Regulations 49 and 83 – LPG reference fuel

Document GFV-02-2

by

Expert from Poland

56 GRPE

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Regulations 49 and 83 – LPG reference fuel

1. Composition of LPG reference fuels in Regulation 83

- The composition of LPG reference fuels specified in Annex 10 A to Regulation 83 is as follows:

Composition		Fuel A	Fuel B
C3 - content	per cent vol.	30±2	85±2
C4 - content	per cent vol.	balance	balance
<C3, >C4	per cent vol.	max. 2	max. 2
olefins	per cent vol.	max. 12	max. 15

Regulations 49 and 83 – LPG reference fuel

It is not clear what “balance” means:

- balance = 100 - C3 (if so, the total may be higher than 100, e.g. C3 - 31, C4 – 69, <C3 – 2, total = 102) or
- balance = 100 - C3 - <C3 - >C4 (the most probable) or even
- balance = 100 - C3 - <C3 - >C4 – olefins.

It is proposed to clarify this problem and correct Regulation 83.

Regulations 49 and 83 – LPG reference fuel

2. Different composition of LPG reference fuels B in Regulations 49 and 83

- The composition of LPG reference fuels specified in Annex 7 to Regulation 49 is as follows

Composition		Fuel A	Fuel A	Fuel B	Fuel B
		Min.	Max.	Min.	Max.
C3 - content	per cent vol.	48	52	83	87
C4 - content	per cent vol.	48	52	13	17
olefins	per cent vol.	0	12	0	14

Regulations 49 and 83 – LPG reference fuel

There are the following differences between fuels B in Regulation 49 and Regulation 83:

a) if “balance” in Regulation 83 means “balance = 100 – C3 - <C3 - >C4”, C4 content may be different, e.g.

- Regulation 83: C3 = 87, <C3 + >C4 = 2, C4 = 11% vol.,
- Regulation 49: C4 can not be lower than 13 % vol.,

b) <C3, >C4 are not permitted in Regulation 49,

c) maximum content of olefins:

- Regulation 83 – 15 % vol.,
- Regulation 49 – 14 % vol.

These differences do not seem to be justified. It is proposed to harmonize the composition of LPG reference fuel B in both the Regulations.

Regulations 49 and 83 – LPG reference fuel

3. H/C ratio for LPG

The H/C ratio for LPG is assumed to be equal to:

- 2,525 in Regulation 49 (paragraph 2.7),
- 2,525 in Regulation 83 (paragraph 2.4).

To verify the above ratios, the calculation has been made based on the compositions specified in respective Regulations.

Regulations 49 and 83 – LPG reference fuel

The calculation proves that the average H/C ratio for LPG reference fuels differs from that specified in Regulations 49 and 83. It is important to note that the average H/C ratio for LPG specified in Regulation 49 should be different from that specified in Regulation 83 as the composition of fuels A is different.

In light of the above, it is proposed to assume the following H/C ratio:

- **2.55 in Regulation 83,**
- **2.57 in Regulation 49.**

The HC density calculated for the above ratio is equal to:

- 0.651 in Regulation 83,
- 0.652 in Regulation 49.

Regulations 49 and 83 – LPG reference fuel

The following corrections are required, among other things:

- Regulation 83 – paragraph 2.4 in the body, paragraph 8.2 in Annex 4, paragraph 1.5.2.3 in Appendix 8 to Annex 4,
- Regulation 49 – paragraph 2.7 in the body, paragraph 4.3.1.1 in Appendix 2 to Annex 4.

Proposal for Draft Amendment to Regulation 101 – gas fuels

Document GFV-02-3

by

Expert from Poland

56 GRPE

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Proposal for Draft Amendment to Regulation 101 – gas fuels

1. The first two indents in paragraph 5.2.4 of **Revision 1** of Regulation 101 have “vanished” in **Revision 2** for unknown reasons. Consequently, it is not clear whether one or two reference gas fuels must be used. The interpretation that two gas fuels must be used is possible. It is desirable that GFV clarifies this problem. If two reference gas fuels were used, it would be required to correct the method of calculation of fuel consumption in item 1.4.3 of Annex 6.

Proposal for Draft Amendment to Regulation 101 – gas fuels

2. Paragraph 5.2.4, amend to read:

"5.2.4. For the purpose of the calculation mentioned in paragraph 5.2.3., the fuel consumption shall be expressed in appropriate units and the following fuel characteristics shall be used:

(1) density: measured on the test fuel according to ISO 3675 or an equivalent method. For petrol and diesel fuel the density measured at 15 ºC will be used; for LPG and natural gas a reference density will be used, as follows:

0.538 kg/litre for LPG

0.654 [0.631] kg/m3 for NG 3 /

(2) hydrogen-carbon ratio: fixed values will be used which are:

1.85 for petrol

1.86 for diesel fuel

2.525 [2.55] for LPG

4.00 for NG

3 / Mean value of G20 and G23 G25 reference fuels at 15 °C.

Proposal for Draft Amendment to Regulation 101 – gas fuels

Justification.

(i) NG reference fuels are G20 and G25, but not G20 and G23. It seems that the mean density specified in Regulation 101 is calculated for G20 and G23 (for G20 – 16.042/23.63 = 0.679; for G23 – 0.6789*0.925 = 0.6280; (0.679+0.628)/2 ≈ 0,654) According to our simplified calculations the mean value for G20 and G25 is about 0.631 (for G20 – 16.042/23.63 = 0.679; for G25 – 0.6789*0.86 = 0.584; (0.679+0.584)/2 ≈ 0,631) instead of 0.654.

(ii) H/C ratio for LPG – see the separate document GFV-02-2 “Regulations 49 and 83 – LPG reference fuel”. It is proposed to use the average H/C ratio equal to 2.55.

(iii) Footnote – self-evident.

Proposal for Draft Amendment to Regulation 101 – gas fuels

4. Annex 6, item 1.4.3, (c), amend to read:

(c) for vehicles with a positive ignition engine fuelled with NG:

$Fcnorm = (0.1336 / 0.654) \cdot [(0.749 \cdot HC) + (0.429 \cdot CO) + (0.273 \cdot CO2)]$

$Fcnorm = (0.1336 / 0.631) \cdot [(0.749 \cdot HC) + (0.429 \cdot CO) + (0.273 \cdot CO2)]$

Justification.

(i) It is assumed that one reference fuel is used. If two fuels were used, further changes would be required.

(ii) The mean density is corrected – see item 2 above. The difference in fuel consumption is about 4%.

Proposals for Draft Amendments and Comments to Regulation 115

Document GFV-02-4

by

Expert from Poland

56 GRPE

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Proposals for Draft Amendments and Comments to Regulation 115

Experiences with the application of Regulation 115 in Poland (several type approvals granted, about 300 vehicles tested) have proved that it has many defects and needs amending. It is required, in particular:

- **to clarify the scope of application,**
- **to delete the concept of "non-intrusive" retrofit systems,**
- **to sort out the problem of switch over time,**
- **to adapt to technical progress and to correct provisions for vehicles of M2, M3, N2, N3 categories,**
- **to correct a huge number of errors, unclear provisions etc. leading to misinterpretation.**

Proposals for Draft Amendments and Comments to Regulation 115

I. Clarification of the scope of application

- **intention - to limit the scope of application to Euro 3, Euro 4 and later vehicles**
- **the majority of vehicles are approved under Directives 70/220/EEC and 88/77/EEC or 2005/55/EC**
- **Regulation 115 applies also to pre-Euro, Euro 1, Euro 2 vehicles type-approved pursuant to the above Directives because they are not exempted**

Proposals for Draft Amendments and Comments to Regulation 115

Paragraph 1.4, amend to read:

„1.4. This Regulation applies to retrofit systems intended to be fitted on vehicles of categories M and N, type approved pursuant to Regulation 83 or 49, or equivalent UE Directives with the exception of:

.....

.....

(f) vehicles type-approved pursuant to Directive 70/220/EEC and Directives amending this Directive, earlier than Directive 98/69/EC,

Proposals for Draft Amendments and Comments to Regulation 115

(g) vehicles equipped with diesel engines type-approved pursuant to Directive 98/69/EEC and later Directives amending Directive 70/220/EEC,

(h) vehicles other than M1 and N1 categories type-approved pursuant to Directive 98/69/EEC and later Directives amending Directive 70/220/EEC,

(i) vehicles type-approved pursuant to EU Directive 88/77/EEC and Directives amending this Directive, earlier than Directive 1999/96/EC."

Proposals for Draft Amendments and Comments to Regulation 115

II. Deletion of the splitting of retrofit systems into "intrusive" and "non-intrusive"

Experiences with the application of Regulation 115 have proved that the concept of "non-intrusive" systems does not serve a purpose and is not justified for the following reasons.

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a). By virtue of the definition in paragraph 2.1.5 of Regulation 115 all gas injection systems may be regarded as “non-intrusive”. However, what matters is not only the change in the original air and petrol feed system, but also the change in the engine operation. Compliance with the definition does not necessarily ensure that the operation of the engine fuelled with petrol is not affected after the retrofit.

Proposals for Draft Amendments and Comments to Regulation 115

Pollutant	Emission [g] - first 133 s (petrol)	Emission [g] – total urban cycle
Before retrofit		
CO	5.28	5.89
NOx	0.02	0.17
HC	0.54	0.55
After retrofit		
CO	8.32	8.79
NOx	0.02	0.42
HC	0.73	0.76

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b). For “non-intrusive” systems the values of the petrol CO2 emission and fuel consumption required for the calculation of the ratios of CO2 emissions and fuel consumption (K_{co2}, K_{cons}) may be the values determined during the type-approval of the original vehicle (paragraph 6.1.2.5.3.4). Some values of K_{co2}, K_{cons} determined in this way for some retrofit systems type-approved pursuant to Regulation 115 are listed in Table below.

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System/ vehicle	1	2	3	4	5	6
K_{co2}	0.94	1.08 !	0.98	0.95	1.04 !	0.92
K_{cons}	1.41	1.58 !	1.44	1.35	1.50 !	1.35

The method of K_{co2}, K_{cons} calculation specified for "non-intrusive" systems in paragraph 6.1.2.5.3.4. of Regulation 115 "falsifies" the type-approval results. In several cases the values of K_{co2}, K_{cons} obtained are wrong and worthless.

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c). The provisions in paragraph 6.1.2.5.1.4.2 making it possible to reduce the number of type 1 tests (from 3 tests to 1 or 2 tests) for “non-intrusive” systems do not serve a purpose as 3 type 1 tests must be anyway conducted to collect the data for CO2 emission and fuel consumption (paragraph 6.1.2.5.3.1).

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d). The “official” values of the CO2 emission, fuel consumption and net power required for the calculation of K_{co2}, K_{cons} , K_{power} for “non-intrusive” system are not available for some vehicles in service, in particular in some non-EU member countries.

e). The introduction of the “non-intrusive” concept leads to the situation that the emission limit values for the “intrusive” and “non-intrusive” systems are different which should not be acceptable.

Consequently, the limit values are not performance-oriented, but are design-oriented.

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Value of the emission with petrol, S	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Limit value for “intrusive” system with LPG	0.65	0.74	0.82	0.91	0.99	1	1	1
Limit value for “non-intrusive” system with LPG	1	1	1	1	1	1	1	1
Difference,%	53	35	21	10	0.5	0	0	0

Proposals for Draft Amendments and Comments to Regulation 115

Proposed amendments:

(i) The following paragraphs should be deleted:

- 2.1.5,
- 3.2.5,
- 5.2,
- 6.1.2.2,
- 6.1.2.5.1.4,
- 6.1.2.5.1.4.1,
- 6.1.2.5.1.4.2,
- 6.1.2.5.3.4,
- 6.1.3.4,
- Annex 1A, item 11.1, the second line,
- Annex 3A, item 2.4.

(ii) Paragraph 6.1.2.5.1.2 should be amended.

(iii) Paragraph 6.1.3.1 should be amended.

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III. The problem of switch over time from petrol to LPG in LPG mode

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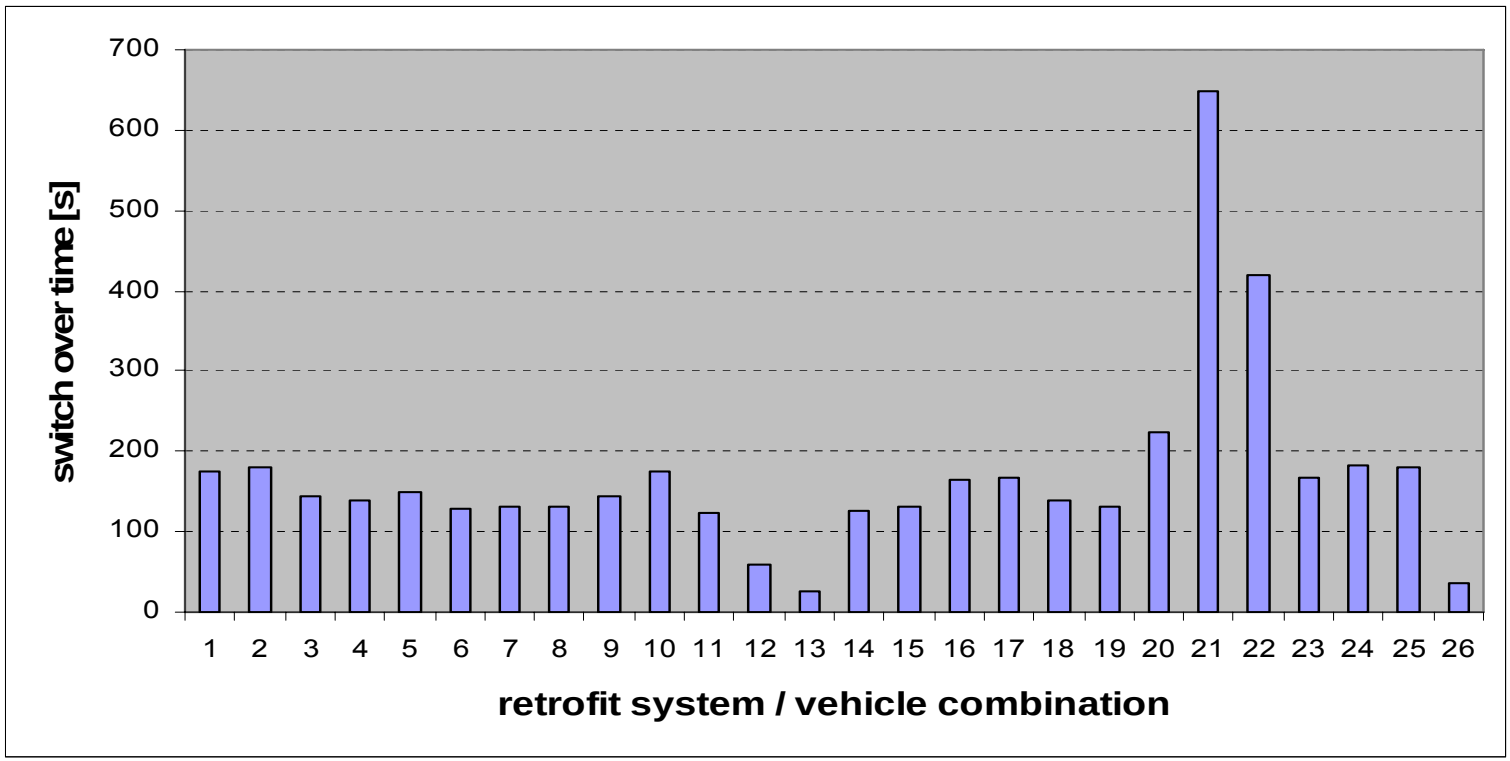
The switch over time of some retrofit system/vehicle combinations submitted for the type-approval in Poland is shown below



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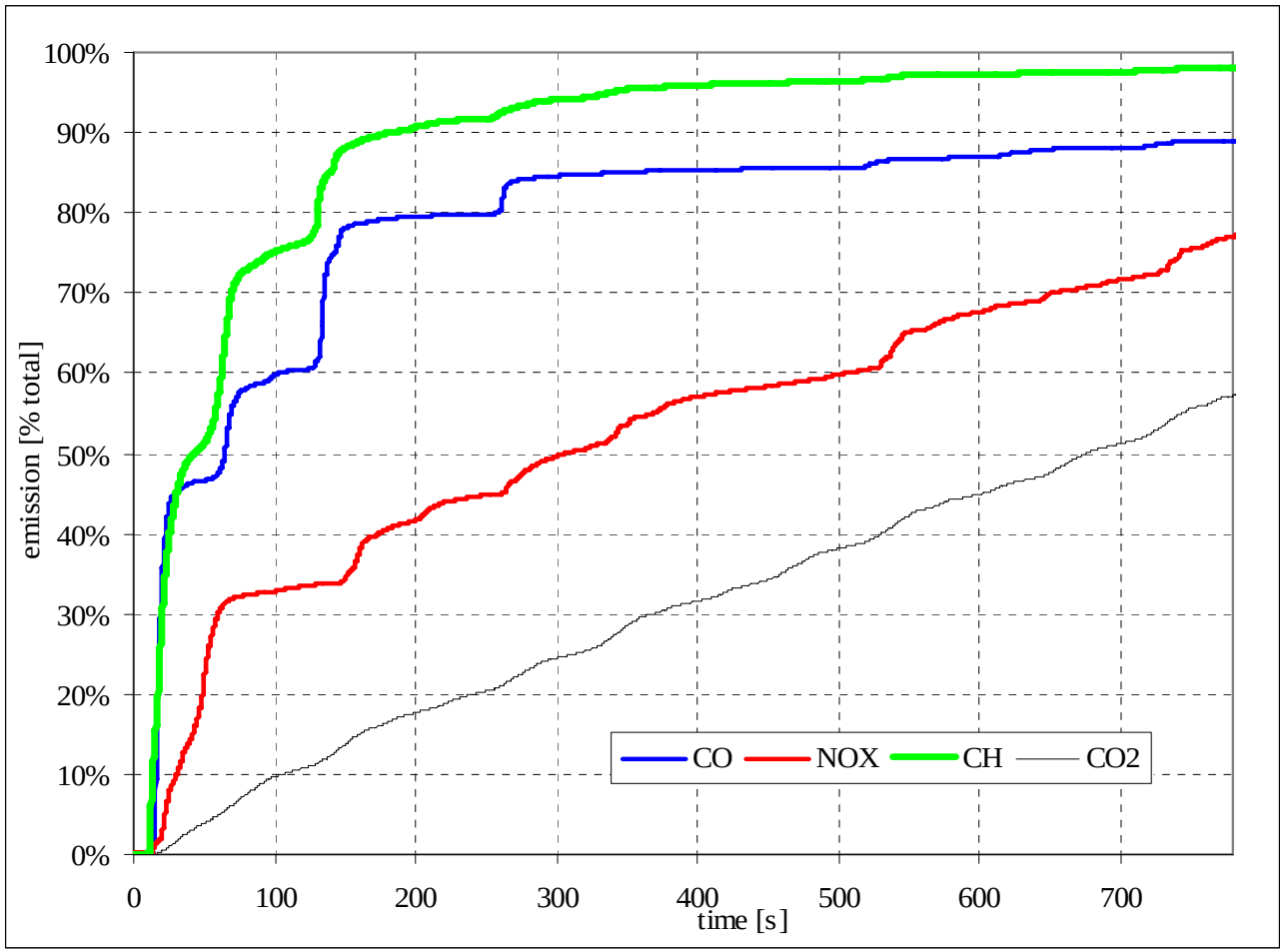

Relative emission versus time for vehicle A (Euro 4) in the urban part of the type 1 test (Source: Environmental Protection Centre, Motor Transport Institute, Warsaw, Poland)

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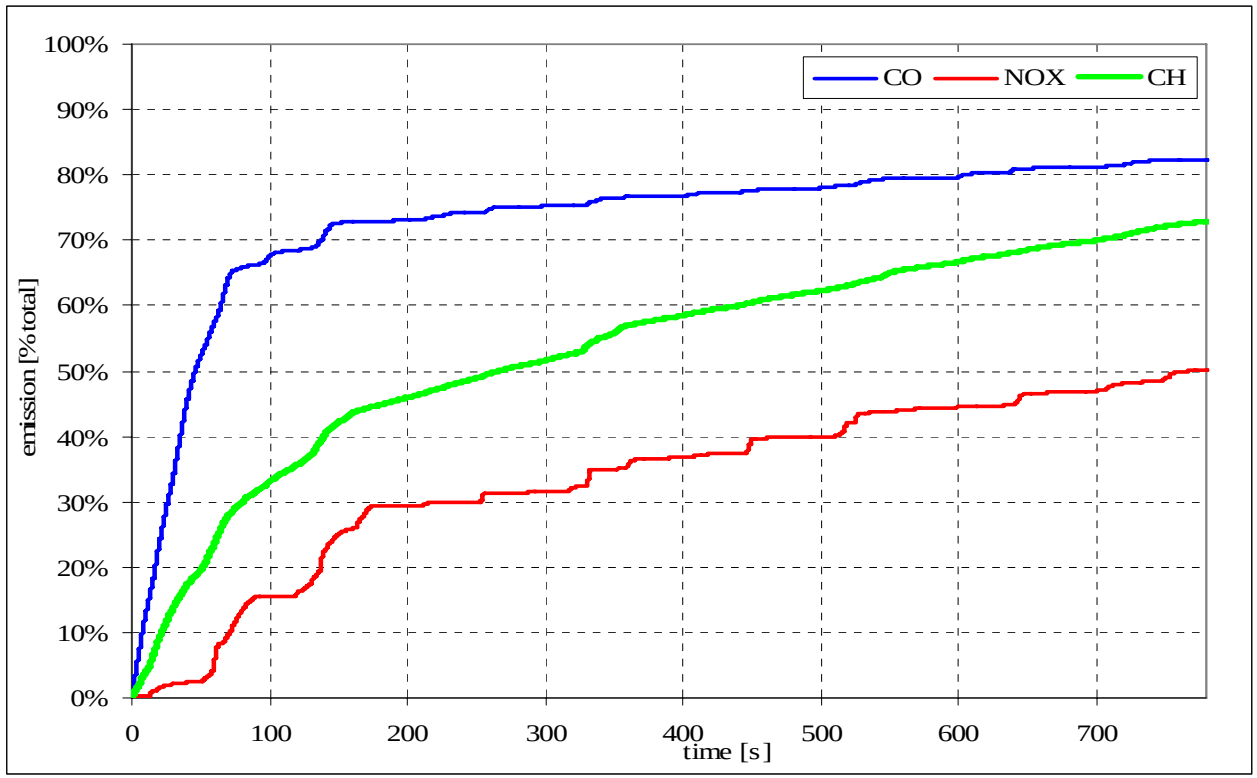

Relative emission versus time for vehicle B (Euro 3) in the urban part of the type 1 test (Source: Environmental Protection Centre, Motor Transport Institute, Warsaw, Poland)

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The ratio **of the emission with LPG in LPG mode** divided **by the emission with petrol in petrol mode** in the period equivalent to the operation with LPG in LPG mode (referred to as “LPG/petrol emission ratio” hereinafter) is calculated for each pollutant for “non-intrusive” retrofit systems installed in vehicles A and B. The following assumptions are applied:

(a) The retrofit system is truly, not apparently, “non-intrusive”, i.e. the emission with petrol before the retrofit is identical to that with petrol in LPG mode or in petrol mode after the retrofit.

(b) The switch over time is equal to 60 s. This time is selected because the EU draft comitology Regulation for LDV specifies that “During the type 1 test the vehicle shall use only petrol for a maximum of 60 s when operating in gas mode”.

(c) The ratio of the emission with petrol measured over the type 1 test to the emission limit is equal to 40%, 60%, 80%, 100%

(d) The total emission in the type 1 test in LPG mode is equal to the limit.

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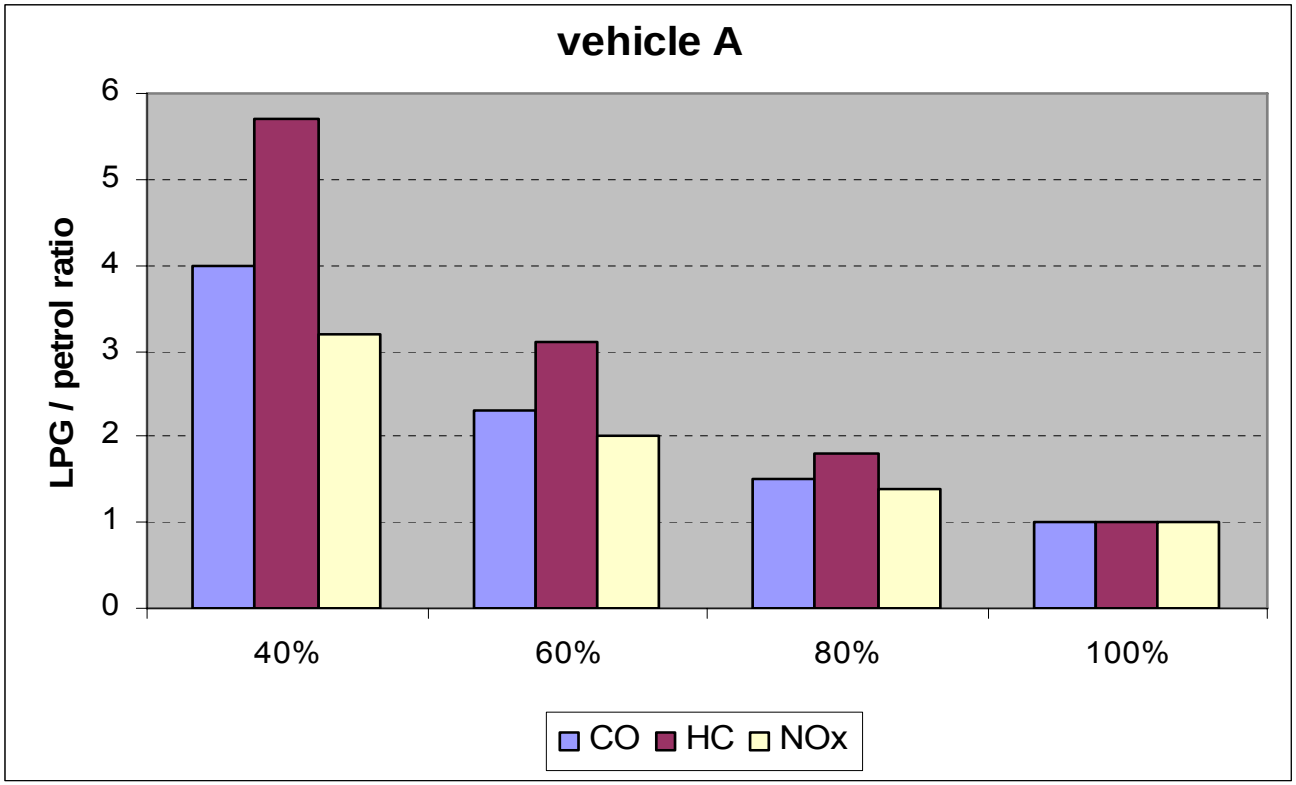

LPG/petrol emission ratio for different ratio of actual emission with petrol to limit (40%, 60% 80%, 100%) for "non-intrusive" retrofit system

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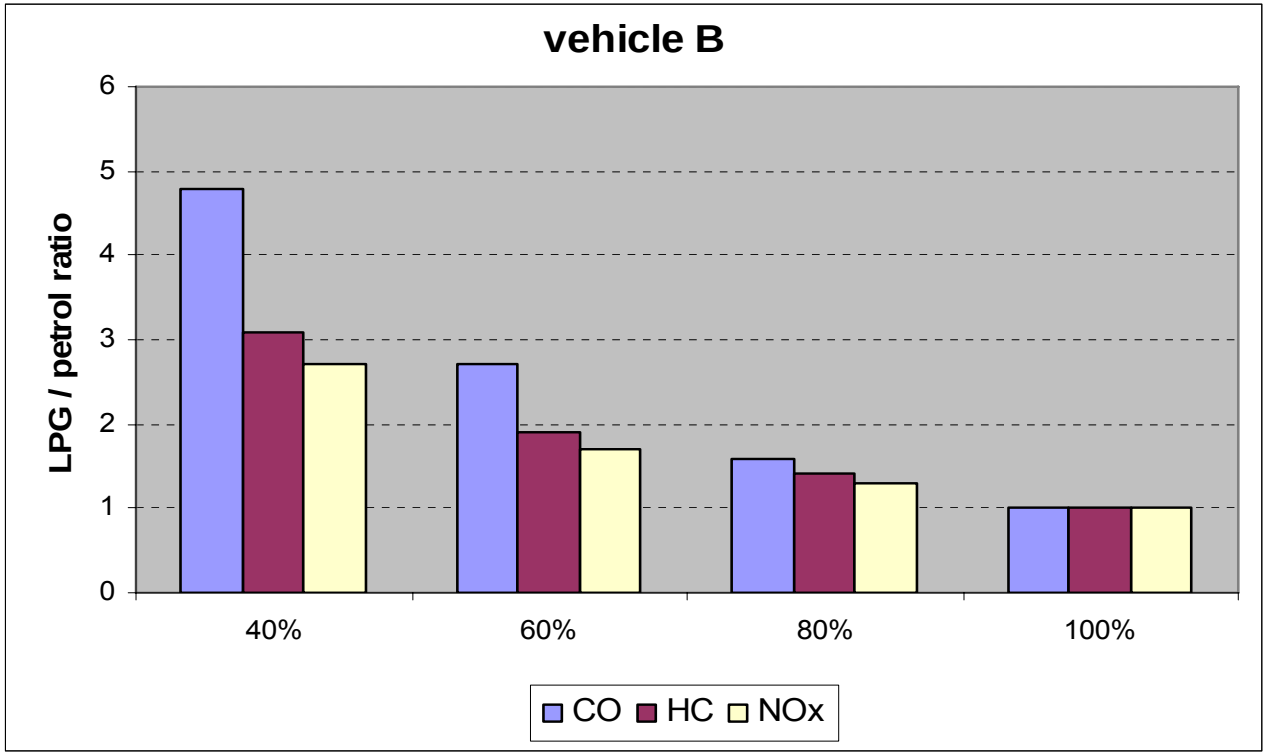

LPG/petrol emission ratio for different ratio of actual emission with petrol to limit (40%, 60% 80%, 100%) for "non-intrusive" retrofit system

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The ratio of the actual emission with petrol to the limit value is usually in the order of 40% - 60% for Euro 3 and Euro 4 vehicles. If:

- it is equal to 40%,
- the relative emission versus time curve is similar to those shown above,
- and the switch over time is 60 s,

the emission with LPG may be even about 5 times higher than that with petrol and the vehicle is deemed to comply with the requirements of Regulation 115 for “non-intrusive” retrofit systems.

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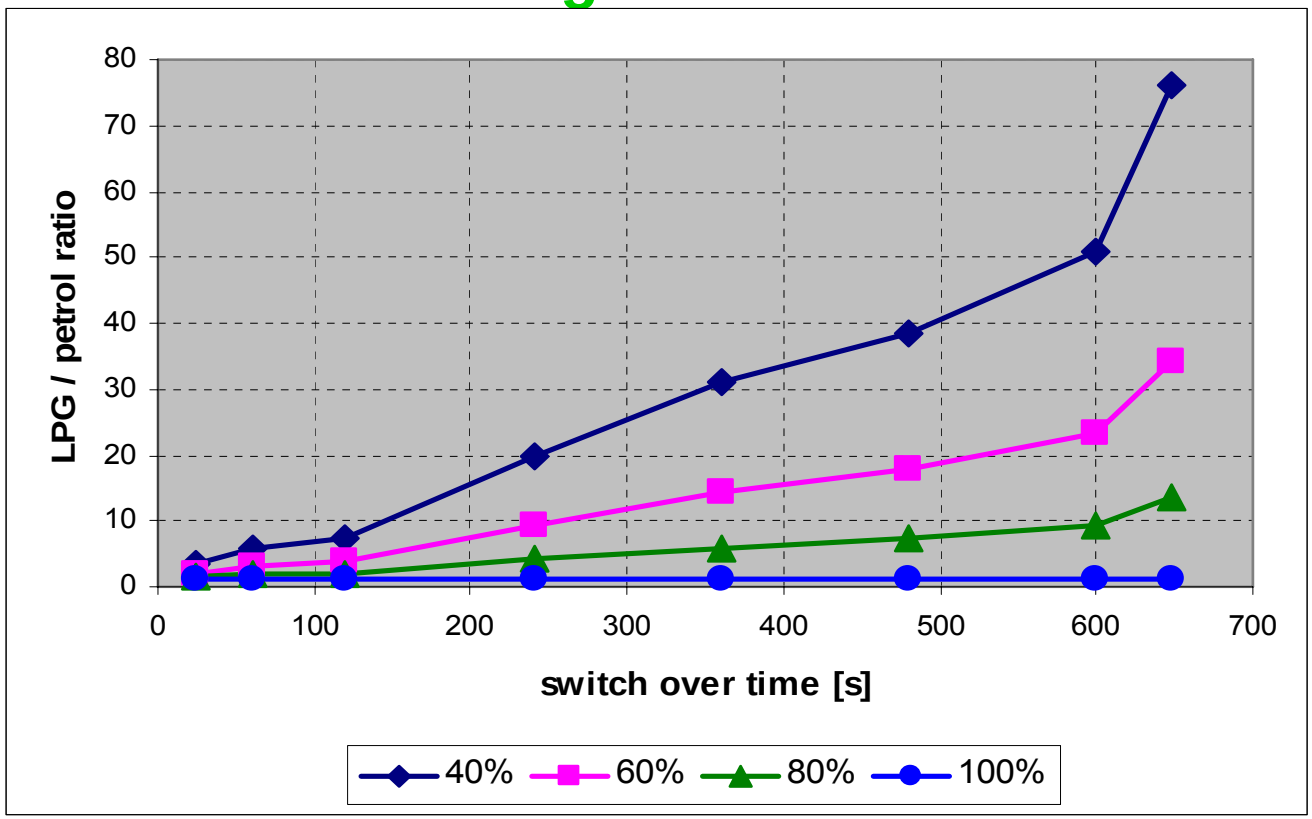

LPG/petrol emission ratio versus switch over time for different ratio of actual emission with petrol to limit (40%, 60% 80%, 100%) for "non-intrusive" retrofit system (HC, vehicle A)

Proposals for Draft Amendments and Comments to Regulation 115

In Figure above the switch over time varies from 25 s (the shortest time found) to 648 s (the longest time found). If:

- the ratio of the actual emission with petrol to the limit value is 40 %,
- the switch over time is 648 s,
- and the relative emission versus time curve is similar to that shown above,

the emission with LPG may be even 70 times higher than that with petrol and the vehicle is deemed to comply with the requirements of Regulation 115 for "non-intrusive" retrofit systems. Even when the switch over time is 25 s, the emission with LPG may be 3 times higher.

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The purpose of this part of the presentation is to draw attention of this group to the problem of switch over time.

No concrete proposals are given how to solve the problem.

Several options are available from very lenient to very stringent.

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A Regulation concerning retrofit gas systems serves a purpose only if it ensures, among other things, that the vehicle after the retrofit is at least as clean as the original vehicle. Regulation 115 does not seem to meet this precondition. This is its main defect and the main problem to be solved.

LPG is believed to be a “clean” fuel. It has several features that can contribute to the reduction of emission. It is necessary to take advantage of those features, but it is not the case. The emission with LPG may be several, in extreme case even more than 70, times higher than that with petrol (Figure 5) and the system passes the tests.

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IV. Adaptation to technical progress and correction of provisions for M2, M3, N2, N3 vehicles

- 13-mode test does not apply to Euro 3 and later vehicles.
- This proposal refers only to the conversion of diesel engines to SI gas engines. It does not refers to dual-fuel engines.
- It is proposed to amend paragraph :

  „6.1.2.6. Exhaust emissions (M2, M3, N2 and N3 categories of vehicles)”.
- Details are given in document GFV-02-4.

Proposals for Draft Amendments and Comments to Regulation 115

V. Correction of errors, unclear provisions etc.

It is proposed to:

– amend several paragraphs,

– insert new paragraphs,

– some proposals are given below.

Proposals for Draft Amendments and Comments to Regulation 115

Insert new paragraphs 2.xx, to read:

“2.xx. “Safety device” means a pressure relief valve or fusible plug (fuse) or a combination of these two devices, as defined in Regulation 67, 01 series of amendments.”

“2.xx. “Original vehicle/engine” means a vehicle/engine before the installation of the retrofit system”

“2.xx. “Gas injection device” means .....?”

Proposals for Draft Amendments and Comments to Regulation 115

Paragraph 2.2 needs correcting and clarifying:

“2.2. "Specific LPG or CNG retrofit system of an approved type" means systems, which do not differ in such respect as:

2.2.1……..

2.2.2. pressure regulator/vaporiser type by the same manufacturer (only the type with which the parent vehicle(s)/engine(s) is(are) fitted can be used; different versions in respect of the maximum gas delivery are permitted);

2.2.3. gas fuelling system type by the same manufacturer (i.e. induction mixer or gas injection device or injector device, vapour or liquid, single or multi-point injection system, direct or indirect injection; for the gas injection device or injector only the type with which the parent vehicle(s)/engine(s) is(are) fitted can be used, different versions in respect of the maximum gas delivery are permitted);

2.2.4. …….

Proposals for Draft Amendments and Comments to Regulation 115

2.2.5. the fuel container type (i.e. as amended by TRANS/WP.29/GRPE/2005/8 liquid take off/ vapour pressure, vapour take off, liquid take off / pressurized by pump), the safety devices and fuel container accessories, as required by Regulation No. 67, 01 series of amendments, or Regulation No. 110, where applicable. (i.e. relief valve, …);"

2.2.6. ……..

2.2.7. ECU (Electronic Control Unit) type by the same manufacturer (only the type with which the parent vehicle(s)/engine(s) is(are) fitted can be used; versions for different cylinder number/configuration are permitted);

2.2.8. the same basic software principles and control strategy (software versions for different cylinder number/configuration are permitted);

2.2.9…….

2.2.10…….

Proposals for Draft Amendments and Comments to Regulation 115

Paragraphs 2.5.1 and 2.5.1.1 need correcting and clarifying:

“2.5.1. According to this Regulation, "a member of the family" is a vehicle equipped with retrofit system type of which type approval is requested and sharing the following essential characteristics with its parent one:”

Comment.

(i) According to our interpretation this definition refers to a vehicle after the retrofit **(“....a vehicle equipped with retrofit system type**....”), but according to some technical services this definition refers to the situation before the retrofit, to the original vehicle. This problem should be clarified.

(ii) The definition in the current paragraph 2.5.1.1 should apply only to M1 and N1 vehicles. It is not suitable for M2, M3, N2, N3 vehicles. According to Regulation 49, an engine type-approved under Regulation 49 can be used in any vehicle, irrespective of its manufacturer and category. It is not justified that Regulation 115 should be more restrictive than Regulation 49. That is why it is proposed to introduce separate definition for M2, M3, N2, N3 vehicles.

Proposals for Draft Amendments and Comments to Regulation 115

Paragraph 6.1.2.5.1.1, amend to read:

"6.1.2.5.1.1. Three measurements of tailpipe emissions shall be performed after a cold start with each fuel:

…….

The reference mass of the parent vehicle equipped with the retrofit system and tested with petrol shall be equal to that of the original vehicle. The reference mass of the parent vehicle equipped with the retrofit system and tested with LPG shall be determined according to the provision of Regulation 83.

The emissions of CO, HC, NOx and HC + NOx are calculated according Regulation No. 83. 4/ "

Justification.

(i) The reference mass of a vehicle equipped with the retrofit system differs from that of the original vehicle. A question arises how to test vehicles after the retrofit.

Proposals for Draft Amendments and Comments to Regulation 115

Paragraph 6.1.2.5.1.2, amend to read:

"6.1.2.5.1.2. The test vehicle(s) equipped with the retrofit system, and with the reference petrol, shall comply with the limit values according to the type approval of the vehicle(s) including the deterioration factors applied during the type approval of the vehicle(s).

This condition is deemed to be met if the emissions values for each pollutant or combination of pollutants obtained in each test with reference petrol are less than the limit divided by the deterioration factor.

Notwithstanding the provision of the first indent, the mono-fuel vehicle may be tested with the reference petrol before the retrofit if tests after the installation of the retrofit system are not possible or may result in false results. The total vehicle mileage between the tests before and after retrofit shall not exceed [200] km. "

Proposals for Draft Amendments and Comments to Regulation 115

Paragraph 6.1.3.1, amend to read:

"6.1.3.1. One LPG retrofit system sample as described in paragraph 2 of this Regulation, installed in the parent vehicle(s) or on the parent engine(s) shall be submitted to the test procedures of paragraph 6.1.3.2. or 6.1.3.3. The measured maximum power with LPG shall be lower than that measured with petrol + 5 per cent.

Notwithstanding the provision of the first indent, mono-fuel vehicles of M1 and N1 categories may be tested with the reference petrol before the retrofit if tests after the installation of the retrofit system are not possible or may result in false results. The total vehicle mileage between the tests before and after the retrofit shall not exceed [200] km."

Notwithstanding the provision of the first indent, vehicles of M2, M3, N2, N3 categories or their engines shall be tested with the reference diesel fuel before the retrofit. The total vehicle mileage between the tests before and after the retrofit shall not exceed [500] km. The total engine operation time between the tests before and after the retrofit shall not exceed [20] h.

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An example of shortcomings of editorial nature in Regulation 115

- Annex 1A, item 2 – „trade name or mark”
- Annex 2A, plate – „name or trade mark”
- Annex 3A, item 2.1 – „trade name or mark holder”