ASSISTANT ADMINISTRATOR FOR AIR AND RADIATION
WASHINGTON, D.C. 20460

March 26, 2026

IACD-2026-05 (LDV,HDE,NRCI)

SUBJECT: DEF Quality Monitoring Using Alternate Sensor Technologies

Dear Manufacturer,

The purpose of this letter is to provide guidance to manufacturers of diesel engines equipped with Selective Catalytic Reduction (SCR) emission controls regarding Diesel Exhaust Fluid (DEF) as an adjustable parameter. This guidance supplements prior Environmental Protection Agency (EPA) guidance that addressed DEF quality as an adjustable parameter.[1] The contents of this guidance do not have the force and effect of law and are not meant to bind the public in any way. This guidance is intended only to provide clarity to the public regarding existing requirements under the law or Agency policies.

Background

In 2013 for SCR equipped on-highway diesel engines and in 2014 for SCR equipped nonroad diesel engines, the EPA issued guidance describing the adjustable parameter provisions of the Agency's regulations,[2] and the Agency's conclusion that Urea Quality Sensors (UQS) could be installed in new on highway vehicles by model year (MY) 2016 and in new nonroad equipment by MY 2017 to meet the EPA's adjustable parameter regulations. The EPA also acknowledged that nitrogen oxides (NO_X) sensors had been successfully used to meet these requirements in previous MYs, and that it may be possible to continue to use NO_X sensors to meet the adjustable parameter regulations.

Since that time, only one diesel engine manufacturer has continued to demonstrate compliance with the adjustable parameter requirements using NO_X sensors. All other manufacturers switched to UQS because of the UQS's ability to directly measure DEF quality and more quickly determine if DEF has been diluted.

The Truck and Engine Manufacturers Association (EMA), on behalf of their members, has identified UQS as having among the highest failure rates of any SCR components. EMA further suggests that using alternate detection methods (e.g., NO_X sensors) could further improve SCR system robustness and reduce unnecessary inducements.

[1] The EPA previously issued guidance documents regarding DEF quality as an adjustable parameter, including CISD-13-13 for on-highway engines and CISD-14-10 for nonroad engines.
[2] *See* 40 CFR 86.094-22(e), 40 CFR 1039.115(e), and 40 CFR 1068.50.

The EPA's preliminary assessment of warranty data submitted to the Agency in response to information requests that the Agency sent to diesel engine manufacturers further suggests that UQS failures are a significant source of warranty claims and DEF-related inducement.

Given this, the EPA is issuing this guidance letter to make clear that alternative methods of meeting the adjustable parameter provisions, including the use of NO_X sensors, are allowed under EPA regulations. Further, the EPA is providing an illustrative example of how a manufacturer may make the necessary demonstrations to certify NO_X sensor-based systems. Finally, the EPA is stating that software updates to implement one or more elements of this guidance may be installed in existing diesel engine products in place of, or to augment, existing UQS-based systems without such action being considered tampering under the Clean Air Act.

Adjustable Parameter Provisions and DEF Quality

Adjustable Parameter Provisions of 40 CFR Part 1039[3]

The provisions that govern adjustable parameters in 40 CFR Part 1039 authorize the EPA to determine which parameters are adjustable for emission testing purposes, the adequacy of the limits, stops, or other means used to inhibit adjustment, and the resulting practically adjustable range for such a parameter.[4] Any parameter on any engine that is physically capable of being adjusted and may significantly affect emissions may be considered adjustable.[5] In determining the parameters subject to adjustment, the EPA will generally consider the likelihood that settings other than the manufacturer's recommended setting will occur during in-use operation. Manufacturers may ask the EPA to exclude a parameter that is difficult to access if it cannot be adjusted in a way that affects emissions without significantly degrading engine performance. Once a parameter has been determined to be an adjustable parameter, the EPA then determines the range of adjustment for emission testing based on whether the means used to inhibit improper adjustment (*e.g.,* physical limits, stops, or other means) are effective in preventing adjustment on in-use engines to settings outside the intended physically adjustable range. Finally, the resulting physically adjustable range for any such parameter is established based on whether the parameter is determined to be adequately inaccessible, sealed, or otherwise restrained in adjustment outside the intended physically adjustable range.

The provisions governing adjustable parameters are of particular relevance for the certification of diesel engines using SCR technology to comply with the NO_X emission standards of 40 CFR §§ 1039.101 and 1039.102. SCR technology in use with certified engines today relies upon injection of an aqueous urea solution, DEF, into the exhaust to control NO_X emissions. DEF is stored in a tank on the equipment and must be replenished routinely by the operator with DEF meeting the engine manufacturer's recommended specification. Engine manufacturers

[3] While the regulatory provisions described in this section are specific to nonroad diesel engines using SCR, the EPA's assessment and conclusions regarding the application of the adjustable parameter regulations are functionally the same for the on-highway regulations for products certified under 40 CFR Part 86 and new on-highway products certified under 40 CFR 1068.50.

[4] 40 CFR §§ 1039.115(e) and 1039.205(s).

[5] 40 CFR §§ 1039.801 and 1039.235(c)(3).

predominantly recommend use of DEF meeting the industry-recognized ISO 22241-1 quality standard, which specifies a 32.5 percent-by-weight urea concentration for the solution. SCR systems are calibrated to the 32.5 percent urea concentration to ensure optimum NO_X reduction during operation. Given the need for operator intervention to replenish DEF, there exists the possibility that the operator can put fluids other than the manufacturer's recommended DEF in the tank, either accidentally or intentionally. Using fluids other than the manufacturer's recommended DEF could contribute to a significant increase in NO_X emissions.

Given an operator's ability to physically adjust DEF quality, the increase in NO_X emissions that would result if they do so, and the significant possibility that they could be tempted to make such adjustments on in-use equipment, the EPA has previously determined that DEF quality is an adjustable parameter.[6]

Range of DEF Quality Adjustment

At the time of certification or when reviewing running changes and field fixes, the EPA will review the manufacturer's engine design to assess the adequacy of the means used to inhibit DEF quality adjustment (*e.g.,* physical limits, stops, or other means) by reviewing the likelihood that it will be circumvented, removed, or exceeded on in-use vehicles or engines. The EPA can determine that a physical limit, stop, or other means used to inhibit adjustment of a parameter is adequate based on the effect of settings beyond the limit, stop, or other means on equipment or engine performance characteristics other than emission characteristics. In the EPA's July 2011 presentation, the Agency provided the example of an engine design that incorporates the ability to detect DEF quality and activate engine or equipment-based performance inducements in a timely manner as one that could represent an adequate restraint on adjustability. The EPA continues to believe that such an approach represents one example of an adequate restraint on adjustability. Manufacturers may, however, devise alternate restraints subject to EPA review.

Upon establishing that adequate restraints on adjustability exist, the EPA will next review the manufacturer's engine design to determine the physically resulting range of DEF quality adjustment for emission testing. The EPA generally considers the range of adjustment for emission testing to span the change in urea concentration from 32.5 percent (unadulterated DEF) to the point at which poor DEF quality can be detected. This point represents the limit for DEF quality adjustment because it is the first point at which a manufacturer is able to implement inducements to prevent sustained engine or equipment operation with poor quality DEF. Poor DEF quality is any urea concentration at which the engine is unable to comply with the relevant NO_X standard over an applicable test cycle.

For example, an engine that first detects poor quality when DEF is diluted with water by 50 percent would be subject to emissions testing at any urea concentration ranging from 32.5 percent (unadulterated DEF) down to, but not including, 16.25 percent (DEF diluted with water by 50 percent). Over the full span of this range, the engine would need to comply with the relevant NO_X standard over all applicable test cycles. In this example, if the engine will exceed the NO_X standard

[6] *See* http://www.epa.gov/otaq/cert/documents/nrci-scr-web-conf.2011-07-25.pdf, presented July 26, 2011.

when DEF quality drops below 26 percent urea concentration, the engine might exceed the NO_X standard within the adjustable range for emissions testing purposes. In this case, the manufacturer should improve their detection capability to restrain adjustment between 32.5 percent and 26 percent urea concentration. Such an adjustable range would be appropriate for certification. Manufacturers should describe the DEF quality range of adjustment in their application for certification or when incorporating updates to their software in running changes or field fixes.

EPA regulations authorize certification of an engine design that detects poor DEF quality such that there is a small range in which poor DEF quality will not be detected and the engine will not comply with a specific emission standard if the manufacturer has demonstrated to the EPA that the adjustable range in which noncompliance is found is so small that it is sufficiently unlikely an operator would adjust to that setting in-use.[7] As a second example, if the manufacturer improved their detection capability to restrain adjustment between 32.5 percent and 21 percent urea concentration (*i.e.*, the range contains a "non-compliant" setting between 21 and 26 percent urea that represents a five percentage point span in urea concentration, or a roughly 15 percent increment of dilution with water), manufacturers have previously been able to demonstrate that such a narrow setting is so difficult for an operator to target in-use that it is sufficiently unlikely that they will attempt to make such an adjustment.[8] The EPA notes that a manufacturer is unlikely to be able to make such a demonstration if its engine's level of detection has a noncompliance margin that is large enough to likely be targeted by consumers.

DEF Quality Detection Using NOx Sensors

The EPA has previously certified engines that demonstrate an approach using NO_X sensor-based strategies for detecting some, but not all, DEF dilution levels consistent with the example in the preceding section. These strategies monitor NO_X concentration in the exhaust stream and determine SCR catalyst efficiency by measuring changes in NO_X across the catalyst. Significant deviations in NO_X conversion across the SCR catalyst from the expected or modeled conversion rate can be an indication of poor DEF quality. In most applications, NO_X sensors have been able to detect poor DEF quality for many, but not all, DEF dilution scenarios. The EPA has continued to certify such systems if manufacturers demonstrate that the range of potential DEF dilution levels in which the product would be noncompliant are small enough to make it sufficiently unlikely that operators will attempt to dilute DEF.

[7] *See* 40 CFR 1068.50(h)(1) "We will determine the range of adjustability based on the likelihood of in-use operation at a given point in the physically adjustable range. We may determine that operation in certain subranges within the physically adjustable range is sufficiently unlikely that the subranges should be excluded from the allowable adjustable range for testing. In such cases, the engines/equipment are not required to meet the emission standards for operation in an excluded subrange."

[8] In the case of an excavator with a 50-gallon diesel fuel tank and a 2-gallon DEF tank, the economic benefit available to an operator by targeting the maximum dilution in the example (21 percent urea concentration) would be 15 percent x 2 gallons x $3 gallon DEF = $0.90, while risking inducement if the operator mistakenly dilutes below 21% concentration. Further, such diluted DEF would necessitate more frequent DEF refills because the engine will compensate by injecting more of the diluted DEF to maintain NO_X control. The EPA finds it unlikely in such a situation that users would attempt to dilute DEF and, therefore, the Agency would expect to approve the manufacturer's adjustable range from 26 percent to 32.5 percent, even recognizing that it is theoretically possible to dilute to 21 percent before triggering inducement.

EPA Expectations for DEF Quality Monitoring In-Use

The EPA has long recognized that neither NO_X sensors nor UQS can monitor DEF quality under all operating conditions and situations. For example, NO_X sensor technology relies on the calculation of conversion efficiency across the SCR catalyst to determine DEF quality. This calculation cannot be made unless DEF dosing is occurring, which typically requires a minimum exhaust temperature of 190 ºC. Similarly, UQS can have accuracy errors when excessive bubbles are present in the DEF tank. Neither NO_X sensors nor UQS can monitor DEF quality when the fluid is frozen. The EPA accepts and continues to approve monitoring strategies designed to only make determinations regarding DEF quality under circumstances in which the determinations will be accurate and avoid false failures. This includes approving monitoring under conditions which require more than one hour to make accurate determinations. While EPA expects monitoring strategies to generally make determinations within one hour, EPA expects that to be limited to circumstances where accurate determinations can be made within one hour. If more than an hour is necessary to make an accurate determination, EPA expects the system to continue to monitor beyond the hour and not to automatically determine there is a fault when a decision cannot be made within one hour. The EPA may approve monitoring strategies that operate only after a DEF tank refill, within a prescribed temperature window, or within certain engine speed and load conditions that support accurate determination of DEF quality. Manufacturers should describe their DEF quality monitoring strategy in their application for certification or when incorporating updates to their software in running changes or field fixes.

Conclusion

The EPA has significant concerns about ongoing reports of DEF inducements due to the failure of UQS impacting the owners and operators of diesel-powered equipment unnecessarily. Manufacturers who can improve the robustness of their SCR systems through the use of alternative monitoring technologies, including the use of NO_X sensors, are encouraged to make such changes, including on their existing products. EPA staff are prepared to work with manufacturers to evaluate and approve alternate approaches on an expedited basis.

Should you have any questions concerning this guidance, please contact your certification representative or Stephen Healy, Acting Director of the Diesel Engine Compliance Branch at Healy.Stephen@epa.gov.

Sincerely,

Aaron Szabo
Assistant Administrator