Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labelling of Chemicals

24 June 2022

Sub-Committee of Experts on the Transport of Dangerous Goods

Sixtieth session
Geneva, 27 June-6 July 2022
Item 5 (c) of the provisional agenda
Transport of gases: miscellaneous

Report of the intersessional working group on the pV-product limit for pressure receptacles

Transmitted by Chair of the informal working group

1. The working group met under the chairmanship of Dr Georg W. Mair (Germany) a fourth time on the 27 January 2022 from 1 to 5 p.m. Geneva time (CET). In total 17 delegates from Belgium, Germany, Sweden, The United Kingdom, The United States of America, CGA, ECMA, EIGA and ISO joined the meeting. The delegation from Germany provided the secretary.

2. The working group (WG) considered the following documents in the meeting: ST/SG/AC.10/C.3/2020/18 with related informal documents INF 52 (ECMA) and INF 53 (GER), the last report of the intersessional working group on the pV-product limit for pressure receptacles UN-SCETDG-58-INF.38 and the reports of the TDG Sub-Committee of Experts ST/SG/AC.10/C.3/114, ST/SG/AC.10/C.3/116 and ST/SG/AC.10/C.3/118.

3. For the meeting the chair drafted an agenda that was confirmed by the participants. This agenda addressed the parts mentioned in the following items in the order of discussion. Again, this online meeting was guided by the usage of a prepared set of slides that are appended to this report.

4. The chair repeated all results elaborated so far. These are especially the reference values for the criticality of consequences: 30 fatalities or 450 injured persons at a reference population density of 6000 pers./km^2. Also, the range of consequences that was calculated for 1.5 million, 2 million and 3.6 million bar litres[1] during the last meeting was shown again.

5. Representatives from EIGA asked for further clarifications about the simulation model used for the pressure wave and for confirmation that the results are exclusively valid for hydrogen. CGA stated that not only the pressure peak but also the duration of the pressure wave is of importance for the determination if the consequence. Some details of the model that is not just a simple TNT-based model were discussed again.

6. Initiated by a question of an expert from EIGA the discussion of risk assessment versus the proposed pV-limitation was raised again. The chair explained that a risk assessment would not solve the initial problem with salvage pressure receptacles. He described some of the problems met when performing an adequate quantitative risk assessment. Already a qualitative one is an enormous effort, since it may then become necessary to get an agreement for the result of the risk assessment from all countries involved in a transport. Therefore, the chosen approach for the limitation of the maximum possible consequence for pressure receptacles seems to be the simplest and easiest way for the avoidance of acceptance problems and for avoiding the high effort for risk assessment in transport of hydrogen and other gases transported in pressure receptacles.

[1] In the context of the consequence analysis addressing the physical energy of a sudden rupture the pressure must stand for the actual pressure at the time of rupture.

7. ECMA raised again the issue of containments larger than 3000 litres. The group stated that those units are neither covered by the definition of pressure receptacles nor in the scope of this working group. Therefore, the limitation of a pressure-volume-product[2] as it is under discussion in this WG exclusively for pressure receptacles will not limit the volume or the acceptable pV-product of other containments than pressure receptacles.

8. After having clarified this aspect, the chair came back to the open point of the final discussion of the pV-value that should be proposed by the WG to the plenary. The expert from the United Kingdom and other member states stated that they had some problems in finalizing their national advisory process. Especially the intention of tracing back all relevant details could not be performed without a detailed discussion with experts from BAM. The chair confirmed that he is available for relevant discussions. Thus, this item could not be finalised and will need a 5th meeting of the WG as soon as the national analysis and exchange of experts are finalised. Especially the United Kingdom and Sweden expressed their interest in interdisciplinary national analysis.

9. With the intention of finalising the work of the WG as far as possible the chair tried to clarify the current opinion of the delegates on the provided consequence values, under the reservation that the outcome of the provided simulations will be confirmed later. In this context an EIGA representative presented a table on the pressure limitation that results from a pV-limit dependent on the water capacity of a pressure receptacle. He stated that the resulting pressure limit to PH = 450 bars[2] (500 bars) for the largest tube of 3000 litres should be sufficient for the moment. ECMA stated that there are larger units on the road with a pressure of 450 bars and higher. But they do not fall under the definition of a pressure receptacle and are approved according to special permits.

10. The chair asked the experts around the virtual table what they were thinking about the pV-limits when reflecting the provided consequence level. Almost all members stated that they preferred the pV-limit of 1.5 Mio bar litres[1]. Some of them are willing to accept 2.0 million bar litres[1] if there are very good economic reasons, which had not been provided so far. A pV-product of 3.6 million bar litres[1] was not acceptable. This was discussed under the reservation that the outcome of the provided simulations can be confirmed in the last meeting.

11. The chair raised a new issue that needs to be explained for being consistent in all details: The analysis has been performed for the actual pressure at the time of rupture, which differs from test pressure PH[1,2]. Except for fire engulfment, the maximum service pressure at 65°C is seen as reference pressure for the consequence assessment. All analysis so far is based on the properties of hydrogen with a maximum service pressure that is just about 80% (exact 79%) of test pressure PH (compare EN 17339). This leads to a nominal PH-water capacity-product that – in case of hydrogen - is 25% higher than the actual pV[1] used in the calculation of consequence as far as the analysed failure is not based on a gas temperature higher than 65°C. This means the consequence displayed for hydrogen with an actual pV-product of 1.5 million bar litres[3] would cover the rupture of a pressure receptacle filled with hydrogen up to a nominal PH-Vol-value of nearly 1.9 million bar litres[2], which should be rounded down to 1.8 million bar litres[2].

12. On the one hand, it needs to be reflected on that most other gases will show a more severe consequence than hydrogen, which might make it necessary to introduce a gas-specific pV-value[4] in e.g., packing instruction P 200. On the other hand, this made clear that pressure receptacles with a pV-product[2] near to the limit should be equipped with a (T)PRD for a reliable avoidance of a rupture with a gas heated up to a temperature of more than 65°C[3].

[2] The only relevant pressure value, which can be used for the definition of pressure receptacles is the test pressure. It is independent from the gas and is clearly marked on each pressure receptacle. Further gas requirements are presented in packing instructions like P 200.

[3] In the case of hydrogen, the actual pressure in temperature range below 65°C (maximum service pressure) stays below 120% test pressure PH.

[4] This would address a gas related selection of pressure receptacles depending on the developed pressure at 65° and the gas-dependent consequence.

13. As a last step in this meeting and for some preparation of the recommendations of the WG, the group pre-discussed some explanations that should be provided in the final decision paper, which are shown in the appended set of slides and in the written appendix.

14. The group is interested in continuing its work and in finding a proposal for a test pressure based pV-limit[2] and sees the meaning for the capacity of salvage pressure receptacles without a limitation of its water capacity. Therefore, the working group asks the Sub-Committee to confirm the continuation of this work.

- END OF THE REPORT -–

Appendix

For giving a deeper impression of the state of the work the considered changes are presented here as they would look when presented as proposals:

15. Proposal 1 (compare ST-SG-AC10-C3-2020-18, proposal 1)

Modify para. 1.2.1 as follows:

Pressure receptacle means a transportable receptacle intended for holding substances under pressure including its closure(s) and other service equipment and is a collective term that includes cylinders, tubes, pressure drums, closed cryogenic receptacles, metal hydride storage systems, bundles of cylinders and salvage pressure receptacles with a test pressure volume product not exceeding [1.8] million bar litres;

16. Proposal 2 (compare ST-SG-AC10-C3-2020-18, proposal 2)

Modify the definition of salvage pressure receptacles in Para 1.2.1 as follows:

Salvage pressure receptacle means a pressure receptacle ~~with a water capacity not exceeding 3 000 litres~~ into which are placed damaged, defective, leaking or non-conforming pressure receptacle(s) for the purpose of transport e.g., for recovery or disposal;

17. Rational

The pV-value presented in proposal 1 is an estimated reference value that considers almost all expectable worst-case scenarios for a single pressure receptacle during the transport of compressed hydrogen[5]. As such it provides a representative reference for the avoidance of catastrophic consequences without any consideration of the likelihood of a sudden rupture of a pressure receptacle. As reference limit between a major consequence and a catastrophic consequence of 30 fatalities or 450 injured persons at a population density of 6000 pers/km^2 has been fixed.

Due to the variability of scenarios with respect to people, buildings and secondary effects the presented pV-value cannot be accurately calculated. The effect of projectile is not considered explicitly but is merged in the pressure-wave-based consequence estimation.

Compressed hydrogen[6] has been chosen as the reference gas since it provides the lowest pressure impulse of frequently transported compressed gases, which is appropriate for the purpose of a global definition for a containment. The rupture of a pressure receptacle filled with gases such as non-flammable, another flammable or toxic gas is expected to cause more severe consequences than filled with compressed hydrogen.

If avoidance of catastrophic consequences is intended for all gases, then a gas specific pV-value should become a necessary requirement in the relevant packing instruction. This value

[5] with exception of fire engulfment, especially for type 1

[6] The pressure wave caused by a sudden rupture of a pressure receptacle containing compressed hydrogen is expected to have more severe consequences than the (partial) conversion of the chemical energy of hydrogen into a subsequent pressure wave. This is not valid for other flammable gases.

is in all cases probably lower than the one for hydrogen. This is not part of the work of this group.

The proposed definition of pressure receptacles does not change the general limit of a water capacity up to 3000 litres for pressure receptacles. It just impacts the water capacity of salvage pressure receptacles since their amount of a dangerous good is limited by the pressure receptacles accepted for being stored inside.

Containments with a water capacity of more of 3000 litres or a higher pV-product than [1.8 million bar litres] do not fall under the definition of pressure receptacles and should be approved and operated under consideration of additional requirements like a risk assessment for the design under consideration of accidental loads, fatigue and service conditions.

BAM
Bundesanstalt für Materialforschung und -prüfung

Sicherheit in Technik und Chemie

January 27th, 2022

4TH MEETING
TDG - INTERSESSIONAL WG on pV-PRODUCT

REPORT

Agenda accepted

Start at 13:00 CEST

Top 1: **Agenda, attendance and a short introduction round**

Top 2: **Outcome of 59th UN-SubCom ETDG**

Top 3: **Summary of the preliminary meetings**

Top 4: **Further analysis concerning consequences**

Break at about 15:00

Top 5: **Determination of the appropriate pV-value**

Top 6: **Resulting proposals concerning the task**

End at about 17:00

Top 2: The task

Outcome of 57th UN-SubCom ETDG

Report ST/SG/AC.10/C.3/114 says:

Modifications concerning salvage pressure receptacles
Document: ST/SG/AC.10/C.3/2020/18 (Germany)
Informal documents: INF.52 (ECMA) INF.53 (Germany)

35. Following the comments received during the informal session on informal documents INF.52 and INF.53, the Sub-Committee adopted the amendments under proposal 3 in ST/SG/AC.10/C.3/2020/18 (see annex I). It was agreed to set up an intersessional working group led by Germany to further discuss proposals 1 and 2, and to submit a new proposal for consideration during the next biennium.

Outcome of 59th UN-SubCom ETDG

UN-SubCom ETDG – WG „pV-Limit" Report of the Sub-Committee of Experts on the Transport of Dangerous Goods on its fifty-nineth session

held in Geneva from 29 November to 8 December 2021

Report ST/SG/AC.10/C.3/118 concerning INF.18

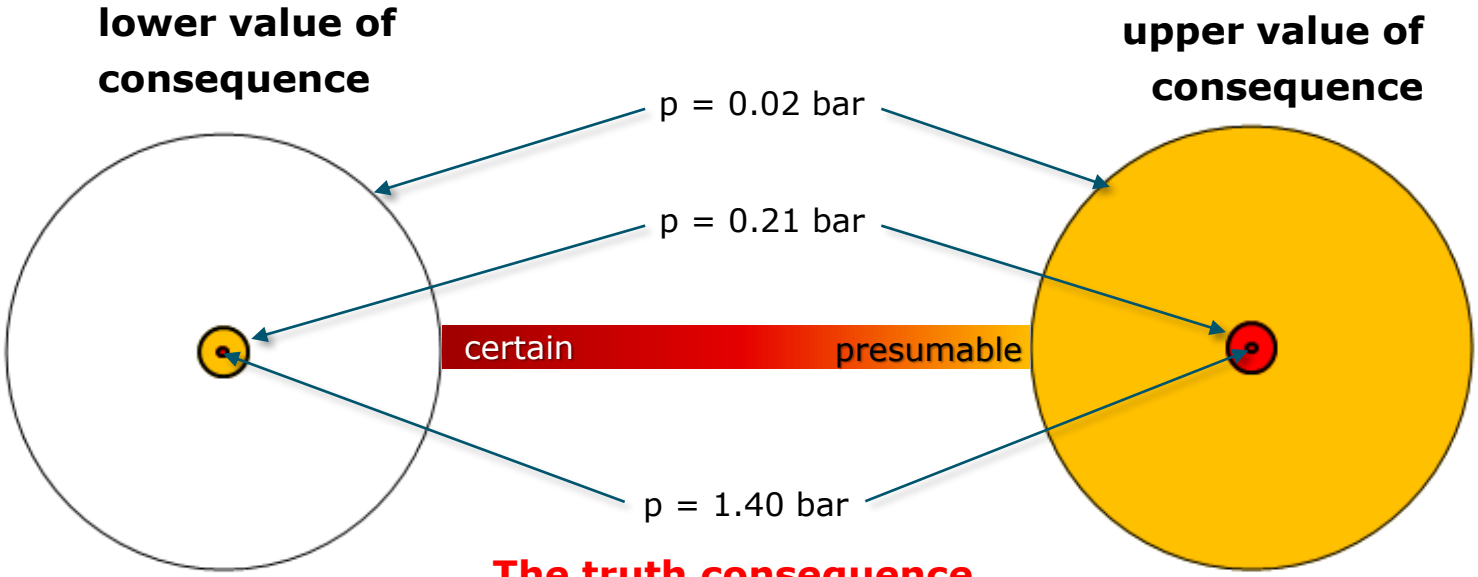
C. Miscellaneous

51. The Sub-Committee noted the work progress of the informal working group on the pV-product limit for pressure receptacles at its meeting on 25 October 2021. It encouraged the group to continue its work and to report back at the next session. The Chair invited all experts interested to participate in the group's work to contact the expert from Germany.

Top 3:
Summary of the preliminary meetings

Estimation of consequence

(without effects of splinters)



The truth consequence

depends on local aspects and is assumed to be somewhere in-between.

Interpretation of areas: 100% fatalities 100% injuries

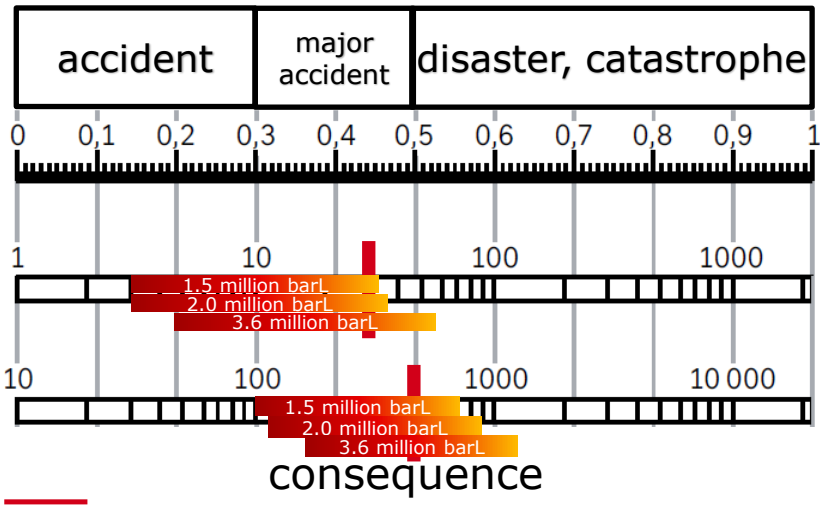
Quantification of "consequence size" for H_2

Estimation for

pV-products = **1.5, 2.0 and 3.6 million bar litres**

and population density of

6000 people/km²



1.5 million barL:

3 to 33 fatalities

$size_{1.5MiobarL}$ = 0.15 to 0.46

101* to 706* injured people

$size_{1.5MiobarL}$ = 0.30* to 0.55

2.0 million barL:

3 to 38 fatalities

$size_{2.0MiobarL}$ = 0.15 to 0.48

120* to 854* injured people

$size_{2.0MiobarL}$ = 0.32* to 0.58

3.6 million barL:

4 to 56 fatalities

$size_{3.6MiobarL}$ = 0.19 to 0.53

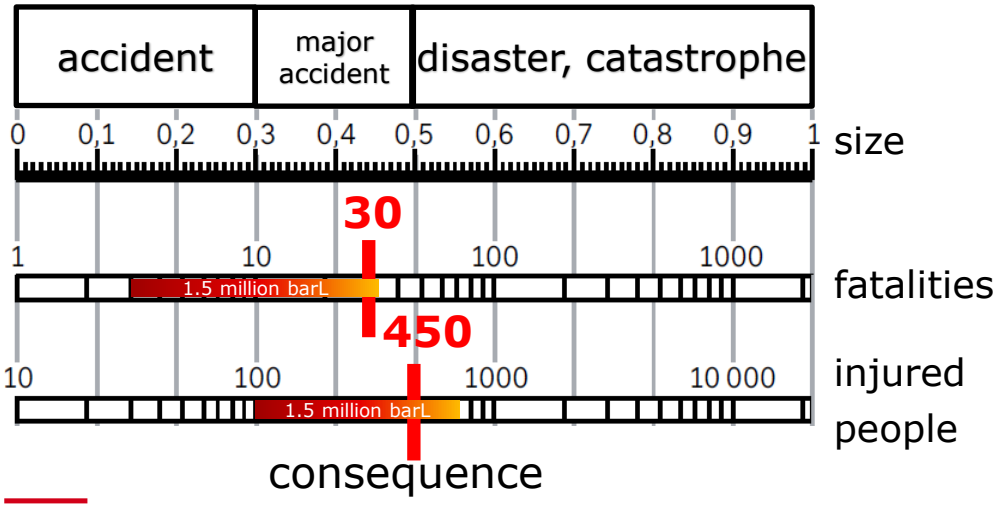
177 to 1248* injured people

$size_{3.6MiobarL}$ = 0.38 to 0.63*

* updated

Results of last discussion

In the last discussion we finalized the work in principle and agreed to give time for further national consideration. Under the condition of national agreement the majority was in favour for operating the lowest consequence level that had been analysed: 1.5 Mio bar litres.



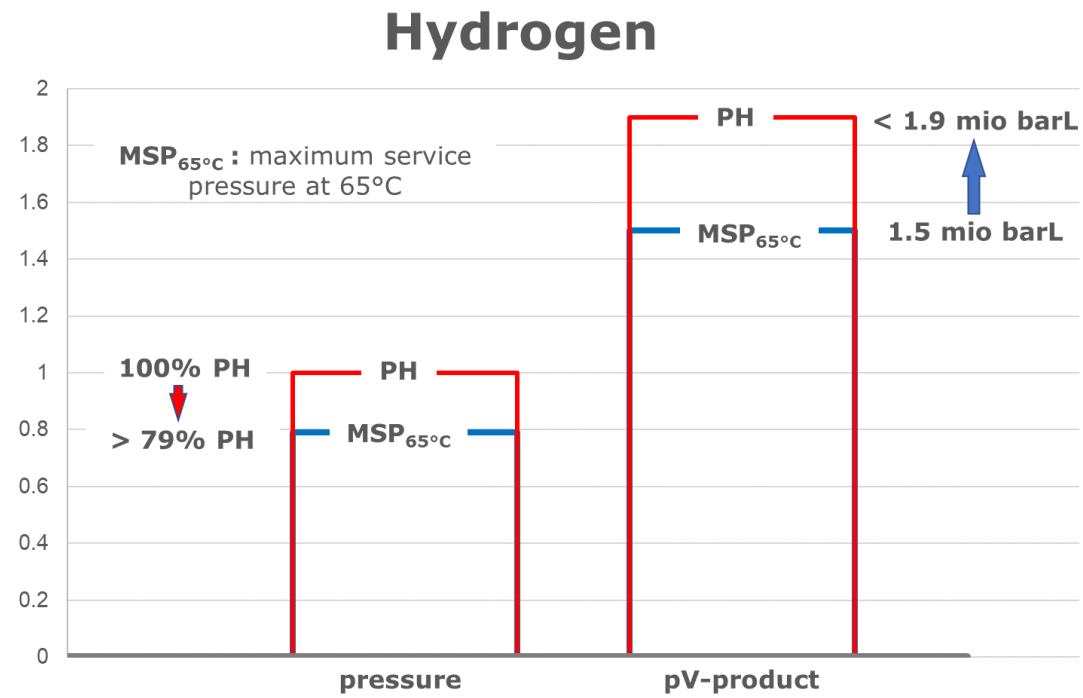
pV-product = **1.5 mio barL**
population density
= **6000 people/km²**

3 to 33 fatalities
$size_{1.5MiobarL}$ = 0.15 to 0.46

101 to 706 injured people
$size_{1.5MiobarL}$ = 0.30 to 0.55

Top 5: Determination of the appropriate pV-value

Results of last discussion



The consequence depends on the water capacity V and the current pressure p that may go up to the maximum service pressure $MSP_{65°C}$ during transport*. Therefore, the ratio of MSP/PH and the pV-limit depend on the gas.

**with exception of fire engulfment, especially for type 1*

Outcome

A test pressure volume product not exceeding [1.8] million bar litres is appropriate to limit the consequence to an acceptable level *(calculated for a sudden rupture of pressure receptacles filled with CGH_2).*

Proposal for a final remark in the report

(not considered for printing in the OB) 1/3

"The above presented pV-value is an estimated reference value that considers almost all expectable worst-case scenarios for a single pressure receptacle during the transport of compressed hydrogen*. As such it provides a representative reference for the avoidance of catastrophic consequences without any consideration of the likelihood of a sudden rupture of a pressure receptacle. A limit between a major consequence and a catastrophic consequence of 30 fatalities or 450 injured persons at a population density of 6000 pers/km^2 has been used.

Due to the variability of scenarios with respect to people, buildings and secondary effects the presented pV-value cannot be accurately calculated. The effect of projectile is not considered explicitly but is merged in the pressure-wave-based consequence estimation.

**with exception of fire engulfment, especially for type 1*

Proposal for a final remark in the report

(not considered for printing in the OB) 2/3

Compressed hydrogen has been chosen as the reference gas since it provides the lowest pressure impulse of frequently transported compressed gases. The pressure wave caused by a sudden rupture of a pressure receptacle containing hydrogen is expected to have more severe consequences than the conversion of chemical energy into a subsequent pressure wave.

The rupture of a pressure receptacle filled with gases such as non-flammable, another flammable or toxic gas is expected to cause more severe consequences than filled with compressed hydrogen.

Proposal for a final remark in the report

(not considered for printing in the OB) 3/3

If avoidance of catastrophic consequences is intended for all gases, then a gas specific pV-value would be required in the relevant packing instruction, that is in most cases lower than the one for hydrogen. This is not part of the work of this group.

The proposed definition of pressure receptacles does not change the limit of a water capacity up to 3000 litres.

Containments with a water capacity of more of 3000 litres or a higher pV-product than [1.8 mio bar litres] should be approved and operated under consideration of additional requirements like a risk assessment for the design under consideration of accidental loads, fatigue and service conditions."

Top 6: Resulting proposals concerning the task

Proposal 1

Compare ST-SG-AC10-C3-2020-18, proposal 1

1.2.1

Pressure receptacle means a transportable receptacle intended for holding substances under pressure including its closure(s) and other service equipment and is a collective term that includes cylinders, tubes, pressure drums, closed cryogenic receptacles, metal hydride storage systems, bundles of cylinders and salvage pressure receptacles with a test pressure volume product not exceeding [1.5] million bar litres;

Proposal 2

Compare ST-SG-AC10-C3-2020-18, proposal 2

1.2.1

Salvage pressure receptacle means a pressure receptacle ~~with a water capacity not exceeding 3 000 litres~~ into which are placed damaged, defective, leaking or non-conforming pressure receptacle(s) for the purpose of transport e.g. for recovery or disposal;

Preparation of next SubCom-meeting

(AC.10/C.3) ECOSOC Sub-Committee of Experts on the Transport of Dangerous Goods (60th session)

27 June - 06 July 2022

Deadline for submission of the official documents: 1 April 2022

Thank you for your contribution

Contact:

Georg W. Mair

Phone: +49 30 8104-1324
Email: georg.mair@BAM.de