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**Economic Commission for Europe****Inland Transport Committee****World Forum for Harmonization of Vehicle Regulations****Working Party on General Safety Provisions****110<sup>th</sup> session**

Geneva, 11–14 October 2016

Item 7 of the provisional agenda

**Regulation No. 67 (LPG vehicles)****Proposal for a Supplement to the 01 series of amendments to Regulation No. 67 (LPG vehicles)****Submitted by the expert from the European Liquefied Petroleum Gas Association\***

The text reproduced below was prepared by the expert from the European Liquefied Petroleum Gas Association (AEGPL) to insert new safety provisions into UN Regulation No. 67 on Liquefied Petroleum Gas (LPG) systems having hydraulic interconnections with the petrol or diesel fuelling system through which inter-flows of fuels may occur. It is based on ECE/TRANS/WP.29/GRSG/2015/35 as amended by informal document GRSG-110-13, distributed during the 110<sup>th</sup> session of the Working Party on General Safety Provisions (GRSG) (see report ECE/TRANS/WP.29/GRSG/89, para. 25). The modifications to the current text of Regulation No. 67 are marked in bold for new characters.

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\* In accordance with the programme of work of the Inland Transport Committee for 2016–2017 (ECE/TRANS/254, para. 159 and ECE/TRANS/2016/28/Add.1, cluster 3.1), the World Forum will develop, harmonize and update Regulations in order to enhance the performance of vehicles. The present document is submitted in conformity with that mandate.

## I. Proposal

List of contents, Annexes, amend to read:

"Annexes

...

**Annex 18 Provisions on the compatibility of metallic and non-metallic components and parts with petrol**

**Annex 19 Provisions on interconnected LPG-systems"**

Insert new paragraphs 2.21. to 2.23., to read:

**"2.21. "LPG-system" means a set of LPG specific equipment intended to be fitted in a vehicle to constitute an integrated and functional whole aimed at enabling the propulsion with LPG;**

**2.22. "Interconnected LPG-system" means a LPG-system having interconnections with the petrol or diesel fuelling system that include a hydraulic path through which flows of petrol or diesel into the LPG container, or vice versa, may occur;**

**2.23. "Multi-component" means a device consisting of all or part of specific equipment of paragraph 2.2. from letter A to Q."**

Paragraphs 6.4. to 6.14. (former), amend to read (inserting a new paragraph 6.15.):

"6.4. - 6.15. Provisions regarding other components

The other components, which are shown in Table 1 ... from the table.

Table 1

Paragraph	Component	Annex
6.4.	Fuel pump	4
6.5.	Vaporizer <sup>1</sup> Pressure regulator <sup>1</sup>	6
...	...	...
6.9.	Gas injection devices/Gas mixing piece <sup>3</sup> or Injectors	11
6.10.	Gas dosage units <sup>2</sup>	12
...	...	...
6.14.	Pressure relief device	3
<b>6.15.</b>	<b>Multi-component</b>	<b>Annexes applicable to the single components</b>

<sup>1</sup> Either combined or separate.

<sup>2</sup> Only applicable when the gas dosage actuator is not integrated in the gas injection device.

<sup>3</sup> Applicable only when the operating pressure of the gas mixing piece exceeds 20 kPa (Class 2)."

*Paragraphs 6.15. to 6.15.3.2. (former), renumber as paragraphs 6.16. to 6.16.3.2.*

*Insert a new paragraph 6.16.3.3., to read:*

**"6.16.3.3. When a remotely controlled shut-off valve is intended to be fitted as a component of an interconnected LPG-system for the purpose of paragraph 17.13.2.2., it shall be submitted, during approval, to an endurance test according to paragraph 9. of Annex 15 with a number of cycles equal to 20,000.**

**The valve shall bear a marking with the following data clearly legible and indelible:**

- (a) the wording "ICS", and**
- (b) the approval mark according to paragraph 5.4. of this Regulation."**

*Paragraphs 6.15.4. to 6.15.13.2.4. (former), renumber as paragraphs 6.16.4. to 6.16.13.2.4.*

*Insert new paragraphs 6.16.14. and 6.16.14.1., to read:*

**"6.16.14. Provisions regarding non-return valves**

**6.16.14.1. When a non-return valve is intended to be fitted as a component of an interconnected LPG-system for the purpose of paragraph 17.13.1.1., 17.13.1.2. or 17.13.2.1., it shall be submitted, during approval, to an endurance test according to paragraph 9.6. of Annex 15.**

**The valve shall bear a marking with the following data clearly legible and indelible:**

- (a) the wording "ICS", and**
- (b) the approval mark according to paragraph 5.4. of this Regulation."**

*Insert a new paragraph 6.17., to read:*

**"6.17. When intended to be fitted as components or parts of an interconnected LPG-system, non-metallic, metallic or a mixture of metallic and non-metallic LPG components, including flexible hoses and their elements, and non-metallic, metallic or a mixture of metallic and non-metallic parts of LPG components which may come into contact with petrol shall meet the requirements specified in Annex 18 to this Regulation.**

**Non-metallic, metallic or a mixture of metallic and non-metallic components or components containing non-metallic parts shall bear an approval mark according to Annex A, Appendix 1."**

*Insert new paragraphs 17.13. to 17.13.2.4., to read:*

**"17.13. Specific provisions for interconnected LPG-systems**

**17.13.1. LPG-system for dual-fuel (LPG-diesel) vehicle**

**17.13.1.1. Means shall be provided to prevent any flow of LPG into the diesel tank. The installation of two non-return valves along the flow line shall be considered as meeting this requirement if the valves comply with the provisions of paragraph 6.15.14.1.**

**17.13.1.2. Means shall be provided to prevent any flow of diesel into the LPG container. The installation of two non-return valves along the flow line shall be considered as meeting this requirement if the valves comply with the provisions of paragraph 6.15.14.1.**

- 17.13.2. LPG-system for bi-fuel (LPG-petrol) vehicle
  - 17.13.2.1. Means shall be provided to prevent any flow of LPG into the petrol tank. The installation of two non-return valves along the flow line shall be considered as meeting this requirement if the valves comply with the provisions of paragraph 6.15.14.1.
  - 17.13.2.2. In order to prevent that flows of petrol into LPG container, occurring during switch-over operations, could lead to an overfilling of the LPG tank (i.e. above 80 per cent of its capacity which means 80 per cent liquid and 20 per cent gaseous fuel), the LPG-system shall contain an Electronic Control Unit complying also with paragraph 6. of Annex 14.  
  
A remotely controlled shut-off valve complying with the provisions of paragraph 6.15.3.3. shall be installed along the flow line.
  - 17.13.2.3. Means shall be provided to prevent that flows of petrol into the LPG fuel container could lead to a content of petrol higher than 16 per cent of the actual volume contained in the LPG tank.  
  
This measure shall be demonstrated in accordance with the procedures laid down in Annex 19.  
  
The present requirement shall be fulfilled also in case of faults, e.g. by use of redundant components, activation of limp home mode or of a malfunction indication to the driver.
  - 17.13.2.4. Non-metallic, metallic or a mixture of metallic and non-metallic LPG components, including flexible hoses and their elements, and non-metallic, metallic or a mixture of metallic and non-metallic parts of LPG components which may come into contact with petrol shall comply with the requirements set out in paragraph 6.17."

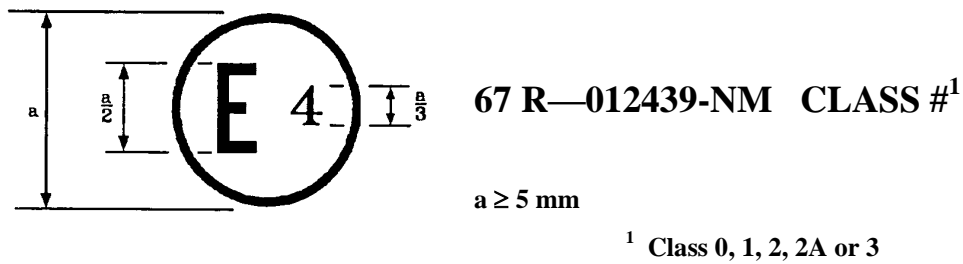
*Annex 1, add new items 1.2.6. and 1.2.7., to read:*

- "1.2.6. Documentation of the safety concept and system description/drawings to avoid overfilling of the LPG tank (paragraph 17.3.2.2.): .....
- 1.2.7. Documentation of the safety concept for interconnected LPG systems (Annex 19): ....."

*Annex 2A, insert a new Appendix 1, to read:*

## "Annex 2A - Appendix 1

Arrangement of the type-approval mark of non-metallic, metallic or a mixture of metallic and non-metallic LPG components and LPG components containing non-metallic, metallic or a mixture of metallic and non-metallic parts compatible with petrol. The letter N indicates non-metallic components. The letter M indicates metallic components. The letters NM indicates a combination of metallic and non-metallic components. (See paragraph 6.17. of this Regulation)



The above approval mark shall be affixed to the LPG component or to an identification plate to be placed in the engine compartment on a visible fixed irreplaceable chassis part, when the component is to be installed in such a way that will no longer be readily accessible.

The approval mark shows that the component has been approved in the Netherlands (E4), pursuant to Regulation No. 67 under approval number 012439. The first two digits of the approval number indicate that the approval was granted in accordance with the requirements of Regulation No. 67 as amended by the 01 series of amendments."

*Annex 14, insert new paragraphs 6. to 6.2., to read:*

"6. When the Electronic Control Unit (ECU) is intended to be fitted as a component of an interconnected LPG-system, it shall inhibit, by controlling the fuel selection system, the vehicle operation in petrol mode after each switch-over operation to LPG mode until a volume of liquid fuel equivalent to that flown into the LPG tank during such an operation is consumed.

Notwithstanding this, the ECU may permit the switch over to petrol mode if a fault in the LPG-system determines the inoperability of the system. Such a fault shall be clearly indicated to the driver.

In case of the inoperability of the LPG-system, the safety concept of the LPG-system shall prevent any flow of petrol into the LPG container after switching-over to petrol mode.

The ECU shall bear a marking with the following data clearly legible and indelible:

- (a) the wording "ICS"; and
- (b) the approval mark according to paragraph 5.4. of this Regulation.

6.1. In order to measure the volume of liquid fuel that flows during the switch-over operations, the following test shall be carried out:

- (a) Install the LPG-system other than the container on a vehicle;
- (b) Place the container on a weighing system and fill up the LPG tank;
- (c) After having pressurized the LPG-system up to the normal operating conditions, record the reading of the weighing system ( $W_1$ );
- (d) Disable the ECU feature described in paragraph 6. above;
- (e) Switch-over from LPG to petrol and vice versa for at least 10 times;

- (f) Record the reading of the weighing system (W2);

The volume of petrol flown per switch-over operation shall be calculated as follows:

$$V_{sw} = (W2-W1) / \#SW / D_{petrol}$$

where:

$$D_{petrol} = 743 \text{ kg/m}^3;$$

#SW = number of switch-over operations from LPG to petrol mode and vice versa during the test.

The weighing system shall have the following:

- (a) A precision of  $\pm 0.02$  per cent of full scale or better;
- (b) A resolution of 20 g;
- (c) An accuracy of  $\pm 2$  per cent of the reading or  $\pm 0.3$  per cent of full scale whichever is better.

6.2. To verify compliance with paragraph 6. of this annex, the ECU shall be tested as follows:

- (a) Install the LPG-system on a vehicle;
- (b) Set the fuel selection system in LPG mode;
- (c) Warm up the engine until all temperatures of cooling and lubrication means and the pressure of lubrication means have reached equilibrium;
- (d) Let the engine run at the lowest idling speed;
- (e) Switch over from LPG mode to petrol mode and vice versa;
- (f) Set the fuel selection system in petrol mode.

Test interpretation

The criteria adopted for the interpretation of the test is as follows:

- (i) Petrol mode is disabled until a volume of liquid fuel equal to  $V_{sw}$ , as calculated in paragraph 6.1. above, is consumed. Such consumption may be calculated making use of the fuel flow signals of the LPG ECU read out by means of an appropriate scan tool.

The test shall be repeated also at the highest idling speed."

*Annex 15, insert new paragraphs 9.7. and 9.7.1., to read:*

**"9.7. Endurance test for non-return valves in interconnected LPG-systems**

**9.7.1. The non-return valve shall be able to withstand 20,000 cycles of operation and 24 hours of chatter flow when tested according to the following procedure:**

- (a) connect the valve to a test fixture and apply a pressure to the valve's inlet equal to pressure of 3,000 kPa or of WP in accordance with the classification pressure of the valve, then vent pressure from its outlet. Lower the pressure on the valve's outlet side to between 0 and a maximum of 0.5 times the above value prior to the next cycle.

- (b) following 20,000 cycles of operation, subject the valve to 24 hours of chatter flow at a flow rate that causes the most chatter.

After this test, the non-return valve shall comply with the applicable leakage test requirements of paragraphs 5. and 8. above.

Failure in any sense during the procedure shall constitute a failure of the non-return valve.

All parts shall remain in position and function properly after this test.

Following this test, the check valve shall comply with the overpressure test according to paragraph 4."

*Insert a new Annex 18, to read:*

## "Annex 18

### **Provisions on the compatibility of metallic and non-metallic components and parts with petrol**

1. Requirements for metallic and non-metallic components and parts
  - 1.1. Non-metallic components or parts which may come into contact with petrol shall not show excessive volume change or loss of weight.
 

Resistance to petrol according to ISO 1817 with the following conditions:

    - (a) Medium: petrol (E10) complying with Annex 10 to Regulation No. 83;
    - (b) Temperature: 23 °C (tolerance according to ISO 1817);
    - (c) Immersion period: 72 hours.
  - 1.1.1. Requirements for non-metallic components and parts:
 

Maximum change in volume 20 per cent;

After storage in air with a temperature of 40 °C for a period of 48 hours, the mass compared to the original value may not decrease more than 5 per cent.
  - 1.3. Metallic components or parts which may come into contact with petrol shall have a permanent resistance against petrol. Metallic parts shall permanently be protected against corrosion (e.g. coating, surface finish, material mix) and fulfil the requirements of Annex 15, paragraph 12."

*Insert a new Annex 19, to read:*

## "Annex 19

### Provisions on interconnected LPG-systems

1. Documentation
  - 1.1. The following documentation shall be provided to the Type Approval Authority and to the Technical Service:
    - (a) A list of all parts of specific equipment mentioned in paragraph 2.2. of this Regulation including the approval documentation that are part of a multi-component according to paragraph 2.23. of this Regulation, if available in the system;
    - (b) The description of the safety concept used to ensure compliance with the requirements specified in paragraph 17.13.2.3. of this Regulation, including all equipment, monitored parameters, relevant factors, criteria and actions;
    - (c) A detailed flowchart that depicts the strategies used for the purposes of meeting the requirements specified in paragraph 17.13.2.3. of this Regulation.

2. Test procedures
  - 2.1. In order to verify compliance with paragraph 17.13.2.3. of this Regulation, a vehicle shall be tested as follows:

#### Test procedure

- (a) Install the LPG equipment on the vehicle;
- (b) Fill up the LPG tank with at least 10 litres of fuel;
- (c) Set the fuel selection system in LPG mode;
- (d) Let the engine run at the lowest idling speed;
- (e) Switch over from LPG mode to petrol mode and vice versa;
- (f) Repeat the action (e) until the disablement of petrol mode becomes permanent.

#### Test interpretation

The criteria adopted for the interpretation of the test is as follows:

$$N_{sw} < 0.16 * V_{in} / V_{sw}$$

where:

$N_{sw}$  = the number of switch-over operations from LPG mode to petrol mode and vice versa until the disablement of petrol mode becomes permanent.

$V_{sw}$  = the volume of petrol flown into the LPG tank per switch-over operation as measured in paragraph 6.1. above."



## II. Justification

### A. Introduction

- A.1. The proposed amendments aim, overall, at improving the safety aspects of gas systems which, by their architectural nature, allow limited flows of petrol into the LPG tank. This is, for instance, the case of the current LPG direct injection systems, in all the versions available today on the market, regardless of the manufacturer: in the rare cases in which the system acts, automatically or upon user's request, a switch over between operational modes (for example, when the LPG tank is nearing empty) a small flow of petrol is flushed into the LPG tank.
- A.2. The unconditioned prohibition of such reverse flows would determine the unjustifiable ban from the market of such innovative systems to the detriment of the environment, as these new gas systems significantly reduce the emission of pollutants and greenhouse gases with respect to analogous petrol technologies.
- A.3. In general, it is observed that:
- (a) the presence of petrol in the LPG tank does not create pressure-related risks as it has a lower volatility, indeed its mixing with the gaseous fuel can only reduce the internal pressure at the same temperatures;
  - (b) the flush of petrol into the LPG tank is triggered only by the switch-over from an operational mode to the other one, and since the gas fuelling system cranks, warms up and runs only on gas, this event is very rare, especially if compared to the other technologies where petrol is used also in gas mode during the driving cycle;
  - (c) petrol has a vapour pressure and a thermal expansion coefficient that are negligible, hence, the presence of some amount of petrol (very small) in place of LPG improves the safety level in pressure-related risks;
  - (d) 80 per cent is a rather conservative filling limit, with a significant margin versus 85 per cent, that is the correct one, as established also in the Transportable Pressure Equipment Directive (TPED) and Pressure Equipment Directives (PED) of the European Union;
  - (e) overfilling of the LPG tank will be prevented by the strategy proposed in this document: each single flushed volume shall be removed by disabling the switch-over from LPG to petrol until this volume is fully consumed; relevant sound laboratory tests have been proposed.

### B. Detailed justifications

- B.1. New paragraph 2.20. introduces the definition of a generic "LPG-system". Although "LPG-system" is referred to in the current Regulation in several points, this lacks a proper definition.
- B.2. New paragraph 2.21., in defining a particular LPG-system, the "Interconnected LPG-system", clarifies the scope of the provisions that are proposed in this amendment.

It is worth noting that this new specific definition excludes LPG-systems with no hydraulic interconnections with the petrol/diesel fuelling system as well as systems with interconnections that do not include a hydraulic path through which flows of petrol or diesel into the LPG tank may occur.

As for "petrol or diesel fuelling system", it is implicitly meant the hydraulic circuit upstream the fuel injection/aspiration point.

- B.3. With new paragraph 2.22., a proper definition of "multi-component" is introduced, filling an evident gap in the Regulation: several points refers to it without a specific definition.

New paragraph 6.15. aims at clarifying the requirements and tests of the Regulation that are applicable to a "multi-component".

Both paragraphs 2.22. and 6.15. are of particular relevance to this amendment proposal because one of the main components of the LPG Direct Injection (DI) system is a multi-component, that is usually commercialized with the name of FSU (Fuel Selection Unit).

- B.4. New paragraph 6.16.3.3. establishes that the remotely controlled shut-off valve installed along the inter-flows line aimed at actuating the switch-over phases shall be compliant with a durability test more stringent than that required to the other components.

This valve shall bear a distinctive ICS marking also to the purpose of repairing and replacing.

- B.4.1. New paragraph 6.16.14. establishes that non-return valves used to prevent flows of LPG into petrol/diesel tanks (see paragraphs 17.13.1.1., 17.13.1.2. and 17.13.2.1) shall be approved in accordance with a specific durability test as defined in paragraph. 9.6. of Annex 15.

These valves shall bear distinctive ICS markings also to the purpose of repairing and replacing.

- B.4.2. New paragraph 6.16.1.6. as proposed in ECE/TRANS/WP.29/GRSG/2015/35 has been eliminated since no additional or specific requirements for 80 per cent stop valve used in ICSs are needed, even when considering the case of a switch from petrol to LPG after having refuelled the LPG container up to 80 per cent.

In particular:

(a) The maximum fill ratio for LPG under assumed temperature conditions lies beyond 85 per cent (see TPED, PED, European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR)). UN Regulation No. 67, 01 series of amendments, provides a safety margin of 5 per cent.

(b) The risk of overfilling of an LPG system would remain most prominent at the time of refuelling regardless of the possible small petrol reflux into the LPG tank, as the 80 per cent stop valve allows for a residual flow of half a litre per minute just to round the money amount of the refuelling. Given the drastic reduction of flow rate (from double-digit litre per minute down to half a litre per minute maximum) and the ample safety margin (80 per cent versus 85 per cent) this has already been adequately addressed in the Regulation.

(c) In accordance with the provision of new paragraph 6. of Annex 14, the interconnected LPG-systems will be forced to consume the single reflux that will be triggered by the switch-over from petrol to LPG after refuelling.

- B.5. New paragraph 6.17. requires an appropriate compatibility test with petrol to the LPG components or parts of interconnected LPG-systems that may come into contact with petrol. A distinctive marking for such components or components containing such parts is also required.

- B.6. New paragraph 17.13. includes the requirements for the interconnected LPG-systems, opening a distinction between dual-fuel (LPG-diesel) vehicle (paragraph 17.13.1.) and bi-fuel (LPG-petrol) vehicle (paragraph 17.13.2.).

In a dual-fuel vehicle, both flows of LPG fuel into the diesel tank and vice versa are prevented by requiring the implementation of an appropriate means, respectively in paragraphs 17.13.1.1. and 17.13.1.2.

The installation of two non-return valves along the flow line is considered effective and reliable means if the valves are approved in accordance with the durability test as defined in paragraph 9.6. of Annex 15 (see justification B.7.1.).

In a bi-fuel vehicle, the flows of LPG fuel into the petrol tank are prevented by requiring the implementation of an appropriate means (paragraph 17.13.2.1., first sentence).

The installation of two non-return valves along the flow line is considered an effective and reliable means if the valves are approved in accordance with the durability test as defined in paragraph 9.6. of Annex 15 (see justification B.7.1) (paragraph 17.13.2.1., second sentence).

Flows of petrol into the LPG tank are permitted only during switch-over operations and under certain conditions aimed at preventing the LPG tank overfilling (paragraph 17.13.2.2.) and the petrol over-blending into LPG (paragraph 17.13.2.3.), above the limit set out in Regulations Nos. 83 and 115 (20 per cent by energy).

A remotely controlled shut-off valve shall be installed along the flow line to actuate the switch-over phases.

This valve shall comply with a durability test that requires a more stringent endurance operation than that prescribed to the other components (see justification B.4.)

- B.7. To prevent the overfilling of the LPG container, due to possible flows of petrol, occurring during the switch-over operations, the Electronic Control Unit (ECU) of an interconnected LPG-system shall comply with the new paragraph 6. of Annex 14, in addition to the other applicable requirements (paragraph 17.1.2.2.).

Paragraph 6. of Annex 14 requires the ECU be capable of consuming an equivalent volume of each single petrol flush when this occurs due to a switch-over operation.

In other words, ECU shall inhibit the switch back to petrol until such a volume is consumed.

A derogation from such a temporary disablement of petrol mode is possible only in the case the LPG-system becomes inoperable as consequence of an internal fault, to avoid putting the vehicle in a more hazardous condition.

Two tests methods are proposed to measure the average petrol flush volume as well as to prove the capability of the ECU to inhibit the switch back to petrol after a flush occurs, respectively in paragraphs 6.1. and 6.2. of Annex 14.

- B.7.1. New paragraph 9.6. of Annex 15 sets out the provisions of a specific endurance test for the non-return valves used to the purpose of paragraphs 17.13.1.1., 17.13.1.2. and 17.13.2.1.

This is based on the "continued operation" test as defined in paragraph 6.4. of ISO15500-3:2012.

The high number of cycles and the long chatter flow operation makes it particularly suitable for the non-return valves used in such interconnected LPG systems.

- B.8. To prevent the over-blending of petrol into the LPG, the interconnected LPG system as a whole shall fulfil the provisions set out in new Annex 19 (paragraph 17.13.2.3.).

Annex 19, paragraph 1.1., requires providing the type-approval authority and the technical service with a proper documentation describing the equipment and the strategy used to prevent the over-blending.

The LPG-system shall be capable to set the permanent disablement of petrol mode (i.e. disablement until LPG container gets empty) when the concentration of petrol into the actual liquid fuel in the LPG tank exceeds the max blending limit of 16 per cent by volume (equivalent to 20 per cent in energy as required by Regulations Nos. 83 and 115).

A performance test is required to demonstrate the compliance of such a max blending limit (16 per cent by volume), comparing the number of switch-over operations before the petrol mode disablement becomes permanent with the number that would cause (by a conservative calculation) the over-blending.

The proposed formula is justified by the following:

- (a) The concentration of petrol into LPG just after the first switch-over will be  $V_{sw}/(V_{in} + V_{sw})$ ; where  $V_{sw}$  is the volume flushed when switching over and  $V_{in}$  is the initial volume of LPG;
- (b) At each further switch-over an additional concentration, equal to  $V_{sw}/V_{in}$ , will be added, considering that the same volume ( $V_{sw}$ ) of liquid fuel will be (first) consumed and (then) injected;
- (c) Since  $V_{sw}$  can be considered negligible in comparison with  $V_{in}$ , the concentration at  $i$  switch-over operation will be  $C_i = i \cdot V_{sw}/V_{in}$ . Therefore,  $i_{max}$  shall be less than  $0.16 \cdot V_{in}/V_{sw}$ .

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