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THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

A STEP-BY-STEP METHODOLOGY FOR VEHICLE TESTING TO CATCH DEFEAT DEVICES

To help regulators and third parties identify defeat devices that manipulate nitrogen oxide (NO_x) levels in vehicle exhaust for the purpose of evading pollutant emission limits, a new study by the ICCT develops and details a practical, seven-step vehicle testing methodology that can be adapted to different regulatory contexts and research purposes.

The methodology was demonstrated in tests performed using two Mercedes-Benz C-Class Euro 6b vehicles, the diesel versions of a C180 and a C200. The paper identifies multiple defeat devices likely being employed on the C180 and C200 to optimize NO_x emissions control under type-approval testing conditions and reduce emissions-control effectiveness in real-world driving.

While the study focuses on excess NO_x emissions from diesel passenger cars in the European Union, the techniques and procedures described can be readily applied to other regions, pollutants, and vehicle types.

BACKGROUND AND METHODOLOGY

A defeat device is any change to engine calibration or operation of the emission controls that increases pollutant emissions under conditions outside the type-approval test cycle but encountered in normal use, unless the calibration change is required for cold starts, safety, or to prevent damage to the engine or emissions aftertreatment system.[1] Detecting defeat devices requires efficient fleet monitoring and effective testing of suspect vehicles. But defeat devices normally take the form of computer code, and this can be difficult for third parties to access and analyze. Additionally, there are many possible "defeat devices" and vehicles with defeat devices can and usually do use multiple calibration strategies.

These difficulties can be overcome by a well-conceived testing protocol. A testing protocol capable of detecting even the most sophisticated defeat device should begin with on-road testing, as an initial screen to detect high emissions. When a defeat device is suspected, the trigger for the high emissions can be isolated through a combination of on-road and chassis-dynamometer testing using additional engine and aftertreatment instrumentation.

The new study, which includes testing flow charts, details a seven-step method.

Step 1: Select a vehicle for testing, based upon pre-screening from other testing and remote sensing

Step 2: Confirm proper vehicle operation on the type-approval test and real-world emissions discrepancies using inexpensive screening sensors

Step 3: Prepare the vehicle and instrumentation for robust emissions testing and investigation of calibration triggers

Step 4: Road test, while changing variables one at a time to identify step changes in emissions

Step 5: Laboratory test, to help identify defeat device triggers for step-changes in emissions

Step 6: Summarize data analyses

Step 7: Discussion and iterative steps with manufacturers (official agencies only)

1 This definition is consistent in both the United States and in Europe. Rachel Muncrief, John German, and Joe Schultz. *Defeat Devices Under the U.S. and EU Passenger Vehicle Emissions Testing Regulations* (ICCT: Washington, DC, 2016). https://www.theicct.org/sites/default/files/publications/ICCT_defeat-devices-reg-briefing_20160322.pdf

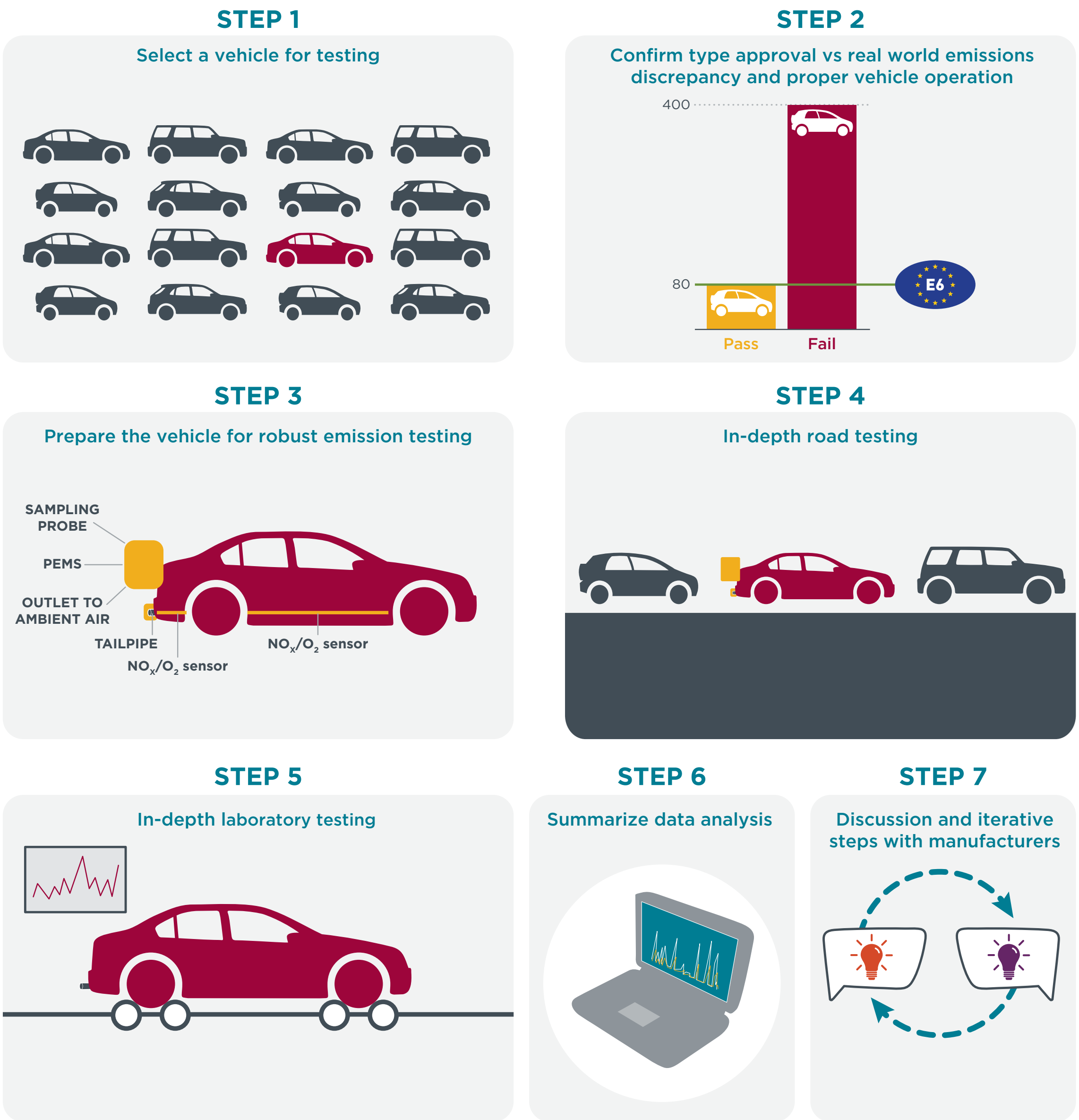

Figure 1. The seven steps of the testing protocol for detecting defeat devices.

KEY FINDINGS

The C180 and C200 demonstration vehicles exhibited inconsistent emissions control and potential defeat-device triggers in their calibration strategies. The study categorized the potential defeat devices, all of which would likely be considered illegal under U.S. regulatory guidance, as follows:

- Reduced exhaust gas recirculation (EGR) based on ambient temperature, around 12°C
- Reduced EGR based on some measure of engine temperature, such as coolant temperature
- Reduced selective catalytic reduction (SCR) efficiency based on ambient temperature, around 12°C
- Reduced SCR efficiency based on some function of time, distance, or accumulated urea consumption since engine-on

Changes in emission control behavior were also detected that could potentially signal the presences of defeat devices linked to the length of the test and preconditioning before the test and system design strategies that limited maximum EGR flow rate to engine conditions found on the NEDC.

For both vehicles, the results show alarming increases in real-world emissions under routine urban driving conditions and after small changes in ambient temperature. Further, as the chart below illustrates, the impacts of the suspected defeat devices seem to be additive. Reading from

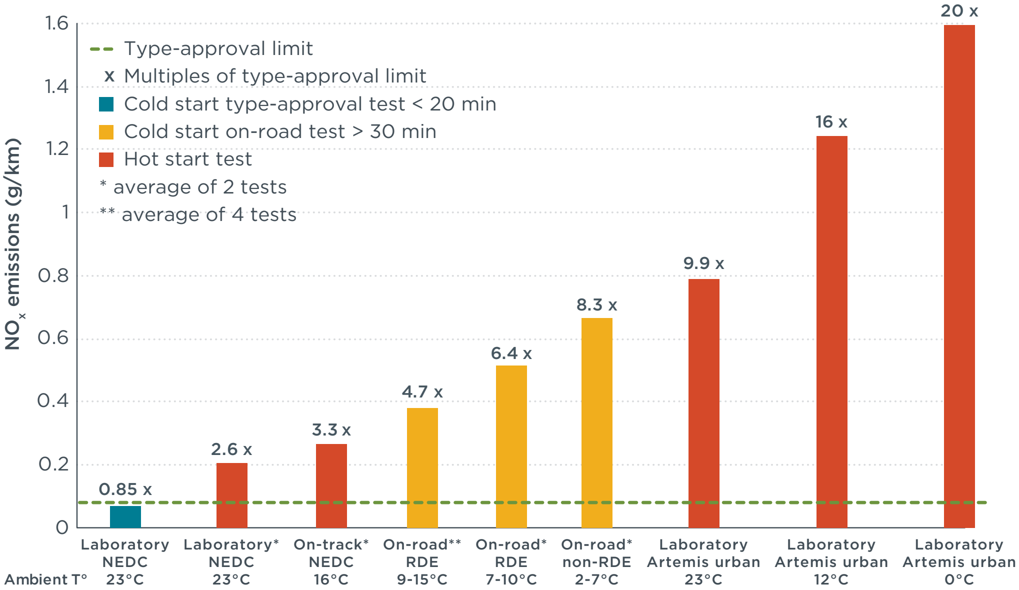

Figure 2. Summary of type-approval test results and key testing conditions that led to elevated NO_x emissions on the Mercedes C200 (first five tests) and C180 (last four tests).

left to right: as multiple defeat devices and design limitations are activated—including hot start, lower ambient temperatures, and different duty cycles—NO_x emissions may increase to as much as 20 times the type-approval limit. None of the conditions represented in this chart are in any way extreme.

REGULATORY IMPLICATIONS

If on-road diesel vehicles performed in the real world within the limits defined in the EU emissions regulation, about 6,800 deaths due to excess NO_x from cars and vans could be avoided in Europe every year.[2] Robust regulatory guidance is important for enforcing defeat-device provisions, but rigorous enforcement testing outside the type-approval process, like the procedure demonstrated in the study, is also needed to determine whether manufacturers are in compliance.[3] This testing methodology provides a sound basis for government agencies to engage with manufacturers, for third parties to urge vehicle alterations, and for regulators to begin enforcement actions.

In 2018, after the tests described in this white paper were completed, Germany's motor vehicle regulator, Kraftfahrt-Bundesamt, investigated the Mercedes Vito van and identified five defeat devices it deemed illegal.[4] While the details of the devices have not been made public, the van's 1.6L engine is similar to the one used in the C180 and the C200. Mercedes has denied any wrongdoing.[5]

2 Susan C. Anenberg et al., "Impacts and Mitigation of Excess Diesel-Related NO_x Emissions in 11 Major Vehicle Markets," *Nature*, 2017, 545 (7655): https://doi.org/10.1038/nature22086

3 Tim Gabriel, Pete Gabriel, *Strengthening The Regulation of Defeat Devices in the European Union* (ICCT: Washington, DC, 2016). https://www.theicct.org/sites/default/files/publications/DefTerre_StrengtheningDefeatDeviceRegulation_Briefing_jun2016.pdf

4 "German regulator found defeat devices in Daimler diesel cars: BamS," *Reuters*, June 9, 2018, https://www.reuters.com/article/us-daimler-software-kba/german-regulator-found-defeat-devices-in-daimler-diesel-cars-bams-idUSKCN1J50ZR

5 Elizabeth Behrman, Birgit Jennen, and Christoph Rauwald, "Daimler gets slapped with recall, but avoids risk of fines," *Bloomberg.com*, June 12, 2018, https://www.bloomberg.com/news/articles/2018-06-11/germany-orders-daimler-to-recall-774-000-diesel-cars-in-europe

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