RDE EVOLUTION IN BRAZIL: FIRST STEPS, ADVANCES AND CHALLENGES

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ABSTRACT

RDE regulation in Brazil is based on European RDE, however an intensive work has been developed to adapt the procedure to some specific Brazilian characteristics, such as: LDV are high VOC emitters, complexity of flexfuel technology to meet regulated emissions, topography with many hills, main cities with altitude close to 1,000 m and type approval laboratory procedure based on US EPA driving cycle FTP-75.

The goal of this paper is to share achievements, advances and future challenges regarding the Brazilian RDE procedure. Some points have already been changed, such as priority for metropolitan pollution control, CO_2 reference points and some parameters such as altitude and temperature. Concerns about RDE Brazil are arising, related to emissions from cold start at low temperatures, dynamic CO_2 criteria, hydrocarbon emission when driving at high road slope and parameters for hybrid electric vehicles.

INTRODUCTION

When Europe defined Regulation 715/2007 [1], brought new type-approval emission standards for Light Duty Vehicles (LDV) and Light Commercial Vehicles (LCV), called Euro 5 and Euro 6. This regulation also points to the need for revision of the laboratory test procedure, called New European Drive Cycle (NEDC), to one closer to actual traffic conditions, which resulted in the Worldwide harmonized Light vehicles Test Procedure (WLTP). Another important issue assigned in this regulation was the need of ensuring that real world emissions correspond to the measurements in laboratory, recommending the use of Portable Emissions Measurement Systems (PEMS) and the introduction of a specific procedure.

Under this directive, Europe developed the Real Driving Emissions (RDE) test procedure for type-approval and in-service conformity. RDE is based on testing the vehicles on streets and roads, subjecting them to “real world” conditions, such as traffic conditions, variable topography and larger temperature range than in laboratory, among others parameters. Thus, RDE in Europe is described by Regulation 2016/427, named “Pack 1” [2] and was complemented by Regulations 2016/646 (Pack 2) [3], 2017/1154 (Pack 3) [4] and 2018/1832 (Pack 4) [5]. They define the steps to prepare and execute the RDE test, limits to ambient conditions as temperature and altitude, required instruments, calculation methods, criteria for evaluate the dynamics and emissions limits to NOx and particulate number (PN). In RDE Europe CO_2 and CO are measured and reported but they are not regulated.

RDE is adopted or is being implemented by many countries such as South Korea, China, Japan, India, USA and Brazil, for type-approval or for defeat device chasing [6]. The RDE Europe is the basis for the global RDE, although in many countries is made some adjustments are made to the procedure and parameters, according to the local needs. The United Nations Economic Commission for Europe (UNECE) is driving an important effort to define this global RDE procedure, called United Nations Regulation for RDE (UNR RDE), under final review since March/2020 [7].

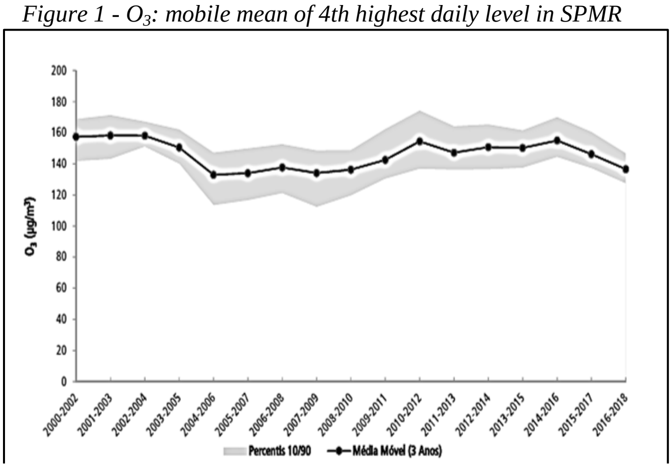
The Brazilian regulation for vehicle emissions is defined by a federal program called PROCONVE (Programa de Controle da Poluição do Ar por Veículos Automotores), which started in 1986 and is now in Phase L6 for LDV/LCV [8]. RDE is going to start in the next stages, Phase L7 (monitoring) and L8 (type-approval); they will enter in force at Jan/2022 and Jan/2025 respectively [9]. Like what happened in other countries, RDE procedure must be adapted to the typical Brazilian characteristics, in order to be closer to “real world” and effectively control vehicle’s emissions.

BRAZILIAN CHARACTERISTICS

AIR POLLUTION IN METROPOLITAN AREAS – According to WHO [10], the main pollutants in urban areas are particulate matter of less than 10 micron (PM10) and 2.5 micron (PM2.5) in diameter and ozone (O_3). Vehicles play a significant role as source of PM10 and PM2.5, as well as precursors to O_3 such as nitrogen oxides (NOx), carbon monoxide (CO), hydrocarbons (HC) and volatile organic compounds (VOC).

These characteristics can be found also in Brazilian cities. For example, in the Sao Paulo Metropolitan Region (SPMR), during the year of 2018, O_3 limit of 140 μg/m^3 x 8 h-mean was exceeded in 18 days and PM2.5 limit of 60 μg/m^3 x 24 hour-mean in 12 days [11]. It is important to note that these standards are higher than WHO recommendations for O_3 of 100 μg/m3 x 8 h-mean and PM2.5 of 25 μg/m3 x 24 h-mean [12]. Another point to be considered is that O_3 level in SPMR remains high over the years, as shown in Figure 1.

Figure 1 - O_3: mobile mean of 4th highest daily level in SPMR

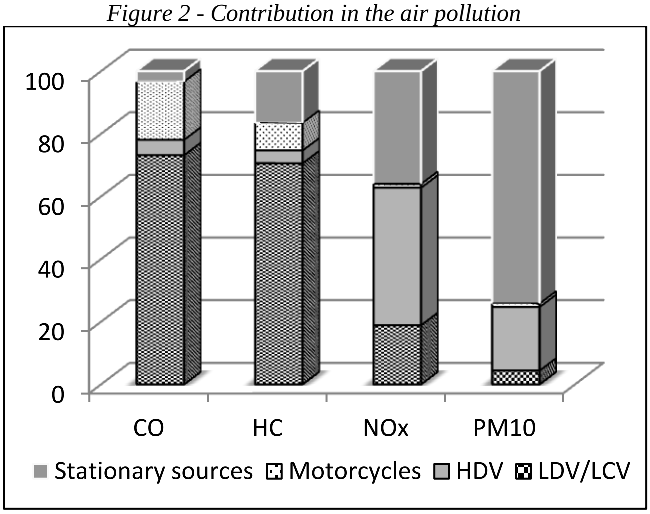


Source: CETESB [11]

LDV/LCV EMISSIONS – The Brazilian vehicle fleet has about 65.8 million units, of which 41.2 million LDV (62.7%), 7 million LCV (10.7%), 2.4 million HDV (3.6%) and 15.1 million motorcycles (23%) [13]. 96.5% of LDV/LCV in SPMR have spark ignition engines; they can burn gasoline with 22 to 27% ethanol or 100% ethanol and, for flexfuel vehicles, they can burn both fuels in any proportion [11]. Diesel engines are allowed just for some LCV due to legal restrictions, because Diesel has lower taxes than gasoline and ethanol in order to reduce the freight prices.

LDV/LCV are high CO and HC emitters, on the other hand, NOx emissions come mainly from HDV and stationary sources such as industries. The Companhia Ambiental do Estado de Sao Paulo (Environmental Company of Sao Paulo State – CETESB) shows that LDV/LCV are responsible for 73.2% of CO emissions and 70.6% of HC emissions in the SPMR [11], as shown in Figure 2.

Figure 2 - Contribution in the air pollution



Source: CETESB, adapted [11]

FLEXFUEL TECHNOLOGY – Ethanol as vehicular biofuel has been available in Brazil since the late 1970s and flexfuel vehicles have been sold since 2003 [14], offering the possibility of choosing the fuel to burn in the vehicle, which is an interesting alternative for deal with the fluctuation of gasoline and ethanol prices.

This technology is based on a wide-band oxygen sensor, able of identifying the fuel or the proportion of both fuels being burned through the air-fuel ratio and making the appropriate adjustments [14] [15]. Ethanol has a lower vapor pressure than gasoline, so special care must be taken at cold start, as in flexfuel engines it is necessary to balance some characteristics for both fuels, such as the compression ratio. In the early years of the development of flexfuel technology, compression ratio used to be closer to ideal gasoline ratio; now it is higher, close to ideal ethanol ratio although with a risk of pre-ignition [14]. Thus, the flexfuel engine is more complex to develop and needs more engineering efforts to achieve an ECU calibration that meets the requirements of regulatory emissions and drivability.

AMBIENT CONDITIONS – Brazilian topography is characterized by large cities such as Sao Paulo, Belo Horizonte, Curitiba and Brasilia with an altitude close to or higher than 1,000 meters above sea level [16]. About

90% of the streets and roads have a slope of up to 2.5% that represents a cumulative positive altitude gain of 1,200 m / 100 km [17].

The climate varies widely from equatorial in the North and semiarid in the Northeast, with maximum temperatures around 30-36ºC in the summer, to temperate in South and Southeast, with minimum temperature around 8-12ºC in the winter with occasional events of negative temperatures of down to -5ºC [18].

LABORATORY TEST PROCEDURE – The standard laboratory test procedure adopted in Brazil, normative ABNT NBR 6601 [19], is based on US-EPA procedure FTP-75 [20]. This becomes relevant when takes into account that RDE Europe is based on many parameters from WLTP cycle, such as CO_2 emissions, typical acceleration and average speeds for urban, rural and motorway trips to assess driving dynamics. In fact, during the development of the UN RDE, it was a point of discussion by American representatives, on how to apply FTP-75 parameters in the evaluation of the RDE test [21].

ACHIEVEMENTS

In order to face the challenge of adapting RDE Europe to the Brazilian needs, a workgroup has been organized since January/2019, composed of representatives of vehicles manufacturers, engineer consultants and technical representatives of Federal Environment Ministry, such as CETESB. This workgroup, along many meetings and studies, have built an agreement around many significant points, as summarized in Table 1. The Brazilian RDE procedure is not yet finalized at this time (Nov/2020) because some points are in discussion and require further testing.

Table 1 - Comparison between RDE Europe and Brazil

PARAMETER	RDE Europe	RDE Brazil
Altitude (moderate)	0-700 m	0-1,000 m
Altitude (extended)	700-1,300 m	1,000-1,300 m
Cumulated positive altitude gain	0-1,200 m / 100 km – usually far from the limit	0-1,200 m / 100 km – usually close to the limit
Ambient temperature (moderate)	0-30ºC	15-35ºC
Ambient temperature (extended)	-7 to 0ºC and 30 to 35ºC	10 to 15ºC and 35 to 40ºC
Trip share	Urban 29-44% Rural 29-43% Motorway 29-43%	Urban 55-75% Rural 25-45% No motorway
Trip duration	90-120 minutes	60-120 minutes
Reference speeds	Mean speeds from WLTP phases 1 (P1), 2 (P2) and 4 (P3)	Mean speeds from FTP-75 phases 2 (P1) and 3 (P2), P3: 90 km/h
CO_2 reference points	WLTP CO_2 phases 1 (P1), 2 (P2) and 4 (P3)	FTP-75 phases 2 (P1) and 3 (P2 and P3)
CO_2 reference mass	WTLP CO_2 mass x 0.5	FTP-75 phases 2 and 3 mass
Fuel	Commercial: Gasoline E10, Ethanol E85, Diesel B7	Reference: Gasoline E22, Ethanol E100, Diesel B7
Pollutants evaluated	NOx, PN; CO and CO_2 only reported	CO, NMOG, NOx, CO_2 (for efficiency)

Source: Workgroup RDE Brazil [17]

It is relevant to highlight here the issue of Non-methane Organic Gases (NMOG), because the Brazilian Regulation RC 492/2018 [9] determines limits to emission of NMOG + NOx instead of THC or NMHC. NMOG is defined as the emission of hydrocarbons except methane (NMHC) plus some species of oxygenate hydrocarbons (OHC): ethanol, formaldehyde and acetaldehyde [22], however PEMS measures only total hydrocarbons (THC) with a Flame Ionization Detector (FID) analyzer what is not able to control NMOG. Thus, the solution found is to apply the NMOG/THC ratio, or alternatively the NMOG/NMHC ratio, found in the laboratory test over the PEMS measurement, as shown in Equation 1.

Equation 1 - Calculation of NMOG RDE

$$NMOG$$

Alternatively:

Source: Workgroup RDE Brazil [17]

CONCERNS

The theoretical basis of RDE Brazil is becoming clear to the workgroup throughout the meetings, however some problems and concerns are coming to light in the sequence when the first tests are been carried out.

COLD START ETHANOL EMISSION – Due to the lower ethanol vapor pressure than gasoline, THC emission in the exhaust gas can reach values of around 30,000 ppm in the first minutes when the engine is cold and the ambient temperature is below 20°C, worsening the lower the temperature; after the catalyst turns on, THC usually do not exceed 1,000 ppm [17]. There are some technologies available that can be applied to reduce THC emission in cold start, for example, heated fuel injectors and pre-heated catalyst but the overall impact and how much engineering development will be required it is not clear for now.

CO_2 DYNAMIC CRITERIA – The CO_2 criteria allows assessing how aggressive the driver drove the vehicle, by comparing the CO_2 emitted during RDE with the CO_2 emitted in the laboratory test. The RDE criterion is that the vehicle is allowed to produce up to +45% (urban) and +40% (rural) and -25% (urban and rural) CO_2 than in the laboratory. The concern about CO_2 criteria is that sometimes these tolerances could be exceeded when the vehicle is driven on a road slope close to the limit of 1,200 m / 100 km of positive cumulative altitude gain [17]. Up to this time, there is a consensus to increase the reference value of specific CO2 emission for urban trip around + 20% to +25%.

THC and CO EMISSION – To avoid pre-ignition in flexfuel engines under certain conditions such as positive altitude gain close to 1,200 m / 100 km and ambient temperature about 30ºC and above, the vehicle's ECU usually reacts by enriching the air-fuel mixture and delaying the spark point but these strategies tend to raise THC and CO levels [15], although it is not yet clear how much this will impact the overall emissions.

CO_2 REFERENCE POINTS FOR HYBRID ELECTRIC VEHICLES (HEV)– the laboratory test performed to evaluate HEV must follows the Brazilian normative ABNT NBR 16567 [9] [23] instead ABNT NBR 6601. The driving cycle is similar, based on FTP-75, but with one more phase to meet the battery charge requirements. So, for collect the exhaust gas, depending on the design of the bench, the samples from phases 1 and 2 are joined in just one bag and 3 and 4 in another, making it impossible to determine separately the CO_2 mass and the specific CO_2 emission from phases 2 and 3, as proposed by RDE Brazil. The workgroup still has some ideas under discussion, e.g. to carry out one additional laboratory test with only three phases, like FTP-75, after the type-approval tests, just to get the required data [17].

PEMS OVERHEATING – Some PEMS components are sensitive to ambient temperature close to 40ºC, requiring special care when installing in the vehicle. Probably the expertise of PEMS manufacturers in India and China should be put into practice in Brazil to avoid problems during tests at high temperatures [17].

CONCLUSIONS

The general task of adapting the RDE procedure to Brazilian conditions is almost complete, surely some adjustments and improvements will occur in the near future but the expectation of measuring vehicle emissions in the real world is being more feasible.

Other improvements from PROCONVE L7 and L8, such as Onboard Refueling Vapor Recovery system (ORVR), 48 h evaporative test, NMOG control instead of NMHC are also very important and will help to reduce hydrocarbon emissions and all coordinate efforts and improvements in LDV/LCV emissions will certainly be reflected in better air quality in the Brazilian cities.

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