Submitted by the IWG on WLTP

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Proposal for a technical report on the development of a new global technical regulation on Evaporative emission test procedure for the Worldwide harmonized Light vehicles Test Procedure (WLTP EVAP)

Technical Report on the development of a new global technical regulation on Evaporative emission test procedure for the Worldwide harmonized Light vehicles Test Procedure (WLTP EVAP)

I. Introduction

1. Compliance with emission standards is a central issue of vehicle certification worldwide. Emissions comprise criteria pollutants having a direct (mainly local) negative impact on health and environment, as well as pollutants having a negative environmental impact on a global scale. Regulatory emission standards typically are complex documents, describing measurement procedures under a variety of well-defined conditions, setting limit values for emissions, but also defining other elements such as durability and on-board monitoring of emission control devices.

2. Most manufacturers produce vehicles for a global clientele or at least for several regions. Albeit vehicles are not identical worldwide since vehicle types and models tend to cater to local tastes and living conditions, the compliance with different emission standards in each region creates high burdens from an administrative and vehicle design point of view. Vehicle manufacturers, therefore, have a strong interest in harmonizing vehicle emission test procedures and performance requirements as much as possible on a global scale. Regulators also have an interest in global harmonization since it offers more efficient development and adaptation to technical progress, potential collaboration at market surveillance and facilitates the exchange of information between authorities.

3. The development of WLTP is being carried out under a program launched by the World Forum for the Harmonization of Vehicle Regulations (WP.29) of the United Nations Economic Commission for Europe (UNECE) through the working party on pollution and energy (GRPE). The aim of this project is to develop a World-wide harmonized Light duty Test Procedure (WLTP). A roadmap for the development of a UN Global Technical Regulation (UN GTR) was first presented in August 2009.1

5. In a first phase (WLTP Phase 1) the objective was to develop a harmonized test procedure covering the measurement of exhaust emissions after a cold start (Type I test).

6. The informal group of WLTP started in 2009. The original schedule and scope were described in ECE/TRANS/WP.29/AC.3/26 and AC.3/26 add.1. The informal group of WLTP submitted a GTR text of WLTP and it was adopted as GTR (No.15 of the Global registry) in November 2013.

7. In the second phase (WLTP Phase 2) the objective is to develop harmonized test procedures covering other test types. A starting note on WLTP Phase 2 was first presented at GRPE Session No. 70 in January 2015.

8. A draft proposal for a WP.29/AC.3 mandate was submitted by Technical GTR Sponsors to GRPE Session No. 71 (GRPE-71-27).in June 2015 and later approved by WP29 (WP.29-167-29).

9. The work of the group on WLTP Phase 2 should be completed by end of 2018.

10. Among the several working items to be addressed in the WLTP Phase 2, it was proposed to complete the development of a harmonized test procedure for evaporative emissions within 2016 and to present a GTR proposal in January 2017 as a separate GTR from GTR15.

[1] See document ECE/TRANS/WP.29/2009/131 at http://www.unece.org/fileadmin/DAM/trans/doc/2009/wp29/ECE-TRANS-WP29-2009-131e.pdf

11. It should be noted that since the beginning of the WLTP process, the European Union had a strong political objective set by its own legislation (Regulations (EC) 715/2007 and 692/2008) and communications (Communication on the application and future development of Community legislation concerning vehicle emissions from light-duty vehicles and access to repair and maintenance information (Euro 5 and 6) - (2008/C 182/08)) to review the test procedure for evaporative emissions to ensure that:

(a) Evaporative emissions are effectively limited throughout the normal life of the vehicles under normal conditions of use,

(b) Due to the expected wider introduction of biofuels, the effects of long term use of fuels containing ethanol on evaporative emissions are duly controlled.

13. Japan also had a strong desire to complete the development within 2016, because they were in the process of revising their evaporative emission procedure.

II. Objective of WLTP

14. The primary objective of the global technical regulation (GTR) developed in the WLTP process is to form the basis for the emission regulation of light-duty vehicles within regional type approval and certification procedures, as well as an objective and comparable source of information to consumers on expected fuel/energy consumption and electric range, if applicable. Each of the Contracting Parties to the 1998 Agreement could then transpose this new standard into their own legislative framework.

15. As a result of this overarching objective, the work on WLTP aimed to develop a test procedure that would fulfil the following basic demands:

(a) The test procedure should be globally harmonized and applicable, and
(b) The results should be representative for average real-world vehicle performance in terms of emissions, fuel and/or energy consumption.

16. One of the essential elements to be addressed within the mandate for WLTP is the evaporative emission test procedure.

17. Evaporative emissions from vehicles is a complex phenomenon involving different sources and depending on multiple factors. Among these, the fleet composition and the typical ambient temperatures differ strongly from region to region. As a consequence, in some cases different solutions have been implemented at regional level to control certain evaporative emissions sources such as, for instance, refuelling emissions or potential leaks. For this reason aiming at a fully harmonized test procedure for all evaporative emissions was considered unrealistic and therefore it was decided to focus only on those elements of the procedure that can be more easily harmonized.

III. Organisation, structure of the project and contributions of the different subgroups to the UN GTR

A. WLTP Informal Working Group (WLTP-IWG)

18. In its November 2007 session, WP.29 decided to set up an informal WLTP working group under GRPE to prepare a road map for the development of the WLTP[2]. After various meetings and intense discussions, WLTP informal working group presented a first road map in June 2009 consisting of 3 phases. This initial roadmap was subsequently revised a number of times, and consists of the following main tasks:

(a) Phase 1a (2009 - 2013): development of the worldwide harmonized light duty driving cycle and the basic emission test procedure (Type I test). This led to the first version of GTR15, which was published as an official working document ECE/TRANS/WP.29/GRPE/2013/13 and a series of amendments published as informal document GRPE-67-04-Rev.1;

(b) Phase 1b (2013-2016): further development and refinement of the Type I test procedure, while including additional items into the GTR15. This led to the second version of this GTR15, which was published as official working document ECE/TRANS/WP.29/GRPE/2016/03.

(c) Phase 2 (2016 - 2019): low temperature/high altitude test procedure, durability, in-service conformity, technical requirements for on-board diagnostics (OBD), mobile air-conditioning (MAC) system energy efficiency, evaporative emissions;

(d) Phase 3 (2019 - …): emission limit values and OBD threshold limits, definition of reference fuels, comparison with regional requirements.

19. The test procedure for evaporative emissions was developed in 2016 as Phase 2 activity of WLTP-IG.

B. WLTP EVAP Task Force (WLTP-EVAP)

20. In its January 2016 session, WLTP informal working group decided to set up an EVAP task force to develop the harmonized evaporative emissions test procedure. At the first task force meeting, the following objectives were agreed upon:

(a) To establish the harmonized evaporative emissions test procedure (avoiding Contracting Party's option as much as possible.)

(b) The test result could be used for mutual recognition.

(c) Adoption of GTR at GRPE Session No. 74 in January 2017.

21. To achieve these objectives, the discussion points shown below were identified and discussed over seven task force meetings held in 2016. In the October 2016 WLTP meeting, the WLTP informal group adopted the Evaporative Emission GTR proposed by EVAP task force.

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[2] The UNECE World Forum for Harmonization of Vehicle Regulations (WP.29) is a worldwide regulatory forum within the institutional framework of the UNECE Inland Transport Committee. For more information refer to the UNECE website: http://www.unece.org/trans/main/wp29/introduction.html

Table 1
Major discussion points of WLTP EVAP task force

E#	Discussion Points	conclusion
E#1	Test Fuel	Test fuel for mutual recognition in addition to regional fuel
E#2	Equipment	Higher accuracy requirement, some error correction on R83.
E#3	Purge cycle	Low – medium – high – medium for class 2 and 3 vehicles Low – medium – low x 2 times for class 1
E#4	Fuel fill level	40%
E#5	Canister stabilization	Alternative canister stabilization was not included. Could be phase2b issue.
E#6	Permeability Factor	Assigned PF = 120 mg /24 hours for multi layer tank.
E#7 E#11	Test Result Regulation limit	CP option $M_{HS} + M_{D1} + M_{D2} + 2PF \leq 2.0$ g/test or $M_{HS} + M_{D\_max} + PF \leq$ limit value determined by CP
E#8	Baking	HC source from non fuel system may be removed.
E#9	Sealed fuel tank	Phase2b issue.
E#10	Evap family	Family criteria added
E#12	Temperature profile	No change from UNR83
E#13	Test vehicle	the largest ratio of fuel tank capacity to canister butane working capacity within the family to be tested
E#14	Test for OVC-HEV	Phase2b issue.

WLTP EVAP Task force Chairs

Takashi Fujiwara(Japan), Panagiota Dilara (European Commission)

C. Drafting GTR

Serge Dubuc – on behalf of the European Commission

22. The same Drafting Coordinator (DC) for GTR15 joined the WLTP EVAP task force. The main objective of the DC would be to coordinate all drafting activities into a logically structured and technically, legislatively and grammatically robust technical regulation.

23. The final GTR version at the end of Phase 2a was uploaded to the UNECE website as formal document ECE-TRANS-WP29-GRPE-2017-07e.

IV. Test procedure development

A. General Purpose and Requirements

24. Evaporative emissions from a vehicle can be defined, in a very generic way, as Volatile Organic Compounds (VOCs) emitted by the vehicle itself in different operating conditions but not directly deriving from the combustion process. In petrol vehicles, the most important potential source of evaporative emissions is the loss of fuel through evaporation

and permeation mechanisms from the fuel storing system. Fuel-related evaporative emissions may occur during any vehicle operation including parking events, normal driving and vehicle refuelling.

25. VOCs may also be emitted by specific components of the vehicle like tyres, interior trim or by other fluids (e.g. windshield washer fluid). These emissions are usually quite low and do not depend on how the vehicle is used and on the quality of the fuel. Evaporative emissions in general do not represent a significant problem for diesel vehicles due to the very low vapour pressure of the diesel fuel.

26. During parking events, an increase of the temperature of the fuel in the tank due to rising ambient temperature and solar radiation may lead to the evaporation of the lightest petrol fractions with a corresponding increase of the pressure inside the tank. The fuel tank, by design, is usually vented to the atmosphere through a pressure relief valve, so that the tank pressure is maintained slightly above atmospheric. If the pressure inside the tank rises above that value, a mixture of air and petrol vapours may be released into the air. In modern vehicles, the tank is vented through an activated carbon canister which adsorbs and stores the hydrocarbons preventing emissions to the air. This carbon canister has a limited adsorbing capacity (depending on several factors of which the most important are the carbon quality and mass as well as the temperature) and must be periodically purged to desorb the stored hydrocarbons. This occurs during vehicle driving since part of the combustion air flows through the canister removing the adsorbed hydrocarbons which are then burned inside the engine.

27. During normal vehicle driving conditions, in addition to the ambient air and solar radiation, the temperature of the fuel in the tank may increase as a consequence of the heat coming from other sources (hot engine and exhaust system, fuel pump, fuel return if present, road surface that may be significantly hotter than the ambient air). The fuel evaporation rate, the amount of fuel being pumped to the engine and the purge flow rate through the canister will determine the carbon canister loading which could lead to excessive emissions in case of breakthrough/saturation. These emissions are known as running losses.

28. Hydrocarbons also escapes the vehicle’s fuel system by permeation through the plastic and rubber components; e.g., hoses, seals, and in vehicles with a non-metallic tank, the fuel tank itself. Permeation does not occur through an opening; instead individual fuel molecules penetrate (i.e. they effectively mix with) the walls of the various components and eventually find their way to the outside. Fuel permeation is significant mainly for plastic or elastomeric materials, depending strongly on the temperature and usually occurs in any vehicle operating conditions.

29. Another important source of evaporative emissions is the refuelling operation. When liquid fuel is delivered into the tank, the air/petrol vapour mixture present in the tank is displaced and may be released into the air. Refuelling emissions are partially controlled through the maximum allowed fuel vapour pressure by reducing its value during the hot season. In addition, evaporative emissions during the refuelling operation can be controlled in two different ways. One method is the so-called “Stage II” vapour recovery system. The fuel nozzle is designed to draw the air/petrol vapour mixture displaced by the liquid fuel entering the tank and to route it to the underground petrol storage tank of the service station. An alternative method is an “On-board Vapour Recovery System” (ORVR), which consists in specific design of the fuel system which forces the displaced vapours to be routed to the carbon canister instead of escaping from the refuelling port.

30. An unintended source of HC emissions may occur from leaks in the fuel system. Leaks may occur in the vapour and/or the liquid part of the fuel system as a result of deterioration and/or faulty operation. Examples of deterioration are corrosion of metallic components (e.g., fuel lines, tanks), cracking of rubber hoses, hardening of seals, mechanical failures. On-board diagnostic systems have been developed to check the integrity of the vapour part of the fuel system and the proper functioning of specific components (e.g. purge valve) and are required in some regions.

31. In the existing regional type approval procedures, the various situations that can lead to significant evaporative emissions have been addressed either by developing different tests

or by adopting different measures. As an example, in certain regions refuelling emissions are controlled by mandating the use of the Stage II vapour recovery system while in other regions the ORVR approach has been chosen.

32. The need to represent real driving conditions as much as possible to make the performance of vehicles at certification and in real life comparable therefore puts some limitations on the level of harmonization to be achieved since, for instance, ambient temperatures vary widely on a global scale while other potential sources of evaporative emissions are addressed in different ways across the regions (e.g. refuelling emissions or potential leaks).

33. At the same time, striving for the most representative test conditions might conflict with other important test aspects. There are a number of constraints that need to be observed for the development of the test procedure, such as:

(a)Repeatability
If the test is repeated under the same conditions and in the same laboratory, the test result should be similar (within a certain tolerance for accuracy). This means that for example all conditions at the start of the test (such as the pre-conditioning procedure or the test fuel quality) should be well-defined. If it is difficult to control or measure a vehicle parameter, it will be necessary to fix the start condition at a worst- or best-case value while in real world conditions this parameter may always be somewhere in between. Some of the 'representativeness' of the test is then sacrificed to obtain the goal of repeatability.

(b)Reproducibility
If the test is repeated under the same conditions in a *different* laboratory, the test result should be similar (within a certain tolerance for accuracy). If results from all labs over the world have to be the comparable, this sets restrictions to the test conditions and the use of cutting-edge measurement instruments. For instance, the temperature profile to be used in the diurnal test cannot be adjusted to the typical average hot season temperatures of each country.

(c)Cost-efficiency
A test procedure covering the worst case for all the potential sources of evaporative emissions may increase the complexity and the duration of the test or even require additional testing. The costs of a higher test burden will eventually be charged to the consumers, so there is a need to strike a balance between test effort and quality of the results. Additional testing or more complex test procedures can only be justified if the expected benefits in terms of emission reduction outweigh the extra testing costs. Therefore, some of the 'representativeness' of the test is compromised to reduce the test burden. For example, the length of the diurnal test is 48 hours, which of course does not cover longer parking events which may be common in real world but definitely much less frequent.

(d)Practicability
A test procedure needs to be executable in a practical way, without requiring unrealistic efforts from the testing personnel and/or the test equipment. That would be the case, for instance, if the permeation rate through the plastic components of the fuel system was required to be fully stabilized before performing the evaporative emission test. A full stabilization of the permeation rate after the change of the fuel in the tank may require up to several weeks. For this reason, the use of a permeation factor to take into account the potential increase of the permeation rate over time has been introduced in the test procedure.

The general purpose for WLTP evaporative emission procedure was therefore to primarily aim at a testing procedure that is most representative for real-world conditions, but within the boundaries of it being repeatable, reproducible, cost-effective and practicable. During the discussions in the development process, this often led to discussions in choosing which method to apply.

B. Approach

34. For the development of the harmonized evaporative test procedure, the WLTP-EVAP task force had first to decide the scope of the GTR taking into account existing emissions legislation, in particular those of the UNECE 1958 and 1998 Agreements, those of Japan and the US Environmental Protection Agency Standard Part 1066.

35. It appeared clear from the beginning that due to the different regional approaches in controlling evaporative emissions only part of the existing emissions legislation could be harmonized. The existing emission legislation for evaporative emissions, depending on the region considered, may address up to six different potential sources:

(a) Hot soak losses. Hot soak emissions are usually attributed to the evaporation of the petrol from the fuel system/engine immediately after the engine is shut off after a trip.

(b) Diurnal losses. Evaporative emissions coming from the fuel system as a consequence of diurnal temperatures fluctuation while the vehicle is parked.

(c) Permeation. Hydrocarbons escaping the vehicle’s fuel system by permeation through the plastic and rubber components

(d) Running losses. Emissions from the fuel system/engine while the vehicle is driven.

(e) Refuelling emissions. Vapours present in the tank displaced by the liquid fuel entering into the tank through the filler neck.

(f) Leaks. On-board diagnostic (OBD) systems have been developed to check the integrity of the vapour part of the fuel system.

36. While the US emission legislation contains provisions addressing all these potential sources of emissions, the legislation in force in other regions usually addresses only hot soak losses, diurnal losses and permeation when the vehicle is parked.

37. Due to the regional differences in terms mainly of temperatures, fleet composition and requirements for refuelling emissions (for instance, in the EU the use of Stage II vapour recovery systems is mandatory in refuelling stations while in Japan there is no provision at the moment), it was not considered appropriate to try to develop a GTR covering all the potential sources listed above. Therefore, it was decided to limit the extent of the scope of this GTR to the evaporative emissions occurring only during parking events. In other words, it was agreed to develop a GTR covering only the hot soak and diurnal losses plus the permeation.

38. The other aspect that has been considered in defining the scope of the GTR is the vehicle concept and the fuel tank technology. While most of the conventional vehicles with an internal combustion engine have a fuel tank vented to the air through a pressure relief valve, for the majority of hybrid vehicles sealed tanks have been adopted due to the reduced opportunities to purge the carbon canister. Therefore, two different test procedures were initially envisaged to cover these two situations. However, after some discussions it appeared clear that the development of test procedure for sealed tanks posed some challenges that could not be resolved within the planned timeframe. As a consequence, it was decided to postpone the development of the test procedure for sealed tanks to a later phase.

39. For conventional vehicles it was instead agreed, upon the proposal of the European Union, to use as starting point for the discussion the EU revised evaporative emission test procedure developed by the European Commission together with the interested stakeholders (industry and Member States) during the last years and submitted for final approval end of 2015/beginning 2016. Once again, this revised test procedure focuses only on evaporative emissions during parking events.

40. Starting from the newly adopted EU test procedure, the GTR development process focused in particular on:

(a) Updated specifications for equipment towards the current state-of-art in measurement technology;

(b) Increased representativeness of the test and vehicle conditions.

41. As such, the GTR text was updated and complemented by new elements where necessary.

42. Paragraph 4.3 generally outlines the main improvements in the GTR. The modifications that need some more clarification are detailed in Paragraph 4.4.

C. Improvements in the GTR

43. As a result of extensive analyses and discussions among the involved stakeholders, the WLTP Evaporative Emissions GTR has managed to improve many aspects of the existing emissions testing procedures. These include:

(a) Increased representativeness of the conditioning procedure carried out prior to the start of the evaporative emissions test;

(b) Increased duration of the diurnal test from 24 hours to 48 hours, covering in this way the majority of parking events;

(c) Improved the way the durability aspect is taken into account in the test procedure;

(d) Provisions to take into account the potential long term effect of ethanol on the fuel permeation rate through the plastic components of the fuel system as well as on the reduction of the carbon working capacity.

44. On a more detailed level, the following list shows the main improvements on specific aspects of the testing methodology which have contributed to increase the representativeness or usefulness of the test results:

(a) The duration of the conditioning drive during which the carbon canister is purged after having been loaded to breakthrough has been significantly reduced compared to the current test procedure described in UNECE Regulation 83. Instead of driving the vehicle over, in total, three New European Driving Cycles (corresponding to one hour of driving and 33 km), in the new test procedure the vehicle will be driven over the following combination of WLTC: Low–Medium–High–Medium phases for Class 2 and 3, twice the Low–Medium–Low phases for Class 1. These cycles will correspond respectively to about 32 and 54 minutes driving. The intention was to focus on urban driving conditions that are the most critical as far as the carbon canister purging is concerned for the reduced speeds and trip duration.

(b) The duration of the diurnal test has been extended from 24 hours to 48 hours in order to cover the majority of the parking events. The intention was to reduce the possibility that the carbon canister is saturated after the first day of parking and then evaporative emissions are no longer controlled. The 48-hour test was first introduced in the US in the nineties to cover two day parking events occurring mainly during the weekend.

(c) In addition, for a more conservative approach, the severity of the test may be increased by selecting the possibility to consider, as result of the diurnal test, the total evaporative emissions measured during the 48 hours. This implies additional measures to improve the effectiveness of the evaporative emission control system, like more aggressive purging strategies and/or larger carbon canisters.

(d) The legislation requires emission control systems to be effective over the useful life of the vehicle (corresponding, for instance, to 160,000 km in UNECE Regulation 83). In order to better cover this aspect and to take into account the potential long term effect of ethanol on carbon working capacity, the evaporative emission test will have to be carried out with an aged canister. In addition, a permeation factor will be added to the results of the test to take into account the potential increase of permeation due to the presence of ethanol in the fuel. An ageing procedure for the carbon canister and a procedure to measure the permeation factor of plastic tanks have been also introduced in the legislation.

D. New concepts of the GTR

45. The main improvements introduced by the GTR have been identified in the previous paragraph. In some cases, it was sufficient to add or modify a simple requirement. For other improvements, it was necessary to develop a whole new approach, leading to a new concept in the GTR. To give a more detailed explanation on the background and the underlying principles, this paragraph will outline the main new concepts that were introduced.

1. Conditioning drive

46. The carbon canister can efficiently trap the vapours generated by the evaporation of the petrol contained in the tank until the activated carbon is saturated. In order to restore the capability of the carbon canister of trapping the hydrocarbon vapours, it has to be regularly purged. When the vehicle is running, in certain operating conditions and under the control of the EMS (Engine Management System), part of the combustion air is drawn through the canister and into the engine so that the activated carbon is purged and the fuel vapours are burned in the engine. The amount of air drawn through the canister is managed by the Engine Management System (EMS) and controlled by means of a valve (purge valve) located in the line connecting the canister with the air intake manifold.

47. A correct purging strategy is important to ensure a good efficiency of the evaporative emission control system in all the most common driving conditions but it is important also for other aspects like driveability and exhaust emissions. For example, if after a long parking period the canister is saturated, as soon as the purge valve is opened a lot of hydrocarbons will reach the intake manifold through the canister purging line. This may result in a richer mixture (lambda < 1) and consequently in a reduced efficiency of the three-way catalyst in oxidizing HC and CO. If this occurs during a cold start, exhaust HC and CO emissions may exceed the relevant emission limit. For this reason, the US legislative test procedure for evaporative emissions requires exhaust emissions to be measured during the conditioning drive. In the test procedure defined in UNECE Regulation 83 exhaust emissions may instead be measured during the conditioning drive executed prior to the start of the evaporative emissions test but should not be used to check compliance with the exhaust emissions limits.

48. For the reasons mentioned above, the purging strategy must be carefully optimized taking into account the need of purging the canister quickly and at the same time avoiding negative impacts on driveability and exhaust emissions.

49. However, data generated at the Joint Research Centre of the European Commission shows that in some cases purging rates over the urban part of the legislative driving cycle (NEDC) may be rather low. As a result, the canister may not be purged efficiently in similar driving conditions.

50. The purging strategy of some Euro 4/5 passenger cars available on the European market were investigated at the JRC by connecting a flowmeter to the canister vent.

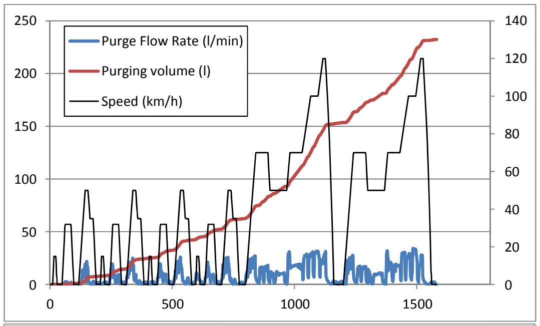
51. Most of these vehicles were tested for evaporative emissions and the second-by-second purging flow rate was recorded both over the pre-conditioning (NEDC+EUDC) and the conditioning drive (NEDC+UDC) prescribed by the relevant legislative test procedure.

52. In one case, the vehicle was tested only for exhaust emissions and therefore the purging flow rate was recorded over the NEDC and over the new worldwide harmonized driving cycle (WLTC, draft version).

53. The following plots provide the instantaneous purging flow rate (blue line) and the cumulative purge volume (red line) for each of the tested vehicles (left vertical axis) over the different driving cycles. The black line represents the speed of the vehicle (right vertical axis). The vehicles are identified with letters having no meaning.

Figure 1
Vehicle X

Vehicle X - 1360cc 55 kw Euro4 MPI



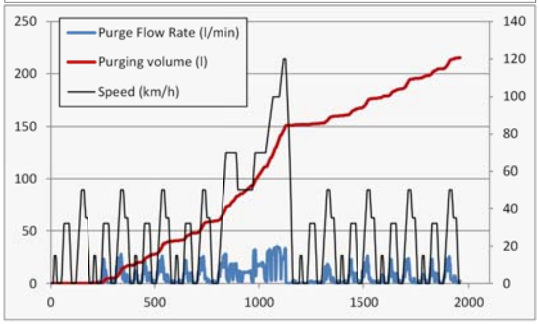
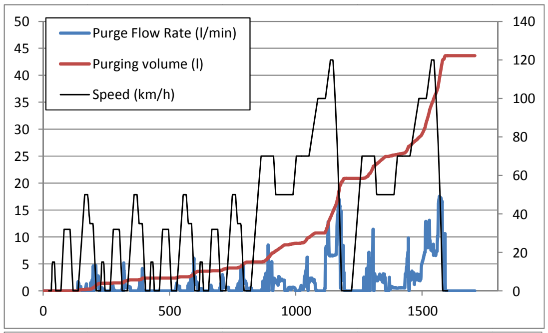


Figure 2
Vehicle Y

Vehicle Y – 1197 cc 47 kW Euro4 MPI



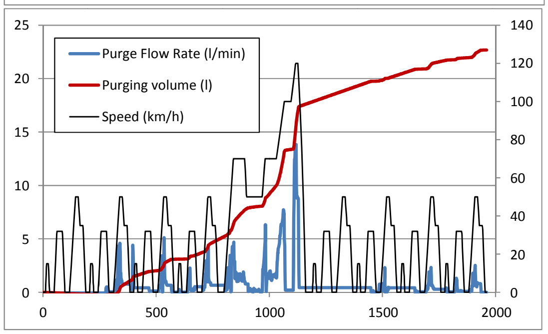


Figure 3
Vehicle Z

<u>Vehicle Z – 1794 cc 88 kW Euro4 MPI</u>

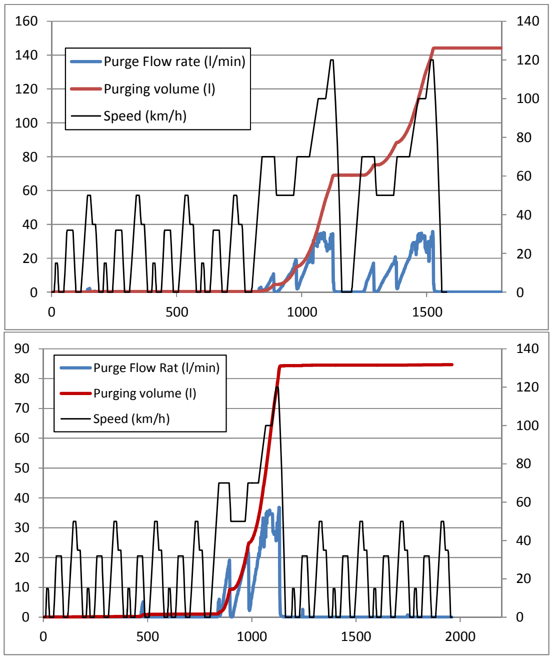


Figure 4
Vehicle W

<u>Vehicle W – 6063cc 313kw Euro4 MPI</u>

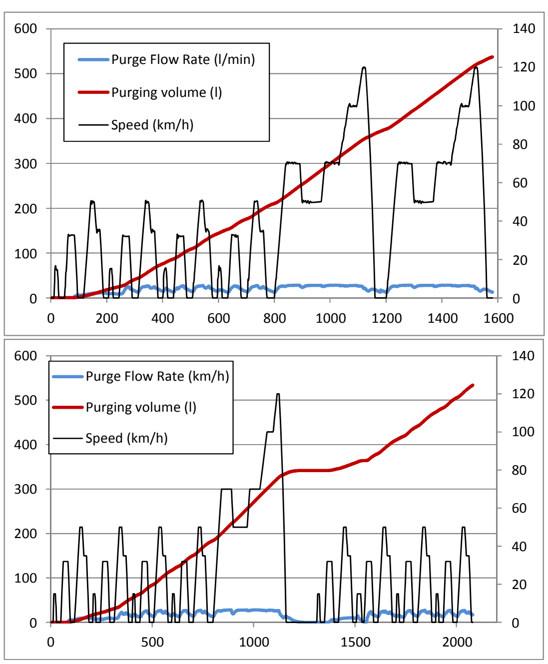
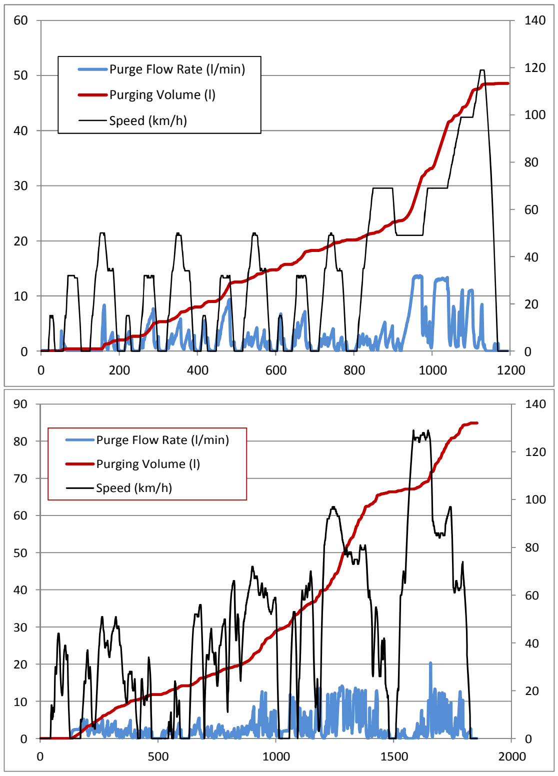


Figure 5
Vehicle Q

Vehicle Q – 875cc 62.5kw Euro 5 MPI



54. The results presented above show that the purging strategy of typical European passenger cars may vary significantly from model to model. In general, the purging flow rates recorded over the urban part of the cycle are significantly lower compared to those measured over the extra-urban part. In some cases, this difference is very important and the flow rate over the urban driving cycle is very low or close to zero.

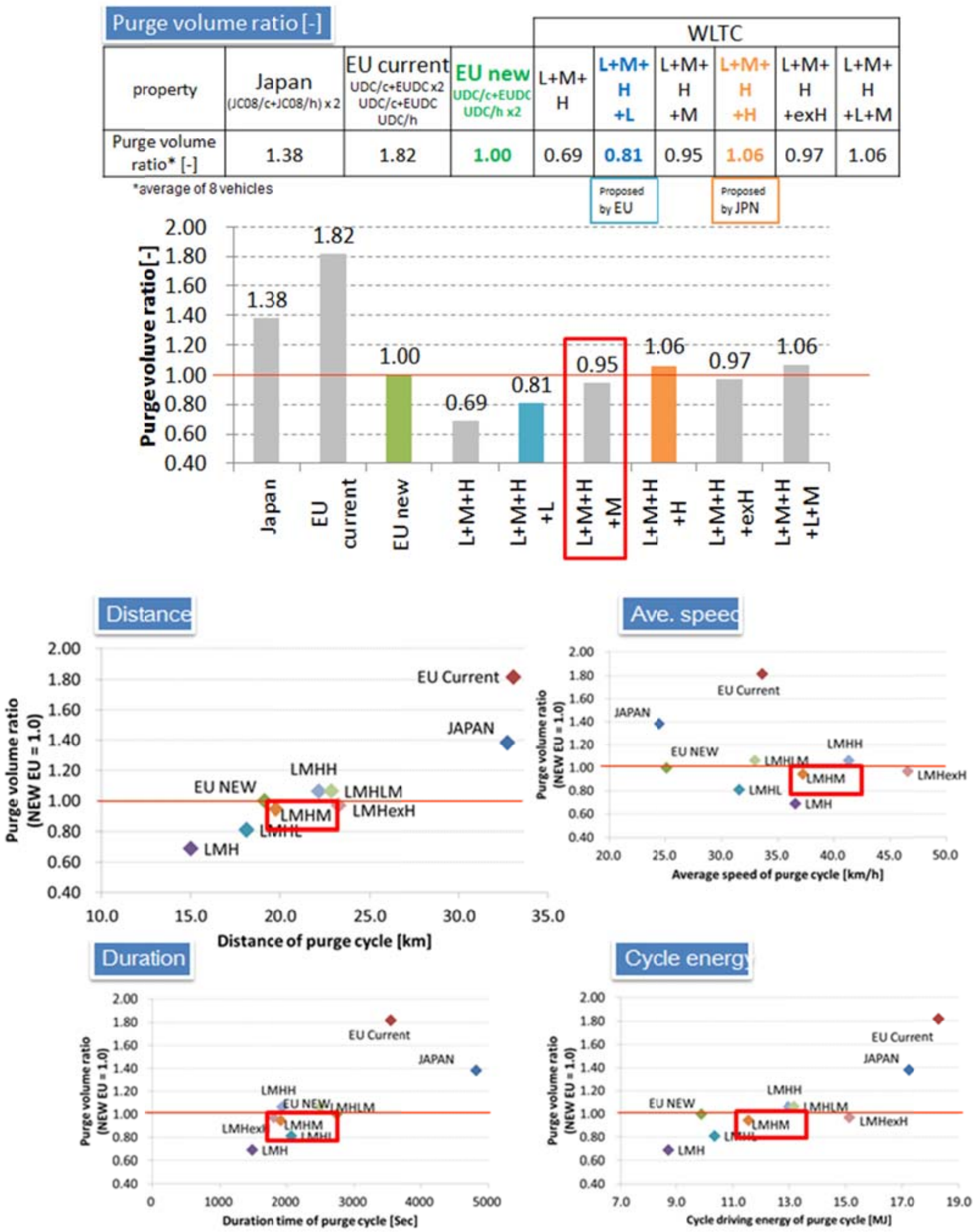
55. From the above considerations, it is clear that the most critical driving pattern for real world evaporative emissions is when the vehicle is driven for very short distances at low speeds as can very easily happen in city driving. This may lead to a situation in which the carbon canister, being purged only for short periods and with very low purging flow rates, is most of the time close to the saturation condition and might get saturated also during short parking events.

56. In the WLTP EVAP task force, the initial proposal of conditioning cycle from the European Union was Low-Medium-High-Low phases of WLTC in order to cover mainly urban driving, while Japanese proposal was Low-Medium-High-High phases of WLTC in order to cover typical driving condition.

57. The WLTP EVAP task force discussed extensively what could be the best compromise in terms of the conditioning drive in order to ensure a sufficient coverage of the most common driving patterns. As a result of discussions, it was agreed that Low-Medium-High-Medium of WLTC cycle should be used for the conditioning drive. The data shown below was supplied during the discussion by Japan. The data was an average value from tests on 8 vehicles certified using the existing evaporative test procedure. The purging flow rate measured over the proposed new conditioning cycle (Low-Medium-High-Medium) has significantly lower than the current EU and Japanese procedure.

59. Regarding Class 1 vehicles, it was agreed that the conditioning cycle would consist of driving two Low-Medium-Low WLTCs. This is the same set of cycles driven to measure tailpipe emissions.

Figure 6
Cycle characteristics



property	Japan (JC08/c+JC08/h) x 2	EU current UDC/c+EUDC x2 UDC/c+EUDC UDC/h	EU new UDC/c+EUDC UDC/h x2	WLTC L+M+H	WLTC L+M+H+L	WLTC L+M+H+M	WLTC L+M+H+H	WLTC L+M+H+exH	WLTC L+M+H+L+M
Purge volume ratio* [-]	1.38	1.82	1.00	0.69	0.81	0.95	1.06	0.97	1.06

*average of 8 vehicles

2. Duration of the diurnal test

59. The evaporative emissions test procedure described in UNECE Regulation 83 prescribes a diurnal test having a duration of 24 hours. The purpose of this test is to simulate a one day parking event on a summer day.

60. Tests carried out at the Joint Research Centre[3] and in other laboratories show that carbon canisters typically used in European cars are very often saturated after one diurnal test and from the second diurnal test onward a steep increase of evaporative emissions is quite common. This implies that a vehicle may have almost uncontrolled evaporative emissions when left parked for more than one day. It must also be stressed that the evaporative emissions due to breathing losses from the tank are strongly non-linear. As soon as the carbon canister gets saturated evaporative emissions increase steeply and basically all the extra vapours generated in the tank can be released into the air.

61. Of course, actual evaporative emissions in real world conditions depend strongly on the distribution of parking event duration.

62. Data showing the parking duration distribution in an Italian city has been presented by the Joint Research Centre. This distribution has been derived from the analysis of real world vehicle activity recorded by means of GPS-based systems. A set of data owned by the JRC was collected in the city of Modena (Italy) and includes the activity of about 15,000 vehicles recorded over one month (May 2011).

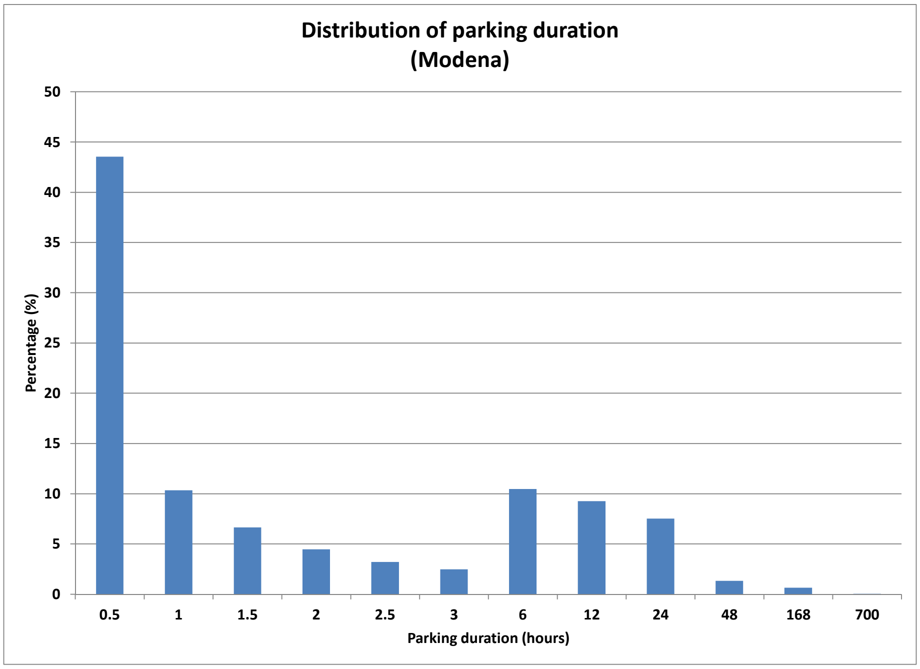
63. The distribution of the trip length and duration of parking events can be derived from the analysis of these sets of data.

64. The distribution of parking duration for the city of Modena is shown in the figure below. It can be seen that many parking events are very short but there is also a small fraction (above 2 per cent) of parking events with a duration of more than 24 hours.

[3] EU Report: "Joint EUCAR/JRC/CONCAWE Study on: Effects of Gasoline Vapour Pressure and Ethanol Content on Evaporative Emissions from Modern Cars, Institute for Environment and Sustainability", 2007, EUR 22713

Figure 7

Distribution of parking duration in the city of Modena (Italy). Total parking events: 2,642,320 in the month of May 2011



65. However, it has to be taken into account that most of the events included in the distribution shown in the histogram are not relevant for evaporative emissions (e.g. parking event occurring when the ambient temperature is decreasing or the parking event is too short). If the analysis is limited to the parking events having a minimum duration of 12 hours that fall totally or partially between 5:00 in the morning and 17:00 in the afternoon (hereinafter called diurnal cycle), which corresponds to the period during which the temperature predominantly rises in Modena in the month of May, the results are as follows:

Table 2

Distribution of parking duration

Diurnal cycles of consecutive parking	1	2	3	4	5	≥ 6
Number of events	94883	18371	5678	2257	1275	2101
Percentage of total events	76 %	15 %	5 %	2 %	1 %	2 %
Events per vehicle per month (average)	5.85	1.13	0.35	0.14	0.08	0.13
Sample size	16223 vehicles					

66. The first column of the table shows the number of parking events with a minimum duration of 12 hours that lasted without interruption from 0.5 to 1.5 diurnal cycles. The second column shows the number of longer parking events that lasted without interruption from 1.5 to 2.5 diurnal cycles, and so on. The third row shows the percentage of the total parking events having a specific duration. Finally, the fourth row shows the average number of times in a month that a single vehicle is parked for the given number of diurnal cycles.

67. It appears clear that the 24-hour diurnal test already covers the majority of the parking events relevant for evaporative emissions but also that about 24 per cent of the parking events are not covered by this test procedure. Taking into consideration the strong non-linearity of evaporative emissions, the contribution of these 24 per cent parking events to the total emissions may be very important. By extending to 48 hours the coverage will be increased to 91 per cent of the relevant parking events and these would of course reduce significantly real world evaporative emissions.

3. Effect of ethanol on evaporative emissions

68. One of the major concerns related to the use of petrol/ethanol blends is the possible increase of evaporative emissions due to a combination of factors:

(a) Increased vapour pressure of the petrol/ethanol blends
(b) Commingling effect
(c) Reduced working capacity of the carbon canister
(d) Increased fuel permeation through plastic and rubber components of fuel system

Increased fuel vapour pressure

It is well-known that the addition of ethanol to petrol at low ethanol concentrations (5 - 10 per cent) results in an increase in RVP of approximately 1 psi. The vapour pressure is directly linked to the volatility of the fuel or, in other words, the higher the RVP value, the more fuel will evaporate at a given temperature.

As a consequence of the effect described above, if a certain amount of ethanol is splash-blended in a commercial petrol, the RVP will increase above 60 kPa that is the maximum value generally allowed during the summer period in countries with a hot climate. On the other hand, the volatility of a petrol/ethanol blend can be corrected to match the 60 kPa specification when blended in a refinery.

Commingling effect

Even if all commercial petrol, including ethanol-petrol blends, must comply with the same DVPE specification, the marketing of ethanol-blends in areas where non-ethanol blends are also being sold will lead to a general increase of the vapour pressure of petrol used in that area. This increase is the consequence of what is referred to as the "commingling effect" that results from the mixing of ethanol-containing and non-ethanol-containing petrol in vehicle and refuelling station fuel tanks.

As an illustration of the commingling effect, consider a motorist who brings his car to a service station for refuelling when the tank is half full. If one assumes that the original fuel in the tank contains a 10 per cent ethanol-blend at a given vapour pressure and that the fuel added to the tank at the station is a non-ethanol blend of the same vapour pressure, the overall effect will be to turn the non-ethanol petrol into a 5 per cent ethanol blend by volume. This will cause the vapour pressure of the non-oxygenated petrol to increase by about 1 psi; since that petrol represents 50 per cent of the fuel in the tank, the average vapour pressure of all the fuel will increase by about half that amount, or about 0.5 psi.

Of course, the impact of the commingling effect on evaporative emission depends on a number of factors:

(a) Spatial distribution of the petrol/ethanol blends

(b) The market shares of ethanol and non-ethanol-containing petrol.

(c) The ethanol content of the petrol/ethanol blend

(d) The amount of petrol remaining in the tank at the moment of the refuelling

(e) The vapour pressure levels of the petrol.

Vapour pressure is the most important fuel property affecting breathing losses. In general, the higher the fuel volatility the higher the evaporative emissions are. However, the relationship between the volatility of the fuel and evaporative emissions is not linear, as canister breakthrough can occur when it becomes saturated. In this condition, the canister can no longer trap petrol vapours; therefore they are released uncontrolled into the air. A higher vapour pressure of the fuel may lead to a faster saturation of the canister.

Impact on carbon canister working capacity

Residual hydrocarbon concentration in the canister after purging has a certain influence on evaporative emissions. Canister breakthrough will occur more easily when the residual hydrocarbon concentration increases, because this reduces the working capacity of the canister. The size distribution of the pores and more specifically the ratio between micropores, mesopores and macropores is one of the main parameter affecting the activate carbon performances in terms of adsorption efficiency and its behaviour on the long term. Activated carbons with a high number of micropores compared to mesopores and macropores can be more efficient in terms of adsorption performance but may result in a worse durability in the long term. A correct compromise between adsorption efficiency and long term durability is needed for automotive applications. Polar molecules like ethanol (or water) or heavier hydrocarbons are usually harder to purge from the carbon. It has been shown that activated carbon affinity for ethanol vapours is greater than for olefins and aliphatic hydrocarbons. Therefore, it is possible that ethanol's propensity to be tightly held by activated carbon in conjunction with its hygroscopic nature may decrease the working capacity of the canisters used to control evaporative emissions and result in increased diurnal emissions. The effect of ethanol on the canister working capacity is considered the most likely explanation for the high failure rate (about 30 per cent) in the evaporative emission test that has been observed in the in-use compliance programmes carried out in Sweden on passenger cars.

Effect of ethanol on fuel permeation

Hydrocarbons also escape the vehicle's fuel system by permeation through the plastic and rubber components; e.g., hoses, seals, and in vehicles with a non-metallic tank, the fuel tank itself. Permeation does not occur through an identifiable opening; instead individual fuel molecules penetrate (i.e. they effectively mix with) the walls of the various components and eventually find their way to the outside. Fuel permeation is significant only for plastic or elastomeric materials.

Fuel permeation rate depends on the material used for the fuel system and on the chemical species contained in the petrol; in particular, alcohols like methanol and ethanol can increase significantly the permeation rate. Ethanol is believed to lead to an increase of the permeation due to the tendency of ethanol to evaporate more readily than other fuel components and to the smaller size of the ethanol molecule.

Several studies co-sponsored by the California Air Resources Board (CARB) and Georgia-based Coordinating Research Council (CRC) carried out in the US have confirmed that petrol/ethanol blends lead to increased permeation rates.

Summarising

In order to take into account the effect of ethanol on evaporative emissions, the new GTR includes specific provisions that can be summarized as follows:

(a) Reference fuel containing 10 per cent ethanol, which may represent the worst case in real world conditions in terms of the fuel quality as far as evaporative emissions are concerned. This will increase the representativeness of the test.

(b) The use in the evaporative emission test of a carbon canister aged with fuel containing 10 per cent ethanol. A specific ageing procedure, consisting in defined mechanical/thermal stress and repeated loading/purging cycles with 10 per cent ethanol fuel, has been developed. The loading/purging cycles may be stopped if it is possible to demonstrate that the Butane Working Capacity (BWC) of the carbon canister has reached a stable value.

(c) A permeation factor to be added to the result of the evaporative emissions test. If the tank of the vehicle to be tested has never entered into contact with a fuel containing ethanol, it may happen that the contribution of permeation to evaporative emissions is not duly accounted for (it may take up to tens of week to reach a fully stable permeation rate). For this reason, the measured value will be increased by a permeation factor (PF). The manufacturers will have the option either to measure the permeation of the tank that will be used in the car according to a well-defined procedure (the permeation rate will be measured after three and 20 weeks of ageing) or to use a default PF.

4. Calculation of the final result

69. The existing legislation applied in some regions, that already includes multiple diurnal tests, generally requires to add to the hot soak test result only the value recorded in the worst day of the 48 hours (or 72 hours) diurnal test (worst day method). The present GTR gives instead the possibility to consider as result of the test the total evaporative emissions measured over the 48 hours (total emissions method) added to the hot soak test result and the PF. The European Union and Japan decided to adopt the total method, keeping the 2g test limit as it is. However, industry argued that the worst method with appropriate limit value should be the best way from technical and harmonization points of view. As a result of discussion, it was agreed that the GTR would include two Contracting Parties options, the total emissions method as a primary method and the worst day method as an alternative option.

70. The PF is added only once when the worst day approach is used while it is added twice when the total emission method is selected.

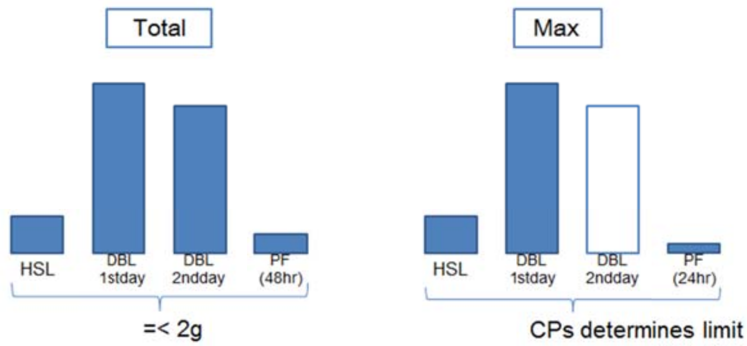
Figure 8
Contracting party options

CP option

$M_{HS} + M_{D1} + M_{D2} + 2PF \leq 2.0$ g/test

or

$M_{HS} + M_{D\_max} + PF \leq$ limit value determined by CP



5. Evaporative Emissions Family

71. In order to reduce the testing burden, the evaporative emissions family approach was introduced in the GTR. This requires the definition of the evaporative emission family and of the "worst case" vehicle within the family. Only the "worst case" vehicle will undergo the evaporative emission test. The WLTP EVAP task force reviewed existing family criteria of US and Japan as well as provisions of EU legislation. After discussions over several task force meetings, it was decided that the following parameters should be taken into account as criteria for the family definition:

(a) Fuel tank system material and construction;

(b) Vapour hose material, fuel line material and connection technique;

(c) Sealed tank or non-sealed tank system;

(d) Fuel tank relief valve setting (air ingestion and relief);

(e) Canister butane working capacity (BWC300) within a 10 per cent range (for canisters with the same type of charcoal, the volume of charcoal shall be within 10 per cent of that for which the BWC300 was determined);

(f) Purge control system (for example, type of valve, purge control strategy).

72. Regarding the selection of the "worst case" within the family, this was identified as the vehicle with the largest ratio of fuel tank capacity to canister butane working capacity. If the ratio is identical, the actual purge volume over the test cycle will be considered.

6. Open issues

73. It was agreed to continue the development of test procedure for sealed tank systems which would not be included in the first GTR version for the moment. Due to specific features (see below) of typical sealed tank systems, WLTP EVAP task

force needs further discussion especially on what is an appropriate condition of the canister prior to the conditioning drive.

1. No fuel vapour flow into the canister during parking.
2. Fuel vapour flow into the puff loss canister mainly just before refuelling.

Figure 9
Sealed tank system

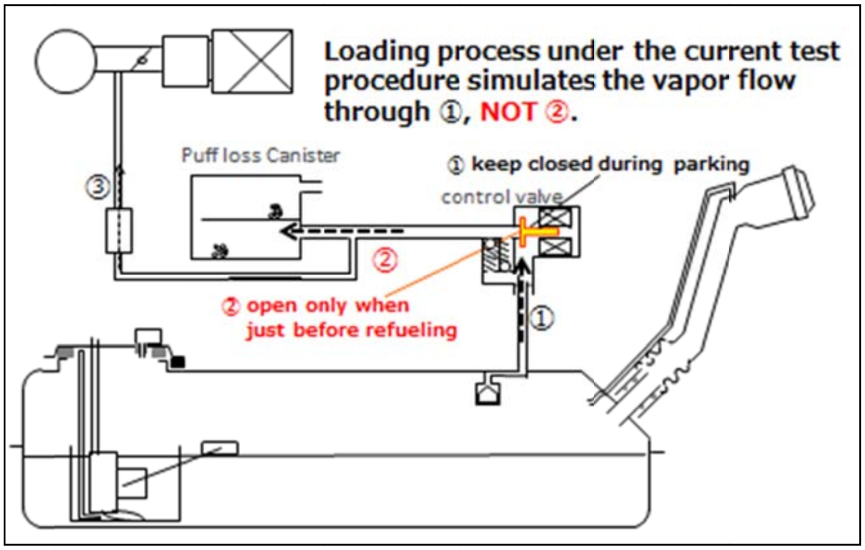
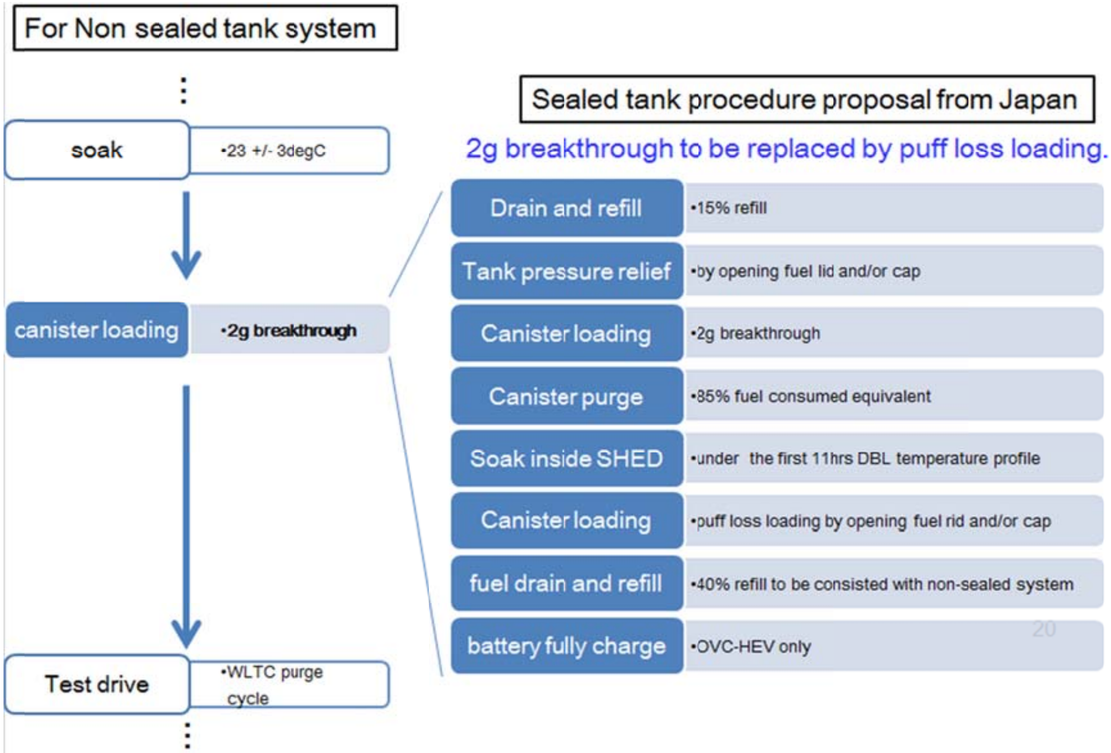


Figure 10
Proposed procedure from Japan



V. GTR structure

A. Annex 1 Type 4 test procedures and test conditions

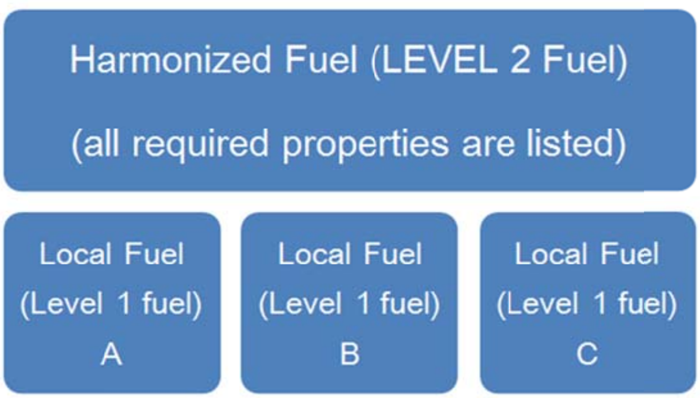
Annex 1 to the GTR describes the procedure for the Type 4 test, which determines the emission of hydrocarbons by evaporation from the fuel systems of vehicles. It is divided in the following chapters:

1. Introduction
2. Technical requirements
3. Vehicle and fuel
4. Test equipment for the evaporative test
5. Test procedure

B. Annex 2 Reference fuels

As there are regional differences in the market specifications of fuels, regionally different reference fuels need to be recognised. Contracting Parties may select their reference fuels (level 1 fuel) either according to Annex 3 to UNECE Global Technical Regulation No. 15. or according to paragraph 2. of this Annex (level2 fuel). The level 2 fuel is designed to be used as the reference fuel for mutual recognition under the rules of the 1998 UNECE agreement.

Figure 11
Reference fuels



Appendix 1 - Emission legislation

The following evaporative emission legislation was reviewed as a basis for the GTR:

US-Regulations (EPA and ARB)

40 CFR Part 86

CALIFORNIA EVAPORATIVE EMISSION STANDARDS AND TEST PROCEDURES

FOR 2001 AND SUBSEQUENT MODEL MOTOR VEHICLES

UNECE (comparable to EC 715/2007, EC 692 /2008)

ECE-R 83

Japan Automobile Type Approval Handbook for Japanese Certification