Informal document No. **GRPE-49-13**
(49th GRPE, 10-14 January 2005
agenda item 5.3.)

Comments on the proposal for draft amendments to Regulation No. 110 (ref. document TRANS/WP.29/GRPE/2005/4) including a new proposal for amendments to Regulation No. 110.

Transmitted by the expert from the Netherlands

Referenced documents

[1] Proposal for draft amendments to Regulation No. 110
TRANS/WP.29/GRPE/2005/4, dated 15 October 2004

[2] Proposal for a new draft regulation using compressed hydrogen
TRANS/WP.29/GRPE/2004/3, dated 31 October 2003

[3] Regulation No. 67: equipment for motor vehicles using LPG
E/ECE/TRANS/505 Add.66/Rev.1

[4] Regulation No. 110: equipment for motor vehicles using CNG
E/ECE/TRANS/505 Add.109/Rev.2

General comments

Document [1] touches upon three different subjects of amendment:

I New definition called "Cylinder assembly",
II Alternative requirements for the installation of an "Automatic Cylinder Valve" and
III Different requirements for periodic requalification.

Ad. I The new definition is not in line with the definition of "Cylinder Assembly" as used in reference doc. [2].

Ad. II In the justification it is stated that the installation of an automatic valve (remotely controlled service valve) on each cylinder is less safe than the installation of a single valve on each cylinder assembly. This statement is however not founded in [1]. In addition, this statement is not in line with the current regulations for LPG (R67) and CNG (R110).

Ad. III Acceptable.

New proposal to amend Regulation No. 110

Insert a new paragraph 2.4.1.

"2.4.1. "Container Assembly" means two or more Containers with integral interconnecting fuel lines protectively encased inside a housing shell."

Insert a new paragraph 6.2.2.

"6.2.2. Container assembly

6.2.2.1. A container assembly shall be approved as one container if both the container assembly and constituent containers are approved in accordance with the provisions laid down in annex 3 to this Regulation.

6.2.2.2. Alternatively a container assembly shall be approved as one container if the container assembly fulfils the provisions laid down in annex 3 to this Regulation. The constituent containers need not fulfil all the provisions laid down in annex 3 to this Regulation provided that the container assembly fulfils all the provisions of annex 3.

6.2.2.3. For all types of container, the container assembly shall fulfil the requirements of paragraphs B15, B20 and B21 of annex 3 to this Regulation. The container assembly shall be encased inside a protective housing shell.

6.2.2.4. A maximum of four containers per container assembly shall be permitted.

6.2.2.5. Flexible fuel lines shall not be used as integral interconnecting fuel lines in a container assembly."

Paragraph 17.4. to paragraph 17.4.3.1., amend to read "container" into "container or container assembly".

Paragraph 17.4.4., amend to read:

"17.4.4. A container or container assembly including the accessories shall be mounted and fixed so that the following accelerations can be absorbed (without degrading the function of safety devices) when the container or container assembly is full. No uncontrolled release of natural gas is permitted.

Vehicles of categories M1 and N1:
a) +/-20 g in the direction of travel
b) +/-8 g horizontally perpendicular to the direction of travel

Vehicles of categories M2 and N2:
a) +/-10 g in the direction of travel
b) +/-5 g horizontally perpendicular to the direction of travel

Vehicles of categories M3 and N3:
a) +/-6.6 g in the direction of travel
b) +/-5 g horizontally perpendicular to the direction of travel

A calculation method can be used instead of practical testing if its equivalence can be demonstrated by the applicant for approval to the satisfaction of the technical service."

Paragraph 17.5., amend to read:

"17.5. Accessories fitted to the container or container assembly"

Paragraph 17.5.1.1, amend to read:

"17.5.1.1. The flow of natural gas from a container or container assembly into the fuel supply line shall be secured with an automatic valve (idle closed). This valve shall be mounted directly on or within either every container or one container in a container assembly."

Insert new paragraph 17.5.1.3. and 17.5.1.4., to read:

"17.5.1.3. In the event of breakage of the refilling lines or fuel line(s), the automatic valves referred to in paragraphs 17.5.1.1 shall not be separated from the container or container assembly.

17.5.1.4. Automatic valve(s) isolating each container or container assembly, shall close in the event of either a malfunction of the CNG system that results in the release of gas or severe leakage between the container or container assembly and the pressure regulator."

Annex 3, paragraph 4.1.4., amend to read:

"4.1.4. Periodic requalification

Recommendations for periodic …… conditions specified herein. Each cylinder shall be visually inspected at least every **48** months **after the date of its entry into service on the vehicle (vehicle registration)**, and at the time of any re-installation, for external damage and deterioration, including under the support straps. The visual inspection shall be performed ….. to remain in service."

Justification

(ref. report TNO/MEP, december 2004)

The new definition is not in line with the definition of "Cylinder Assembly" as used in reference doc. [1].
The differences within the two definitions "Cylinder Assembly" in referenced docs [1] and [2] are summarised in the table below.

Item	Compressed hydrogen	Draft amendments R110
1. Number of cylinders in an assembly	Between 2 and 4	2 or more
2. Installation of the assembly	Encased inside housing shell	Support straps
3. Interconnecting fuel lines	No flexible fuel lines	-
4. Automatic valve	A single automatic valve per assembly (idle closed)	A single automatic valve
5. Tests	e.g. Bonfire test, impact damage test, leak test	-

From the table it can be observed that the requirements for the assembly differ on various items. The influence of each of these items on the safety of the system are considered below.

item 1 *Number of cylinders in an assembly;* For safety reasons it is desirable that the number of interconnected cylinders is not too large, see under ad 4. 'automatic valve'. Therefore it is necessary to define a maximum number of cylinders in the assembly. In the draft amendments no maximum is prescribed.

Item 2 *Installation of the assembly;* The interconnection of a number of cylinders means that the system is extended with a number of cylinders and interconnecting lines. Therefore the probability of a Loss of Containment (LOC) increases. One of the underlying causes for a LOC is external impact on interconnecting lines. In order to reduce the possibility of such a LOC it is preferable to protect the assembly against external impact by using a housing shell. In the draft amendments no housing shell is prescribed.

item 3 *Interconnecting fuel lines*: Since the interconnection lines are part of the cylinder assembly, these lines should have the same integrity as the cylinder itself. For flexible interconnecting lines it is not known whether this material has the same life time as fixed lines. For safety reasons it is therefore recommended to use fixed interconnecting lines only. In the draft amendments the use of flexible lines are not excluded.

item 4 *Automatic valve:* The installation of an automatic valve on an assembly, instead of an automotive valve on each cylinder, reduces the number of automatic valves to be installed. This means that the number of potential leak sources is reduced. On the other hand, the installation of an automatic valve on each cylinder reduces the amount of gas that releases in case of a LOC (see also under item 3 'Installation of an automatic valve'). Both the Regulation for compressed hydrogen and the draft amendments on R110 allow the installation of a single valve on the assembly. In order to maximise the amount of gas that can release in case of a LOC in a cylinder assembly it is recommended to maximise the number of containers in one assembly. As mentioned under ad. 1no maximum number of cylinders is described in the draft amendments.

item 5 *Tests*: As mentioned above, the interconnection of cylinders increases the possibility of a LOC, e.g. by external impact. In order to reduce this risk it is recommended to use a housing shell (see under ad. 2). The effectiveness of this housing should be analysed in an impact test. Since this is not the only test in which a single cylinder might show a different behaviour than a cylinder assembly it is recommended to perform the other tests (like the

bonfire test, leak test, etc.) on the assembly as well. The draft amendments do not include the performance of these tests on the assembly.

Based on the comparison of the two definitions it is concluded that in the draft amendments [1] a number of important elements with respect to the safety of the assembly are missing.

In the justification it is stated that the installation of an automatic valve (remotely controlled service valve) on each cylinder is less safe than the installation of a single valve on each cylinder assembly. This statement is however not founded in [1]. In addition, this statement is not in line with the current regulations for LPG (R67-01) and CNG (R110).
In order to show the differences with respect to safety a comparison is made between these two configurations.

In figure 1a an assembly of n-containers is presented with an automatic valve installed on each cylinder. In figure 1b the same assembly is shown, however in this case only a single automatic valve is installed on the cylinder assembly.

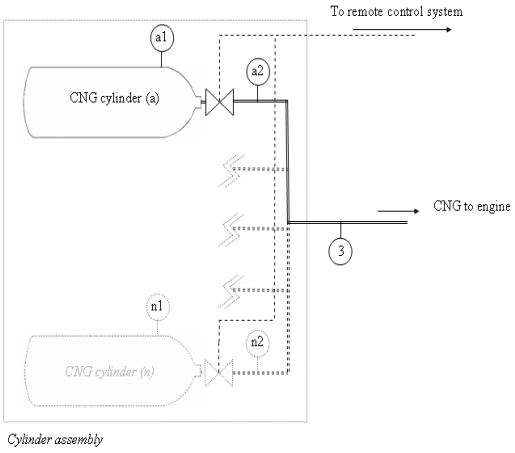

Figure 1a: Automatic valve on each cylinder

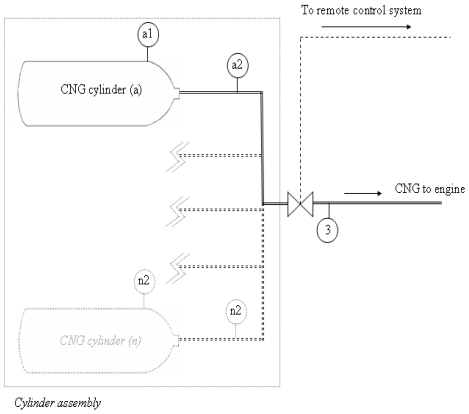

Figure 1b: Automatic valve on each assembly

In each figure a number of 3 study nodes (1, 2 and 3) are defined. For each of these nodes the consequences of a LOC are studied in more detail. The numbering of these scenarios refers to the numbering of the study nodes.

Scenario a1 /../ n1: Leakage of a CNG cylinder
A leakage at location 1 will result in the release of CNG from the cylinder. The total amount of gas that is released in this scenario depends on the configuration and is specified below.

1) *Installation according to R110* (see figure 1a); Due to the presence of the automatic valve directly mounted on the cylinder, the release will be limited to the content of the cylinder involved.
2) *Installation according to draft amendments (see figure 1b);* Due to the presence of the automatic valve mounted downstream of the cylinder assembly the release will not be limited to the content of the cylinder involved but include the content of the whole cylinder assembly.

Scenario a2 /../ n2: Leakage of an interconnecting fuel line
A leakage at location 2 will result in a release of CNG from the interconnecting fuel line. The total amount of gas that is released in this scenario depends on the configuration and is specified below.

1) *Installation according to R110* (see figure 1a); Due to the presence of the automatic valve directly mounted on the cylinder, the release will be limited to the content of the interconnecting fuel lines and the main fuel line. The automatic valve will prevent the release of gas from the cylinder.
2) *Installation according to draft amendments (see figure 1b);* Due to the presence of the automatic valve mounted downstream of the cylinder assembly the release will not be limited to the content of the interconnecting fuel lines but include the content of the whole cylinder assembly.

Scenario 3: Leakage of the main fuel line
A leakage at location 3 will result in the release of CNG from the main fuel line. The total amount of gas that is released in this scenario depends on the configuration and is specified below.
1) *Installation according to R110* (see figure 1a); Due to the presence of the automatic valve directly mounted on the cylinder, the release will not be limited to the content of the main fuel line but also include the content of the interconnecting fuel lines.
2) *Installation according to draft amendments (see figure 1b);* Due to the presence of the automatic valve mounted downstream of the cylinder assembly the release will be limited to the content of the main fuel line. The automatic valve will prevent the release of gas from the interconnecting fuel lines.

The results of the analysis are summarised in the table below.

Study note	valve on each cylinder	valve on each cylinder assembly
1	Release is limited to the content of 1 cylinder	Release of the content of the cylinder assembly, i.e. content of n cylinders and interconnecting lines
2	Release is limited to the content of the interconnecting lines and the main fuel line	Release of the content of the cylinder assembly, i.e. content of n cylinders and interconnecting lines
3	Release of the content of the interconnecting lines and the main fuel line	Release is limited to the content of the main fuel line

From this table it can be concluded that in case of a LOC at location 1 or 2, the outflow is less in case the automatic valve is mounted directly on each cylinder. This difference in the amount of gas that is involved is significant, i.e. a factor of (n-1). In case of a LOC at location 3, the outflow is less in case the automatic valve is mounted on the cylinder assembly. This difference in the amount of gas that is involved is minor, due to the fact that the content of the interconnecting lines is rather low compared to the content of the main fuel line.

The above mentioned LOC scenarios (1a/../1n, up to 3) assume a leakage of the equipment in combination with the correct functioning of the automatic valve. A LOC scenario in combination with a failure of the automatic valve will result in a larger release of gas. For the configuration according to R110 the outflow increases significantly in case of a LOC at location 2 or 3. For the configuration according to the draft amendments the outflow increases significantly in case of a LOC at location 3. The likelihood of such a scenario is however significantly lower since both events have to take place at the same time. This means that the likelihood for this scenario is the quotient of both (failure) frequencies resulting in a relatively low probability.

Another scenario that can occur is the failure of the automatic valve. This scenario will result in an undesired flow of gas in the direction of the motor compartment. For the configuration according to R110 the probability of such an undesired situation is higher than for the configuration as proposed in the draft amendments. This can be explained by the fact that number of valves is larger, i.e. (n-1) valves, through which the probability increases with a factor (n-1). On the other hand, the consequence of failure of the automatic valve installed on the cylinder assembly is larger due to the larger amount of gas that is involved.

Based on the analysis of scenarios as described above it is noticed that the probability of failure of the automatic valve is larger for a configuration in accordance with R110. On the other hand, the consequences of a LOC are larger in case of a configuration in accordance with the draft amendments. In order to determine the overall consequences for the safety of the system it is necessary to calculate the risk (i.e. quotient of probability and consequence). At this moment there is however a lack of insight in the risks related to the two configurations. It is therefore not possible to justify the statement as presented in [1].