipped with drivelines with multi-speed manual transmissions or automatic transmissions with a finite number of gears are not subject to the 5% minimum BSFC additional NTE region.

2.1.1. The 15% ESC Speed is calculated using the formula $n_{lo} + 0.15(n_{hi} - n_{lo})$, where n_{lo} and n_{hi} are the low and high engine speeds defined in Annex III,

Appendix 1, Section 1.1 of the earlier referenced December 3, 1997 Proposal of the Commission of the European Union.

2.1.2. The area below 30% of the maximum power value produced by the engine is excluded from the Not to Exceed Control Area.

2.2 Within the Not-To-Exceed Control Area, the applicable Not-to-Exceed Limit value specified in the guidance applies to emissions of NO_x (or NO_x+NMHC where applicable), when averaged over a minimum time of 30 seconds. In addition, within the Not to Exceed Control Area, the Smoke or alternate Opacity Limit values apply as specified in the guidance. Engines may be tested under conditions that may reasonably be expected to be encountered in normal vehicle operation and use. Testing by the manufacturer under non-FTP conditions shall be done on existing equipment, and shall be carried out only within the limits of operation of the available test equipment with regard to ambient temperature, humidity and altitude. EPA may test the engine in a vehicle in actual use or on a dynamometer, under steady state or transient conditions and under varying ambient conditions.

2.2.1 As part of its certification application, the manufacturer must submit a statement that its engines will comply with the applicable Not To Exceed and Smoke or alternate Opacity limit values under all conditions which may reasonably be expected to be encountered in normal vehicle operation and use.

2.2.2 Until further guidance is issued, the humidity correction factors found in 40 CFR Part 86 shall be used for NOx. Outside the temperature range of 68-86 degrees F, NOx emissions shall be corrected to 68F if below 68F or to 86F if above 86F.

3. Supplemental Emissions Test Smoke Measurements. Supplemental emissions test may involve steady-state or transient smoke measurements. Steady-state smoke measurements may be conducted using opacimeters or filter-type smokemeters. Opacimeter types include partial-flow and full-flow. Only full flow opacimeters may be used to measure smoke during transient conditions.

3.1 For steady-state or transient smoke testing using full-flow opacimeters, equipment meeting the requirements of 40 CFR Part 86, subpart I "Emission regulations for New Diesel Heavy-Duty Engines; Smoke Exhaust Test Procedure" or ISO/DIS-11614 "Reciprocating internal combustion compression ignition engines - Apparatus for measurement of the opacity and for determination of the light absorption coefficient of exhaust gas" is recommended.

3.1.1 All full-flow opacimeter measurements shall be reported as the equivalent % opacity for a 5 inch effective optical path length using the

Beer-Lambert relationship.

3.1.2 Zero and full-scale (100% opacity) span shall be adjusted prior to testing.

3.1.3 Post test zero and span checks shall be performed. For valid tests, zero and span drift between the pre-test and post-test checks shall be less than 2% of full scale.

3.1.4 Opacimeter calibration and linearity checks shall be performed using manufacturer's recommendations or good engineering practice.

3.2 For steady-state testing using filter-type smokemeter, equipment meeting the requirements of ISO-8178-3 and ISO/FDIS-10054 "Internal combustion compression ignition engines - Measurement apparatus for smoke from engines operating under steady-state conditions - Filter-type smokemeter" is recommended.

3.2.1 All filter-type smokemeter results shall be reported as filter smoke number (FSN) that is similar to the Bosch smoke number (BSN) scale.

3.2.2 Filter-type smokemeters shall be calibrated every 90 days using manufacturer's recommended practices or good engineering practice.

3.3 For steady-state testing using partial-flow opacimeter, equipment meeting the requirements of ISO-8178-3 and ISO/DIS-11614 is recommended.

3.3.1 All partial-flow opacimeter measurements shall be reported as the equivalent % opacity for 5 inch effective optical path length using the Beer-Lambert relationship.

3.3.2 Zero and full-scale (100% opacity) span shall be adjusted prior to testing.

3.3.3 Post test zero and full scale span checks shall be performed. For valid tests, zero and span drift between the pre-test and post-test checks shall be less than 2% of full scale.

3.3.4 Opacimeter calibration and linearity checks shall be performed using manufacturer's recommendations or good engineering practice.

3.4 Replicate smoke tests may be run to improve confidence in single test or stabilization. If replicate tests are run, 3 additional valid tests will be run, and the final reported test results must be the average of all the valid tests.

3.5 A minimum of 30 seconds sampling time will be used for average transient smoke measurements.

Attachment III - Design Screening Thresholds

Cold Operation (White Smoke) Strategies

In general, manufacturers advance diesel fuel injection timing under cold operation conditions to prevent misfire and limit white smoke and black smoke. Cold temperature fuel injection timing advance is generally used when 1) the engine itself is cold, and/or 2) the combustion air is cold.

Cold Combustion Air

Air temperature is generally measured either within the engine intake manifold (after the turbo charger and air cooler), or in the pre-turbo charger side of the intake system (under the hood of the vehicle or equipment or in the air cleaner). For engine systems that measure intake manifold air temperature to determine cold air fuel injection timing advance, EPA is establishing a screening threshold of 60F. For any intake manifold temperature strategy that advances injection timing at intake manifold temperatures above this threshold, the manufacturer must demonstrate that the strategy is the minimum strategy necessary to protect against engine damage, white smoke, or misfire. For any system that measures air temperature on the pre-turbo charger side of the intake system (i.e. ambient of underhood air), the manufacturer must demonstrate that the strategy is the minimum strategy necessary to protect against engine damage, white smoke, or misfire.

Cold Engine

Engine temperature is generally measured either in the engine coolant system or the engine oil system. A/C 24 stated that AECDs that reduce the effectiveness of the emission control system in response to engine temperature (as sensed by a direct measure such as oil or coolant temperature) are generally acceptable provided the adverse impact occurs outside the range of normal, stabilized operating temperatures. For the purposes of this guidance, normal, stabilized operating temperature shall be considered to be within 5 percent of thermostatically controlled engine operating temperature (measured in degrees Fahrenheit).

Altitude Strategies

In general, manufacturers advance diesel fuel injection timing at higher altitude conditions to reduce the risk of turbocharger damage, prevent misfire and limit white smoke and black smoke. EPA is establishing a screening threshold of 5,500 feet (or the equivalent pressure). In addition, when descending from an altitude above 5,500 feet (or the equivalent pressure), the altitude timing advance may not remain engaged below 5,300 feet. For any altitude strategy that advances injection timing at altitudes below the 5,500 feet threshold, or which maintain timing advance below the 5,300 feet threshold, the manufacturer must demonstrate that the strategy is the minimum strategy necessary to protect against engine damage, white smoke, or misfire.

Acceleration and Rapid Load Change Strategies

In general, engine manufacturers advance diesel fuel injection timing under conditions of rapid acceleration or rapid load changes to prevent misfire and limit white smoke and black smoke. Once a rapid acceleration or load change is detected, the timing advance may last up to several seconds. EPA is establishing a screening threshold of 3 seconds of timing advance for a rapid acceleration or load strategy. For any acceleration strategy that advances injection timing for longer than three seconds per rapid acceleration or load change, the manufacturer must demonstrate that the strategy is the minimum strategy necessary to protect against engine damage, white smoke, black smoke, or misfire.

Idle Strategies

In general, engine manufacturers advance diesel fuel injection timing under idle or extended idle conditions to prevent misfire, limit white smoke and/or maintain stable engine operation and temperatures. EPA is establishing a screening threshold such that all idle strategies must be limited directly to an engine operating parameter such as coolant temperature, oil temperature, etc., that would indicate the need to advance timing to prevent misfire, limit white smoke and/or maintain stable engine operation and temperatures.