Management Summary

Purging of hydrogen pipes

When commissioning hydrogen pipes, the pipes are first purged with an inert gas - this report is based on nitrogen - and then filled with hydrogen. When decommissioning, the hydrogen pipe is purged with nitrogen. The use of nitrogen is (for the time being) recommended for safety-technical reasons in order to avoid flammable mixtures in the pipeline. It is important to determine the minimum required purging speed at which pipes are sufficiently purged. That is why research has been conducted into the minimum required purging speed.

The aim of the study is to determine the minimum required purging speed for the complete purging of hydrogen distribution pipes. During commissioning, this is the rate for expelling air by nitrogen and for subsequently expelling nitrogen with hydrogen. During decommissioning, this is the rate of hydrogen expelling by nitrogen.

For the flaring or venting of hydrogen, see the Kiwa report Flaring and venting of hydrogen[1].

The research is divided into the following phases:

1. A theoretical calculation has been made based on a purging speed of 1.0 m/s.
2. Field measurements were taken on a PE pipe DN 200 and a PE pipe DN 100.

Conclusions

The main conclusions are:

- A **purging speed of at least 0.4 m/s** is required for pipes up to and including DN 200 to ensure that a hydrogen distribution pipe is completely purged, see also Table 1.
  Explanation: at a lower purging speed, insufficient turbulence occurs and nitrogen - during commissioning - and hydrogen - during decommissioning - can remain in the pipe.
- For safety reasons a **purging speed of 1.0 m/s** is recommended.
  Explanation: the amount of hydrogen-air mixture and the time that a hydrogen-air mixture forms and practical considerations - the time it takes for the purging - are determining factors here.
- Purging produces some mixing of nitrogen with hydrogen in the line. When blowing off hydrogen and hydrogen-nitrogen mixture, this is mixed with the ambient air and a flammable mixture is formed. The period that a combustible mixture is present is limited by choosing a slightly higher purging speed than the minimum required purging speed.
  If it later turns out that in certain conditions during commissioning air can be expelled directly by hydrogen and when shut down, hydrogen can be expelled directly by air, the amount of hydrogen-air mixture increases, namely with the amount of hydrogen-air mixture entering the line arises from mixing during purging.

Table 1: Required purging speed per pipe diameter and required flow rate for venting (commissioning) and degassing (decommissioning), see the explanation.

Pipe diameter	Minimum required purging speed [m/s]	Required flow rate at the required purging speed [m3n/h]	Required flow rate at the recommended purging speed of 1,0 m/s [m3n/h]
DN 32	0,4	2	3
DN 50	0,4	3	8
DN 80	0,4	8	19
DN 100	0,4	12	29
DN 150	0,4	26	64
DN 200	0,4	46	113
DN 250	0,5	89	177
DN 300	0,6	153	255
DN 400	0,8	362	452

Notes to Table 1:

- The minimum required purging speed applies to the displacement of air by nitrogen, to the displacement of nitrogen by hydrogen and also to the displacement of hydrogen by nitrogen.
- The minimum required purging speed applies to all pipe materials.
- During commissioning, the air is first expelled from the pipe by nitrogen and then the nitrogen is expelled by hydrogen; this is simply described as venting.
- During (temporarily) decommissioning, the hydrogen is expelled from the pipe by nitrogen; this is simply described as degassing.
- This required purging speed of at least 0.4 m/s applies to pipes with a diameter smaller or equal to DN 200. For pipes with a larger diameter, the purging speed must be greater in proportion to the diameter[2].
- The required flow rate is based on the nominal diameter, so for DN 200 an inner diameter of 200 mm has been used. For example, for a PE pipe DN 200 (internal diameter 177 mm) the required flow rate is smaller (36 m3n/h), for a steel pipe DN 200 (internal

[1] See the Kiwa report Affakkelen en afblazen van waterstof, onderzoek naar het veilig en doelmatig in- en uit bedrijf stellen van waterstofleidingen, GT-200096.

[2] This follows from: Ri = g/p*Δp * D/Δv2. When Ri remains the same, the square root of the purging speed Δv must increase in proportion to the diameter of the pipe D, see Appendix I.

diameter 210 mm) somewhat larger (50 m3n/h).
- Where there are different pipe diameters in the route to be purged, the required purging speed of the largest pipe diameter must be maintained.

Other conclusions are:
- Apart from the (slightly) higher minimum required purging speed, purging hydrogen pipelines is similar to purging natural gas pipelines.
- It cannot be ruled out that the avoidance of air in the pipe when venting *(commissioning)* of hydrogen pipes is more important than is the case with natural gas pipes, because of the risks for the connected appliances (burner and fuel cells).
  - Venting the pipe first by purging with nitrogen limits this risk. For this reason, venting with nitrogen as buffer gas is still preferred for the time being. Only when it has been conclusively established that hydrogen appliances do not pose a risk for a limited amount of air in the hydrogen, the air can be immediately expelled with hydrogen during venting (commissioning). This even has a slight preference: after all every action gives a chance of making mistakes.
- When converting networks from natural gas to hydrogen, direct displacement of natural gas with hydrogen is more safe than first purging with nitrogen. Explanation:
  - After all, if natural gas is expelled directly by hydrogen, no combustible gas mixture can form in the pipeline.
  - Using nitrogen as a buffer gas has no added value in this case. It even has a (limited) disadvantage, after all every action gives a chance of making mistakes.
- Remaining gas (hydrogen and natural gas) in pipes purged with air can lead to dangerous situations when working on that pipe. One must be aware of this. For natural gas pipelines, this has occasionally led to a (serious) incident. For this reason and because the consequences for hydrogen may be more serious, it is still recommended to purge hydrogen pipelines with nitrogen (when purging with nitrogen, no explosive hydrogen-nitrogen mixture can form in the pipe. Note: during operations where the hydrogen-nitrogen mixture can mix with air, a flammable mixture can be formed).

In Table 2, page 8, the results are summarized.

Recommendations

Based on the results of this study:
- The Gas Distribution Pipelines Standards Committee is advised to specify standards for the use of hydrogen in gas distribution pipes (comparable or in line with the NEN 7244-7) to maintain the same purging speed for hydrogen as for natural gas, namely 1.0 m/s.
- The Regional Network Operators are advised to maintain a purging speed of 1.0 m/s when purging hydrogen distribution pipes, venting *(commissioning)* and degassing *((temporarily) decommissioning)* (equal to the purging speed for natural gas distribution pipelines).

Furthermore, the Regional Network Operators are advised the following:
- To conduct further research into the risks (for appliances) of (a limited amount of) air that remains in the hydrogen pipeline after purging.
- To conduct further investigation of the risks for hydrogen appliances of (a limited amount of) natural gas that remains in the hydrogen after conversion from a natural gas network into a hydrogen network.

Table 2: Overview of purging hydrogen pipelines

Pipe diameter	Minimum required purging speed [m/s]	Activity	Purging-medium	Remarks
DN 32 up to DN 200	0,4	Venting *(commissioning)* of a new pipeline	Hydrogen followed by nitrogen (preferred for the time being) or hydrogen	• Be aware of residual air • Further research into the risks of residual air for hydrogen devices
DN 250	0,5			
DN 300	0,6			
DN 400	0,8			
DN 32 up to DN 200	0,4	Degassing *((temporarily) decommissioning)* of a pipeline	Nitrogen (preferred for the time being) or air	• Be aware of residual hydrogen (during maintenance) • Be aware of residual nitrogen (during maintenance)
DN 250	0,5			
DN 300	0,6			
DN 400	0,8			
DN 32 up to DN 200	0,4	Conversion of a natural gas network into a hydrogen network	Hydrogen (natural gas directly displaced by hydrogen)	• Be aware of residual natural gas • Further research into the risks of residual natural gas for hydrogen devices
DN 250	0,5			
DN 300	0,6			
DN 400	0,8			

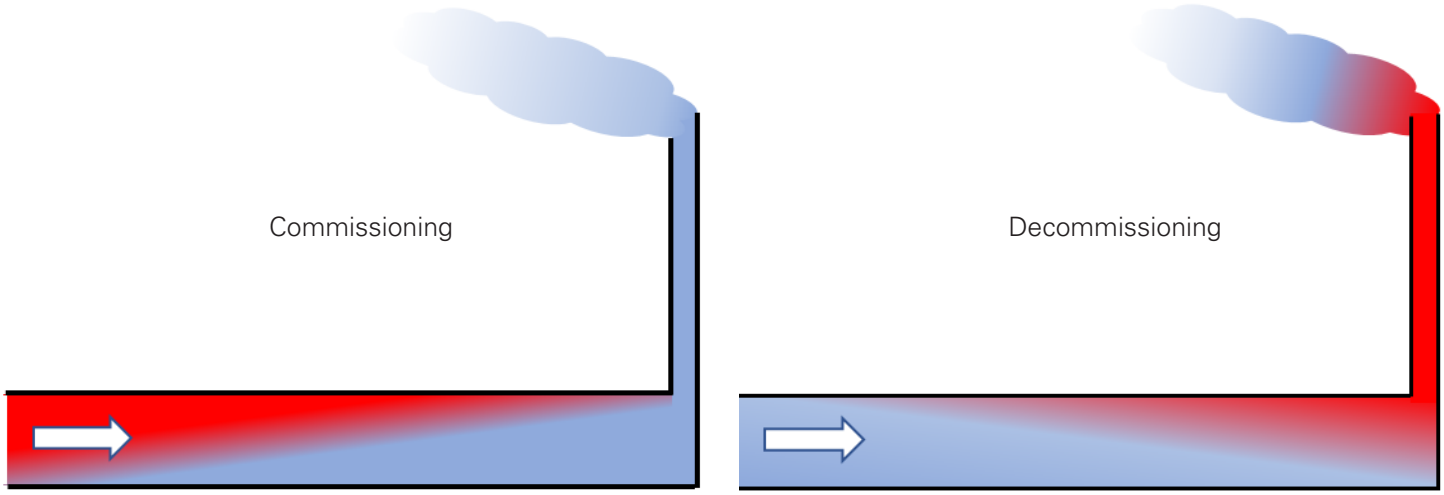

Figure 2:
*Venting (commissioning) can be seen in the left image: **nitrogen** is expelled by **hydrogen***
*Degassing (decommissioning) can be seen in the right image: **hydrogen** is expelled by **nitrogen***
The practice of purging is that a certain degree of layering and mixing is created, this is shown in the figure