www.theicct.org

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

BRIEFING

JUNE 2016

A technical summary of Euro 6/VI vehicle emission standards

This briefing is a comprehensive technical overview of the Euro 6/VI vehicle emissions standards, which tighten limits on air pollutant emissions set in previous European standards and require the best technology currently available for vehicle emissions control.

Countries outside of Europe, the United States and Japan have largely patterned their emissions policies on European regulations and the associated mandates for clean, low-sulfur fuels. By adopting the Euro 6/VI vehicle emission standards, these countries can achieve up to a 99 percent reduction in the emission of pollutants like fine particulate matter (PM2.5), reducing the risk of ischemic heart disease, lung cancer, stroke, and asthma.

In this briefing, we look at the historical context of European regulations, summarize the core technical elements, review the control strategies available to achieve the pollutant limits, and conclude by considering what is likely to come next in the European regulatory pathway.

BACKGROUND

The G-20 countries account for 90 percent of global vehicle sales, and 17 out of the 20 members have chosen to follow the European regulatory pathway for vehicle emissions control. The European pathway consists of six stages of increasingly stringent emission control requirements, starting with Euro 1/I in 1992, and progressing through to Euro 6/

Prepared by Martin Williams and Ray Minjares.

VI in 2015.[1] A number of Asian and Latin American countries currently have Euro 2/II, 3/III, and 4/IV standards in force.

The European Commission's Thematic Strategy on Air Pollution, adopted in 2005, sought to reduce transportation emissions as part of an overall air-quality-improvement strategy. The Euro 6/VI emission standards specifically noted that a "considerable reduction in NO_x [oxides of nitrogen] emissions from diesel vehicles is necessary to improve air quality and comply with limit values for air pollution."[2] It was clear in 2005 that member states would face difficulties achieving ambient NO_2 limit values by 2010, and that adoption of Euro 6/VI emission standards would be a determining factor. The proposal further noted that meeting the NO_x emission standards "requires reaching ambitious limit values at the Euro 6 stage without foregoing the advantages of diesel engines in terms of fuel consumption and emissions of hydrocarbons and carbon monoxide."[3] The Commission recognized that setting more ambitious emission standards for NO_x at an early stage would provide long-term planning security for vehicle manufacturers who wish to continue pursuing diesel technology.

Euro VI limits for heavy-duty vehicles were introduced in Regulation 595/2009, and were amended by Regulations 582/2011 and 133/2014. The Euro 6 limits for light-duty vehicles came earlier and were introduced along with Euro 5 limits under Regulation 715/2007, promulgated in 2007. The simultaneous release of the Euro 5 and 6 light-duty vehicle standards provided the automotive industry with a longer timeline to develop strategies for meeting future emission limits. Other countries following the European pathway can move directly to Euro 6 for light-duty vehicles and Euro VI for heavy-duty vehicles now that the technology is available to meet the emission standards.

A fundamental prerequisite for the efficient operation of exhaust aftertreatment devices for both light- and heavy-duty vehicles is having fuel with a very low sulfur content. The sulfur content of gasoline and diesel fuels in Europe has therefore been regulated to meet very stringent fuel-quality standards. Prior to the Euro 3 and 4 standards, regulations required a minimum diesel cetane number of 51, beginning in 2000, and a maximum diesel sulfur content that year of 350 ppm. Starting in 2005, the maximum diesel sulfur content was limited to 50 ppm. Gasoline sulfur content was regulated to 150 ppm in 2000, and 50 ppm in 2005. By 2005, Europe began the phase-in of virtually sulfur-free gasoline and diesel fuels (<10 ppm sulfur), replacing 50ppm fuels, which were ultimately phased out by 2009. Without these fuel-quality improvements, the increasing stringency of the limits in European standards would not have been possible.

1 The European standards are designated by Arabic numerals for light-duty vehicles, and Roman numerals for heavy-duty vehicles.

2 Regulation (EC) No. 715/2007 of the European Parliament and of the Council, Official Journal of the European Union, L 171/1, June 29, 2007, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:171:0001:0016:EN:PDF.

3 Regulation (EC) No. 715/2007 of the European Parliament and of the Council, Official Journal of the European Union, L 171/1, June 29, 2007, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:171:0001:0016:EN:PDF.

Defeat devices that reduce the effectiveness of emission controls, along with “irrational” control strategies,[4] were prohibited in Directive 2001/27/EC for diesel vehicles. Additionally, durability and on-board diagnostic (OBD) requirements were introduced for Euro IV and V in Directive 2005/55/EC, and the technical requirements were specified in Directive 2005/78/EC. Directive 2005/55/EC also restated the emission limits for Euro IV and V with additional language on the verification of European Transient Cycle (ETC) tests. A full history of the European emission and fuel-quality standards is available at: www.transportpolicy.net.

THE EURO 6 STANDARDS FOR LIGHT-DUTY VEHICLES

EMISSION LIMIT VALUES

European emission standards regulate gasoline and diesel vehicles separately. Considering first the standards for diesel vehicles (see Table 1), Euro 6 is a significant advancement over Euro 5 with regard to NO_x limits. The NO_x limit declines from 0.18 g/km to 0.08 g/km, a reduction of 56%. Explicit NO_x limits were introduced at the Euro 3 level, and in the Euro 6 standards the NO_x limit is 84% lower than the Euro 3 level. This has significant implications for control technologies, requiring for the first time the integration of emission control aftertreatment for NO_x emissions, such as selective catalytic reduction, lean NO_x traps, or others.

The particle mass and particle number standards for diesel cars in Euro 6 are the same as those in Euro 5. Limits on particle mass emissions for diesel cars have nonetheless been reduced by large amounts since the Euro 1 standards were introduced. The Euro 6 particle mass limits for diesel cars represent a reduction of 96% from Euro 1 limits. The particle mass limits are now so low that measurement accuracy and sensitivity are an issue, which has prompted the introduction of limits on particle number, which is easier to measure. These limits were first introduced at the Euro 5 level. Particle number limits are also supported by research in Europe that has found significant health impacts from exposure to high particle number counts.

The limits for gasoline vehicles have also fallen significantly, relative to earlier European emission standards. The Euro 6 NO_x standards for gasoline cars are the same as those for Euro 5, but they are 60% lower than those for Euro 1. Mindful of attempts by car manufacturers to improve the fuel consumption of gasoline vehicles through gasoline direct injection (GDI) technology, European regulators introduced particle mass limits on GDI engines at the Euro 5 level, equal to the limits set for diesel vehicles. Limits on particle number emissions of GDI engines were introduced in Euro 6 (they were introduced at Euro 5 for conventional diesel cars), and they are numerically the same as those for diesel cars. Europe phased in the Euro 6 particle number limit on GDI engines over the first three effective years of the standards. This more lax standard is 6.0×10^{12} #/km, an order of magnitude less stringent than the diesel standard (and the ultimate Euro 6 GDI limit) of 6.0×10^{11} #/km. This three-year phase-in was intended to extend the period of research and development needed to meet the standard, and by 2017 automakers are expected to meet the more stringent

4 An “irrational emission control strategy” means any strategy or measure that, when the vehicle is operated under normal conditions of use, reduces the effectiveness of the emission control system to a level below that expected on the applicable emission test procedures.

standard. Countries adopting the Euro 6 standards after 2017 should not require a phase-in period for particle number, given that technologies needed to meet the more stringent standard will be available. These countries can directly adopt the more stringent standard of 6 x 10^{11} #/km for GDI engines.

Table 1. The light-duty Euro 5 and Euro 6 vehicle emission standards on the New European Driving Cycle (NEDC)

Pollutant	Euro 5 Light-Duty		Euro 6 Light-Duty	
	Gasoline	Diesel	Gasoline	Diesel
CO	1.0	0.5	1.0	0.5
HC	0.1[a]		0.1[e]	
$HC+NO_x$		0.23		0.17
NO_x	0.06	0.18	0.06	0.08
PM	0.005[c]	0.005	0.005[c]	0.005
PN (#/km)		6.0 x 10^{11}	6.0 x 10^{11} [d]	6.0 x 10^{11}

[a] and 0.068 g/km for NMHC; [c] applicable only to DI engines, 0.0045 g/km using the PMP measurement procedure; [d] applicable only to DI engines, 6 x 1012 #/km within the first three years of Euro 6 effective dates.

TESTING

Light-duty vehicles are tested primarily in a controlled laboratory environment on a chassis dynamometer, which functions like a treadmill for vehicles, following a pre-defined drive cycle. Emissions are reported in units of g/km. The pre-defined drive cycle for light-duty vehicles is known as the New European Driving Cycle (NEDC), and it is composed of two sections. The first section, the ECE 15 cycle, was intended to represent urban driving and has been supplemented by the second section, which, is a higher speed test intended to represent highway driving. Both sections are necessary to capture the full range of low speed and high speed urban driving for a typical vehicle in Europe. Prior to the Euro 3 standards, vehicles were allowed to run for 40 seconds from cold before emissions were measured, permitting the catalyst on gasoline vehicles (see next section) to heat up and become effective. From Euro 3 onward this allowance was removed to better reflect the effects of cold start emissions, and so measurements are now made from the beginning of the drive cycle.

Regulation 715/2007, which established the Euro 5 and 6 engine standards, states in its preambular paragraphs that the [European] Commission should "keep under review the need to revise the New European Drive Cycle," and further notes that "Revisions may be necessary to ensure that real world emissions correspond to those measured at type approval."[5] Since the agreement of Regulation 715/2007, research has shown the NEDC to be a poor representation of real-world driving, with serious implications for emissions, particularly those of NO_x from diesel cars, and for the ambient air quality in Europe. The more recently developed Worldwide Harmonized Light Vehicles Test Cycle (WLTC) contains more dynamic driving conditions than the NEDC, such as higher maximum velocity and less idling time, as it was designed using a large number of real-world drives to better reflect real-world driving conditions. The European Commission

5 Regulation (EC) No. 715/2007 of the European Parliament and of the Council, Official Journal of the European Union, L 171/1, June 29, 2007, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:171:0001:0016:EN:PDF.

is preparing to add the WLTC for type-approval testing for new vehicles beginning around 2017. A shift to WLTC for certification of new vehicles would lead to improved compliance with diesel NO_x emission limits in the real world, although by reducing the importance of cold start emissions, a shift to the WLTC may also reduce the stringency of gasoline emissions limits. The European Commission also plans to implement Real Driving Emissions (RDE), a requirement that adds a road test to laboratory-based certification of vehicle engines, with the goal of further reducing the gap between certification and real-world emissions. This may go even further toward improving real-world compliance with emission standards. This is discussed further under "Real World Emissions" below.

DURABILITY AND IN-SERVICE EMISSIONS

In terms of in-service requirements under Euro 6, Regulation 715/2007 requires manufacturers to check in-service conformity for all vehicles it certifies to the Euro 6 emission standards for a period of up to five years or 100,000 km, whichever comes first. Durability testing of pollution control devices undertaken for type approval shall cover 160,000 km, the mileage over which these devices are expected to perform. The Euro 6 standards lower the thresholds for the provision of on-board diagnostic information for NO_x and PM emissions from diesel vehicles (strictly for compression ignition vehicles) by approximately 50% from Euro 5 standards.[6] This action increases the sensitivity of the OBD system to irregularities in the performance of emission control equipment, and requires higher quality engineering of system components by the manufacturer.

EMISSION-CONTROL STRATEGIES

The increasing stringency of the Euro standards has required the deployment of increasingly effective and sophisticated technologies for emission reduction in both gasoline and diesel vehicles. The evolution of such technologies for light-duty vehicles up to and including Euro 6 is the subject of a previous ICCT report: "Estimated Cost of Emission Reduction Technologies for LDVs."[7] The broad compliance approaches for light-duty Euro 5 and Euro 6 engines are given in Table 2 below.

For light-duty gasoline vehicles, the standards for Euro 6 are largely unchanged from Euro 5, with the exception of a new particle number standard for gasoline direct injection (GDI) vehicles, a standard that in Euro 5 applied only to diesel vehicles. As CO_2 standards continue to advance, GDI engine technology has matured and is increasingly deployed. Gasoline direct injection engines produce higher particle emissions than the older port fuel injection gasoline engines, hence the introduction of a PN limit to prevent an increase in particle emissions from the gasoline fleet. This new limit may require the use of particulate filters on GDI engines, in addition to improved fuel-injection techniques.

For diesel vehicles, a lower NO_x limit will require manufacturers to utilize new aftertreatment technologies, as well as exhaust gas recirculation (EGR)

6 Commission Regulation (EC) No. 692/2008, Official Journal of the European Union, L 199/1. July 28, 2008, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:199:0001:0136:EN:PDF.

7 Francisco Posada Sanchez, Anup Bandivadekar, and John German, "Estimated cost of emission reduction technologies for LDVs," June 11, 2012, The International Council on Clean Transportation, http://www.theicct.org/estimated-cost-emission-reduction-technologies-ldvs.

technology. Aftertreatment technologies, such as lean NO_x traps (LNT) or selective catalytic reduction (SCR), may be added alongside technologies already adopted to meet CO, HC, and PM limits, including diesel oxidation catalysts (DOC) and diesel particulate filters (DPF). The technologies necessary to meet Euro 6 NO_x limits should, in principle, counteract any increase in NO_2 emissions that would result from technologies that utilize NO_2 to oxidize particulate emissions. Since higher NO_x emissions can also result from engine calibrations designed to maximize fuel economy, new NO_x aftertreatment could allow such calibration without an increase in NO_x emissions.

Table 2. Compliance approaches for light-duty Euro 5 and 6 engines

	Euro 5	Euro 6
Gasoline	• Combustion improvements over Euro 4 • Faster oxygen sensors • Catalyst improvements-oxygen storage capacity and better coatings	• No changes required for port fuel-injected gasoline engines • Improvements to fuel injection timing or addition of a gasoline particle filter for gasoline direct injection (GDI) engines
Diesel	• Combustion improvements over Euro 4 • Variable fuel injection timing for DPF regeneration • DOC + DPF • Some engines use lean NO_x traps	• Increased fuel injection pressure • Smaller and medium-size engines (<2 liters) tend to use DOC+DPF and primarily LNT for NO_x control • Larger cars (>2L) use DOC+DPF+SCR • Some manufacturers offer EGR-only NO_x control (with no aftertreatment control), and DOC+DPF on medium and larger cars

REAL-WORLD EMISSIONS

Despite the increasing stringency of the European emission standards, serious shortcomings have emerged in the control of diesel NO_x emissions under real-world driving conditions. A series of studies, beginning in 2011, using portable emission measurement systems (PEMS) mounted onboard vehicles, as well as studies utilizing remote-sensing techniques, have quantified unexpectedly high real-world emissions of nitrogen oxides (NO_x) from European diesel passenger cars.[8] Furthermore, PEMS studies show insufficient additional reductions following the transition to Euro 6. A recent review by the ICCT summarized the results of real-world on-road

8 Martin Weiss, Pierre Bonnel, Rudolf Hummel, Urbano Manfredi, Rinaldo Colombo, Gaston Lanappe, Philippe Le Lijour, Mirco Sculati, "Analyzing on-road emissions of light-duty vehicles with Portable Emission Measurement Systems (PEMS)," European Commission, Joint Research Centre, http://ec.europa.eu/clima/policies/transport/vehicles/docs/2011_pems_jrc_62639_en.pdf2; Vicente Franco, Francisco Posada, John German, and Peter Mock, "Real-world exhaust emissions from modern diesel cars," Oct. 1, 2014, The International Council on Clean Transportation, http://www.theicct.org/real-world-exhaust-emissions-modern-diesel-cars; David Carslaw, Sean Beevers, Emily Westmoreland and Martin Williams, "Trends in NO_x and NO_2 emissions and ambient measurements in the UK," July 18, 2011, Department for Environment, Food & Rural Affairs (UK), https://uk-air.defra.gov.uk/assets/documents/reports/cat05/1108251149_110718_AQ0724_Final_report.pdf; David Carslaw and Glyn Rhys-Tyler, "New insights from comprehensive on-road measurements of NO_x, NO_2 and NH_3 from vehicle emission remote sensing in London, UK," *Atmospheric Environment* 81 (2013): 339/347, http://www.sciencedirect.com/science/article/pii/S1352231013007140.

measurements using PEMS in Europe and the United States on modern diesel cars.[9] The results (Figure 1) reflect a mean conformity factor of 7 for Euro 6 cars with a range from best to worst of between 1.0 and 25.4. These studies have shown that despite large reductions in the NO_x limit value for diesel vehicles throughout the European regulatory pathway, very little improvement in real-world NO_x emissions from diesel vehicles has occurred in Europe.

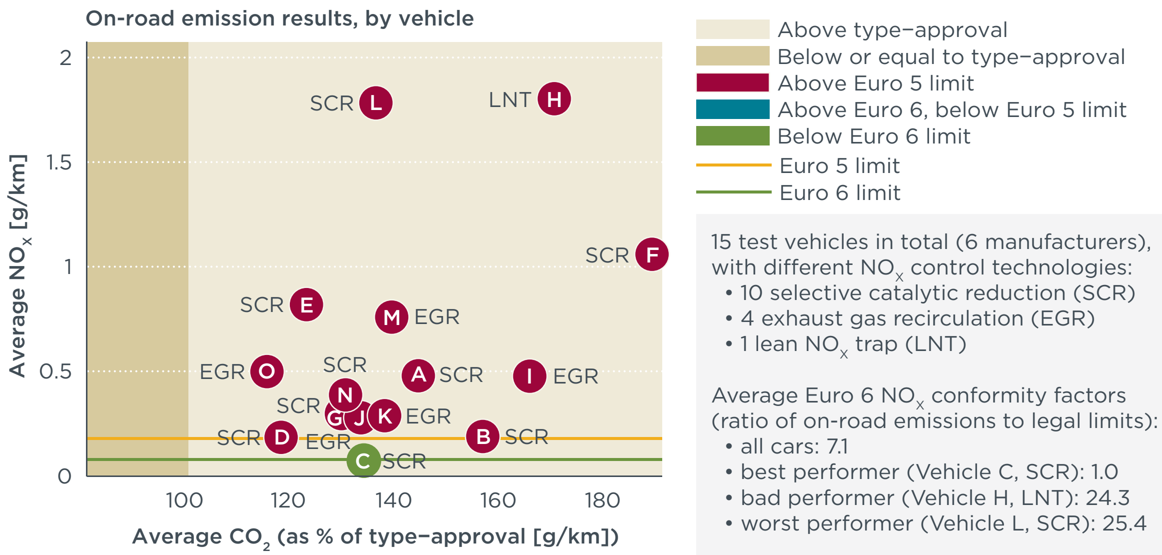

Figure 1. Overview of Euro 5 and Euro 6 diesel car PEMS emission measurements in Europe

The reason is that the NEDC test cycle used for type certification does not capture the full range of operating conditions of the engine map (that is, combinations of torque and engine speed) typical of real-world driving. Manufacturers are therefore able to design and meet these emission standards with vehicles that produce higher emissions in the real world. To ensure that Euro 6 diesel cars offer significant reductions over Euro 5 diesels, the European Commission has stated its intent to adopt regulations by 2017 setting out "not to exceed" limits in addition to the already agreed upon Euro 6 standards.[10]

The procedures for testing vehicles and the "not to exceed" limits are the subject of discussion within the European Commission, among E.U. Member States, and industry stakeholders. In May 2015, the European Union Technical Committee for Motor Vehicles (TCMV) voted in favor of a proposal to introduce a real driving emissions test procedure, which would come into force in September 2017. Tests are likely to be carried out using PEMS in real-world drives, although random drive cycles on a chassis dynamometer are a likely alternative for the measurement of particle number (PN) emissions. A large share of diesel cars will not meet the Euro 6 standards during the initial application period for real-drive testing, so in October 2015 this committee approved a second package of measures setting a "conformity factor" that defines

9 Vicente Franco, et al., "Real-world exhaust emissions from modern diesel cars," Oct. 1, 2014, The International Council on Clean Transportation, http://www.theicct.org/real-world-exhaust-emissions-modern-diesel-cars.

10 The Clean Air Policy Package, European Commission, Dec. 18, 2013, http://ec.europa.eu/environment/air/clean_air_policy.htm.

the ratio of a "not to exceed" limit to the original Euro 6 standards. This committee agreed that a conformity factor of 2.1 will apply to all new vehicle types beginning in September 2017, and extending to all vehicle types beginning in September 2019. The committee also agreed to lower the conformity factor to 1.5 beginning in January 2020 for all new vehicle types, extending to all vehicle types by January 2021. At the time of this writing, these conformity factors were awaiting final approval from the European Council. Conformity factors for PN will be determined at a later date.

THE EURO VI STANDARDS FOR HEAVY-DUTY VEHICLES

The Euro VI standards were originally set out in Regulation 595/2009 and its implementing Regulation 582/2011, with further amendments contained in Regulation 133/2014. The Euro VI emission limits went into effect in 2013 for new type approvals and in 2014 for all registrations.[11]

EMISSION LIMIT VALUES

Table 3, below, shows the emission limits for the Euro V and Euro VI standards. As with light-duty vehicles, the move from Euro V to Euro VI saw a large reduction in the NO_x emission limit, from 2.0 g/kWh to 0.4 g/kWh in steady-state testing, and from 2.0 g/kWh to 0.46 g/kWh in transient testing, or reductions of 80% and 77% respectively. The particle mass limit was also significantly tightened, cut in half from 0.02 g/kWh to 0.1 g/kWh on steady-state testing, and from 0.03 g/kWh to 0.01 g/kWh on transient testing, a reduction of 66%. The Euro VI standards include for the first time a particle number limit. The limit is 8×10^{11} particles per kilowatt-hour under the WHSC test, and 6×10^{11} under the WHTC test. The vehicle certification test cycle to meet the Euro VI standards is different from that used for Euro V, so the comparisons are only approximate. The test cycles are discussed further in the "testing" section below.

The Euro VI standards also set emission limits for ammonia since the tighter NO_x standard will require the use of Selective Catalytic Reduction aftertreatment, which in turn relies on the injection of urea into the exhaust stream. The catalytic reaction can produce ammonia as an unwanted by-product, hence the limits on ammonia emissions for heavy-duty diesel vehicles (gasoline vehicles, also called "positive ignition" vehicles, are exempt from the ammonia limit since urea is not used for NO_x control). The Euro VI standards include a methane emission limit for "positive-ignition" vehicles (i.e., not diesels, but specifically natural gas and liquefied petroleum gas engines) based on the emergence of natural gas-powered vehicles in the heavy-duty vehicle sector and the potential impacts of methane on tropospheric ozone.

11 The amending Regulation 133/2014 introduced later dates for compliance with a PN limit for Positive Ignition engines.

Table 3. The Euro V and Euro VI heavy-duty vehicle emission standards for diesel engines

	Euro V Heavy-Duty		Euro VI Heavy-Duty	
	Euro V SS[a]	Euro V T[b]	Euro VI SS[a]	Euro VI T[b]
Emission limits (g/km)				
CO	1.5	4.0	1.5	4.0
HC	0.46	0.55	0.13	0.16[d]
CH_4[c]		1.1		0.5
NO_x	2.0	2.0	0.4	0.46
PM	0.02	0.03	0.01	0.01
PN (#/km)			8.0×10^{11}	6.0×10^{11}
Smoke (1/m)	0.5			
Ammonia (ppm)[12]			0.01	0.01
Fuel Sulfur Limit (ppm)	10	10	10	10
Test Cycle	ESC & ELR	ETC	WHSC	WHTC

[a] Steady-state testing; [b] Transient testing; [c] For Euro V for Natural Gas only, for Euro VI, NG and LPG; [d] Total HC for diesel engines, non-methane HC for others

TESTING

Regulatory test cycles for heavy-duty engines have continuously improved over the European regulatory pathway for these vehicle types. At Euro I and II levels, the tests were carried out over the R-49 cycle, which was a steady-state cycle sampling thirteen points on the engine map (which reflects all potential combinations of torque and engine speed).

Under the Euro III standards established in 2000, the testing regime was somewhat complex. Heavy-duty engines were tested over three different cycles: the European Steady-State Cycle (ESC), the European Transient Cycle (ETC), and the European Load Response Cycle (ELR, which was instituted to measure smoke emissions). The ESC consists of a weighted sum of emissions over thirteen modes, or combinations of engine load and engine speed, run at steady state. The ETC cycle is based on real-world drives and made up of 3 sections representing, respectively, urban drives with many stops and starts and an average speed of ~50 kph, rural drives with an average speed of ~72 km/h, and motorway driving with an average speed of ~88 kph. For Euro III, ESC/ELR tests were used for conventional diesel engines, ESC/ELR plus ETC tests were used for diesel engines with advanced aftertreatment (NO_x aftertreatment or diesel particulate filters or DPFs), and finally an ETC test was used for positive-ignition engines using natural gas or LPG. For Euro IV and V, diesel engines were tested using the ESC/ELR test and positive-ignition engines were tested on the ETC.

In the Euro VI standards, these tests were replaced by the World Harmonized Stationary Cycle (WHSC) and the World Harmonized Transient Cycle (WHTC). These new cycles were agreed upon within the United Nations Economic Commission for Europe,[13] with

12 The emission limit for ammonia is expressed as a concentration rather than the usual g/kWh.

13 Despite the word “Europe” in the title, the UNECE negotiations cover Western, Central and Eastern Europe, Central Asia and North America.

the European emission limit values being established under both the World Harmonized Stationary Cycle (WHSC) and the World Harmonized Transient Cycle (WHTC).

For certification of heavy-duty vehicle emissions, engines are tested on a test bed and emissions are reported as g/kWh. The WHSC is a steady-state cycle also based on a weighted sum of emissions over thirteen modes, which are combinations of engine speed and load. The cycle is based on real-world drives in Europe, the United States, Japan, and Australia. It is a hot-start cycle following preconditioning at an engine speed of 55% and 50% load. The WHTC test is a transient engine test of 1800 seconds, with several motoring segments, originally developed by the UNECE Working Party on Pollution and Energy. It is based on the worldwide pattern of real-world heavy commercial vehicle use based on typical driving conditions found in Europe, the United States, Japan, and Australia.

DURABILITY AND IN-SERVICE EMISSIONS

To ensure the tailpipe emissions are effectively limited throughout the normal life of the vehicle, under normal conditions of use, tests to ensure the durability of pollution-control devices and in-service conformity should be carried out by manufacturers at the mileage and time periods shown below in Table 4:

Table 4. Durability testing criteria for heavy-duty vehicles

Category of vehicle	Minimum service accumulation period	Useful life (years)[14]
M_1, M_2, N_1	160,000	5
M_3 (=<7.5 tonnes), N_2, N_3 (=<16 tonnes)	188,000	6
N_3 (>16 tonnes), M_3 (>7.5 tonnes)	233,000	7

On-board diagnostic (OBD) requirements for Euro VI heavy-duty vehicles are now quite comprehensive[15] (see EC Regulation 582/2011) and requirements have been strengthened compared with previous regulations. New requirements under the Euro VI standards involve monitoring the DPF (diesel particulate filter) substrate and system, the SCR system including the reagent, lean NO_x trap system capability and reagent, the oxidation catalyst hydrocarbon conversion efficiency, EGR (exhaust gas recirculation) flow and performance, fuel injection systems, and turbocharging systems. In addition, more stringent OBD threshold limits based on the WHTC have been set in Euro VI for PM and NO_x, which are lowered 75% and 82% respectively. A detailed discussion of OBD requirements in the EU and the rest of the world can be found in a recent ICCT report.[16]

14 Regulation (EC) No. 595/2009 of the European Parliament and of the Council, Official Journal of the European Union, L 188/1, July 18, 2009, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:188:0001:0013:EN:PDF.

15 Commission Regulation (EU) No. 582/2011, Official Journal of the European Union, L 167/1, June 25, 2011, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:167:0001:0168:en:PDF.

16 Francisco Posada and Anup Bandivadekar, “Global overview of on-board diagnostic (OBD) systems for heavy-duty vehicles,” The International Council on Clean Transportation, Feb. 9, 2015, http://theicct.org/global-overview-board-diagnostic-obd-systems-heavy-duty-vehicles.

EMISSION-CONTROL STRATEGIES

Euro VI standards have been met by manufacturers through a combination of DPF and SCR technologies, in addition to DOCs, EGR and other advanced engine technologies. The move to a combination of DPF and SCR technologies requires a switch from Vanadium to Zeolite catalysts for the SCR systems. The end result of this technology change and the improved test cycle is that real-world NO_x emissions much more closely match the emissions limits than was the case with previous standards, especially at low vehicle speeds and cold start conditions.

Euro VI standards also require OBD systems to measure performance of emission-control systems in use and to provide early identification of any system failures. These systems operate in addition to the driver inducements for use of urea additives that are necessary for the proper operation of SCR systems required in Euro V.

The voluntary EEV (enhanced environmentally friendly vehicle) standard was first introduced in 1999. The EEV standard is slightly lower for PM and CO emissions limits over the transient test cycle, but does not require any additional vehicle or aftertreatment technologies compared to Euro V.

Table 5. Compliance approaches for heavy-duty Euro V and Euro VI engines

Euro V	Euro VI
• High fuel injection pressure • Variable fuel injection timing and quantity • Redesigns to combustion chamber • NO_x controlled mainly by SCR-Vanadium based systems • EGR offered by few manufacturers and mainly for small trucks	• DPFs required for Euro VI compliance with PM and PN standards • SCR catalyst changes from Vanadium to Zeolite • EGR no longer offered

REAL-WORLD EMISSIONS

Heavy-duty vehicles have historically not achieved the real-world NO_x emissions expected under Euro V and previous standards. In-service emissions for heavy-duty vehicles were initially addressed in Regulation 595/2009, and subsequently adopted in Regulation 582/2011. The Euro VI regulation set out the requirements for checking and demonstrating the conformity of in-service engines and vehicles using PEMS. Additional measures, such as the shift to world harmonized test cycles for stationary and transient testing, and the inclusion of cold-start testing, have greatly improved the certification test and its ability to guarantee real-world achievement of the Euro VI emission limits.

Data is now available to show whether these measures correct the NO_x emissions problems of the previous standards. The evidence thus far shows that NO_x emissions of Euro VI heavy-duty engines indeed are achieving the real-world performance not met under previous standards, even under the most difficult operating conditions.[17]

17 "Comparison of real-world off-cycle NO_x emissions control in Euro IV, V, and VI," The International Council on Clean Transportation, March 2015, http://www.theicct.org/sites/default/files/publications/ICCT_Briefing_EuroIV-V-VI-NOx_Mar2015.pdf.

Measures taken to achieve this level of performance include more efficient catalyst formulations, better thermal management of the catalyst, improved urea dosing strategies, and other aftertreatment optimizations. As a result, Euro VI standards are likely achieving a much greater reduction in NO_x emissions than the emission limits alone would indicate. Countries considering whether to tighten their heavy-duty vehicle emission standards from Euro III or Euro IV would be well advised to leapfrog to Euro VI for maximum real-world emissions benefits.

CONCLUSION

The Euro 6/VI emission standards for light- and heavy-duty vehicles require the greatest emission reductions of any previous stage along the European regulatory pathway. The light-duty Euro 6 standards include more stringent NO_x limits for diesel passenger cars, as well as a new particle number limit for gasoline direct injection engines. The heavy-duty Euro VI standards address high real-world NO_x and PM emissions from diesel trucks with changes to the heavy-duty vehicle test procedure in favor of the World Harmonized Transient Cycle, a new particle number limit, and stronger OBD requirements.

These changes with the Euro 6/VI standards will lead to further advances in the full suite of vehicle engine and aftertreatment design. For light-duty gasoline vehicles, the standards will lead to improvements in fuel injection timing and, for some vehicles, the installation of a gasoline particulate filter. Diesel passenger cars can expect to see an increase in injection pressure combined with an aftertreatment emissions control package that includes a diesel oxidation catalyst, a diesel particulate filter, and either a lean NO_x trap or a selective catalystic reduction. Heavy-duty diesel vehicles can expect to shift from vanadium- to zeolite-based SCR catalysts and to use a diesel particulate filter.

A further step remains on the European pathway for light-duty Euro 6 vehicles: adoption of PEMS and conformity factors under real-drive testing to further address NO_x from diesel engines, as well as a shift to the Worldwide Harmonized Light Vehicles Test Procedure (WLTP). These additional measures will lead to greater conformity with emission standards under real-world conditions.

Ensuring that Euro 6/VI vehicles meet the pollutant emissions limits set by the standards in actual real-world use is important to the achievement of health-related ambient air-quality standards, particularly for ambient particulate matter and nitrogen dioxide. Similarly, there are lessons to be learned in this context for those countries in the rest of the world implementing the European standards framework.