

HyDelta

WP 1C Pipes and indoor installations (components)

D1C.1 Research question 187 – Purging of natural gas pipelines with hydrogen

Status: final

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Document summary

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Executive summary

A research study has been carried out as part of the HyDelta national research programme into purging the existing natural gas pipelines with hydrogen. The research described in this report is part of work package 1C "Pipes and indoor installations" and relates to research question 187. This question is as follows:

How can existing gas distribution pipelines be safely decommissioned as a natural gas pipeline and (simultaneously) commissioned as a hydrogen pipeline during the conversion to a hydrogen network?
What are the associated costs?

During the conversion of the natural gas network to a hydrogen network, the natural gas in the distribution pipes needs to be replaced by hydrogen. On the assumption that no air enters the pipeline, this means that the natural gas can be directly displaced by hydrogen.

The purpose of this study is to determine whether purging of a natural gas pipeline with hydrogen can be carried out safely, and to establish the purging speed needed to obtain sufficient displacement of natural gas. An additional objective of this research is to determine the associated costs.

For the experiment, two pipes (DN 100 and DN 200) with a length of approximately 200 metres per diameter were placed on the Kiwa site in Apeldoorn. The test pipes (including a bridge pipe) were equipped with measuring points at three distances. The minimum purging speed was determined by filling the pipe with 100% natural gas. After that, hydrogen was introduced at different speeds.

The research study shows that hydrogen can be used to displace natural gas from existing natural gas pipelines. It proves that a natural gas distribution pipeline can immediately be recommissioned as a hydrogen distribution pipeline after the natural gas has been displaced. Furthermore, the study shows that purging natural gas with hydrogen including flaring is safe and technically feasible.

At a purging speed of 0.2 m/s in both the DN 100 and the DN 200, the natural gas is completely displaced by hydrogen. However, the conditions in practice when purging pipes may be less favourable compared to purging the test lines. For this reason, a safety factor of two is applied to be absolutely sure that the pipes have been completely purged. The minimum purging speed is therefore 0.4 m/s.

To reduce the duration of purging, a speed of 1.0 m/s is recommended. This also shortens the duration of an open flame (flaring). These minimum and recommended purging speed are in line with the report "Spoelen van waterstofleidingen" (Kiwa Technology GT-200289, reference [1]).

The estimated costs of purging main gas pipes with hydrogen are € 685 (excl. VAT) per kilometre. These costs are limited to the actual purging of the main pipelines. The preparation costs for the work (e.g. drawings, switching plans, KLIC reports) and the conversion to hydrogen in the homes, etc. have not been taken into account, as these are very specific for different sections of the network.

Table of contents

Document summary	2
Executive summary	3
1. Introduction.....	6
1.1 General	6
1.2 Problem definition.....	6
1.3 Research question 187	6
2. Goal	7
3. Method.....	8
3.1 General work methodology.....	8
3.2 Available information	8
3.3 Test programme measurements.....	8
3.4 Test pipe	9
4. Result.....	11
4.1 Purging measurements on DN 100 pipe	12
4.1.1 Pipe DN 100 – measurements 1 to 3.....	12
4.1.2 Pipe DN 100 – measurements 4 and 5	14
4.1.3 Pipe DN 100 – measurements 6 and 7	15
4.1.4 Consideration of results DN 100.....	16
4.2 Purging measurements on DN 200 pipe	17
4.2.1 Pipe DN 200 – measurements 1 and 2	17
4.2.2 Pipe DN 200 – measurements 3 and 4	18
4.2.3 Pipe DN 200 – measurements 5 and 6	19
4.2.4 Pipe DN 200 – measurements 7 and 8	20
4.2.5 Consideration of results DN 200.....	21
4.3 Shift of zero point in relation to complete displacement of natural gas	21
4.4 Measured speeds	22
4.5 Determining total displacement of natural gas and flaring	24
5. Estimation of costs	25
6. Conclusions and answers to research question	26
References.....	27
I List of questions HyDelta WP1C	28
II List of participants in the guidance group and sparring group sub-question 187.....	29
III Risk assessment and evaluation by Kiwa	30
IV Memo test programme - sub question 187 purging	31

V	Detailed drawings of the test pipeline	32
VI	Photos of the test set-up.....	34
VII	Measuring equipment used	35
VIII	Reference to video recordings of flaring.....	36
IX	Purging speeds and flow rates at different pipe diameters.....	37

1. Introduction

1.1 General

This research was carried out within the framework of the national HyDelta research programme. The programme focuses on the safe integration of hydrogen into the existing gas transport and distribution infrastructure and aims to remove barriers that are currently hampering innovative hydrogen projects. The entire research programme is divided into work packages. For an explanation of the various work packages, please visit www.hydelta.nl.

1.2 Problem definition

During the conversion of the natural gas network to a hydrogen network, the natural gas in the pipelines will have to be replaced by hydrogen. Assuming that no air enters the pipeline, this means that the natural gas can be directly displaced by hydrogen. The speed required to obtain sufficient displacement of the natural gas therefore needs to be determined. Flushing the existing pipeline with nitrogen beforehand can also be considered. The Kiwa Technology report “Purging hydrogen pipelines (GT-200289)”, however, states the following:

When converting networks from natural gas to hydrogen, directly displacing the natural gas with hydrogen is safer than first flushing with nitrogen.

Explanatory note:

- If natural gas is directly displaced by hydrogen, no flammable gas mixture can occur in the pipeline; no risk of flame impingement.
- Using nitrogen as a buffer gas has no added value in this case. In fact, there is even a (limited) disadvantage because every additional procedure adds a risk of making mistakes.

The Kiwa Technology “Spoelen van waterstofleidingen” report describes the commissioning and decommissioning of hydrogen pipelines whereby the pipes are first flushed with an inert gas. That research was carried out on the instructions of Netbeheer Nederland.

1.3 Research question 187

The present report answers research question 187 from work package 1C “Pipes and Indoor Installations”¹.

The research questions are as follows²:

How can existing gas distribution pipelines be safely decommissioned as a natural gas pipeline and (simultaneously) commissioned as a hydrogen pipeline during a conversion to a hydrogen network? What are the associated costs?

Based on the original research question, the guiding principle of this research study is that an existing natural gas pipeline is converted to a hydrogen pipeline whereby natural gas is directly displaced by hydrogen.

¹ The other research questions from this work package have been listed in Appendix I.

² The original research question as described in the work package description is as follows: Research to safely decommissioning and recommissioning of pipeline sections in hydrogen distribution during the conversion to a hydrogen network and what are the associated costs? This research question has been rephrased in consultation with the guidance group and sparring group.

2. Goal

The purpose of this study is to determine whether the purging of a natural gas pipeline with hydrogen can be carried out safely, and to calculate the required purging speed to obtain sufficient displacement of natural gas. In addition, the aim of this research study is to determine the costs associated with the actual purging process.

Incorporating the purging of natural gas pipelines with hydrogen into the business operations of network operators, the associated risks of flaring for the environment and how to deal with purging connection pipelines have not been considered or investigated in this study.

Remarks:

As in previous studies, the DN 200 and DN 100 test pipelines were chosen because approximately 96% of the gas distribution pipelines have a diameter smaller than or equal to DN 200. If the test pipes can be purged at the purging speed stated in this report, it can be fairly assumed that the other pipelines with diameters smaller than DN 200 can also be purged at that same purging speed. In other words: by determining the required purging speed for the test pipelines, the required purging speed is known for 96%³ of all gas distribution pipelines.

Based on the results obtained from the measurements on the DN 200 and DN 100 test pipelines, a specification will be made regarding the minimum purging speed for other pipe diameters.

³ Source: "Overzicht van de aanwezige leidingmaterialen in het Nederlandse gasdistributienet", GT-080133 (Kiwa Technology report from 2008). It has been noted that the inside diameter of the SDR 17 PE-pipe DN 200 is smaller than most other gas distribution pipes with a similar outside diameter.

3. Method

3.1 General work methodology

This research study was carried out in coordination with an advisory group and sparring group. Both groups are composed of participants from the network operators (see Appendix II). The risks associated with purging natural gas with hydrogen in the low-pressure distribution pipelines were put forward by the participants of the sparring group (see Appendix III and IV). These points were subsequently discussed and, based on the reports already available (section 3.2), a proposal for a test programme was formulated by the advisory group (included in Appendix IV). This test programme was adopted by the sparring group.

3.2 Available information

The purging of natural gas pipelines and hydrogen pipelines has been investigated in the recent past and described in the following reports:

- Kiwa Technology report GT-200075; Spoelen van aardgasleidingen. The minimum determined velocity (DN 200) is 0.3 m/s, a purging velocity of 1 m/s is advised. This report contains theoretically calculated purging speed (with theoretical background) and purging speed determined in practice.
- Kiwa Technology report GT-200289; Spoelen van waterstofleidingen, reference [1]. The minimum determined velocity (DN 200) is 0.4 m/s, a purging velocity of 1 m/s is advised. This report contains theoretically calculated purging speeds (with theoretical background) and practically determined purging speeds.
- Kiwa Technology report GT-200096; Affakkelen en afblazen van waterstof, reference [2]. Table 1 of the summary also mentions the conversion of natural gas to hydrogen. It recommends flaring the gas (in connection with environmental pollution).

Purging natural gas directly with hydrogen did not form part of these studies; this report is an addition to the previous studies.

3.3 Test programme measurements

The approach is similar to the approach applied in the previously conducted experiments on behalf of Netbeheer Nederland as described in the reports referred to in section 3.2.

The speed required to obtain sufficient displacement of the natural gas has been established with these experiments, as well as the development of the natural gas/hydrogen mixture during the purge process. The resulting findings can therefore provide a reference for the conversion from natural gas to hydrogen gas, which can be used to draft the regulations.

To carry out the tests, pipes present on the Kiwa site in Apeldoorn were used, each of which is approximately 200 metres long and equipped with measuring points and a bridge pipeline. The test pipes (including a bridge pipe) have measuring points at three intervals. The minimum purging speed was determined by filling the pipe with 100% natural gas. After that, hydrogen was introduced at different speed.

Purging the natural gas pipelines with hydrogen was carried out on PE pipes at the following purging speed:

DN 100; 0.2 m/s, 0.4 m/s and 1.0 m/s.

DN 200; 0.2 m/s, 0.4 m/s, 0.8 m/s and 1.0 m/s.

The measurements were performed in duplicate.

During the measurements, the decrease in natural gas concentration was measured (one measurement every second). The meters used are not cross-sensitive to hydrogen (IR measuring principle)⁴. Measurements of the hydrogen concentration were taken just before the flare installations; this meter is cross-sensitive to the presence of natural gas. This measurement was used as a checkpoint for the presence of 100% hydrogen at the end of the measurement. See Appendix VII for an overview of the measuring equipment used.

The natural gas followed by the hydrogen was flared off using a flaring installation (without flame arrestor) as used for natural gas. The flaring has been recorded on film.

3.4 Test pipe

The description below applies to the DN 200 pipe; the DN 100 pipe is laid in the same way.

An overview drawing of the test pipeline is given in Appendix V. See Appendix VI for some photographs.

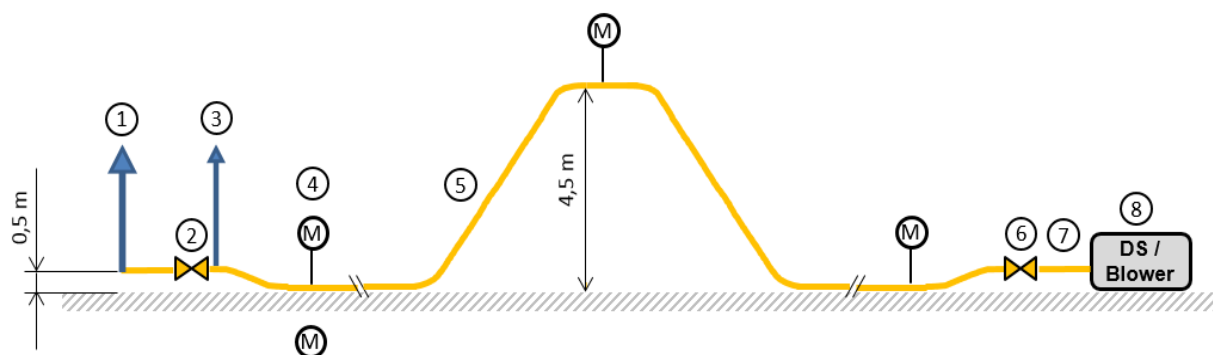


Figure 1. Test pipeline with a total length of approximately 200 metres.

No.	Description	Explanation
1	Blow-off large diameter (DN 200)	Not used in these tests
2	Blow-off valve DN 200	
3	Blow-off saddle diameter (1½")	Used in these tests
4	Gas concentration measuring points (M)	Measurement inside the pipe at each distance at the top, middle and bottom.
5	PE 100 SDR 17 DN 200 - length 200 m	The pipe is laid above ground
6	Feed valve nitrogen/hydrogen DN 200	
7	Flexible connection hose	
8	Natural gas/hydrogen filling point	P _i max. 100 mbar, P _u ~ atmospheric

⁴ The meters used present their measurements as CH₄. The meters, however, are also cross-sensitive to higher hydrocarbons. The natural gas used predominantly contained methane (81,2%), nitrogen (13,4%), carbon dioxide (1,1%), ethane (3,6%) and propane (0,5%). The percentage of higher hydrocarbons will be displayed as a higher methane percentage. For example; when a gas contains 0,5% ethane, the meter will read 1,8% CH₄ and when a gas contains 0,5% propane the meter will read 2% CH₄. This explains why the meters will display 100% CH₄ when they are offered a sample of 100% Groningen gas.

Explanatory note:

Taking measurements at three different heights inside the pipe (top, middle and bottom of the pipe) at each measuring point gives a clear picture of the stratification of the hydrogen-natural gas mixture in the pipe. This stratification can be caused by the difference in specific gravity of natural gas and hydrogen.

Remarks:

The DN 200 pipe is a PE 100 SDR 17 with a 200 mm outside diameter and a 177 mm inside diameter.
The DN 100 pipe is a PE 100 SDR 17.6 with a 110 mm outside diameter and a 97.4 mm inside diameter.

4. Result

This chapter contains the results of the measurements carried out.

Table 1. Measurements performed

Measurement no.	Pipe diameter	Initial purging speed* (m/s)	Section
1	DN 100	0.27	4.1.1
2	DN 100	0.19	4.1.1
3	DN 100	0.19	4.1.1
4	DN 100	0.39	4.1.2
5	DN 100	0.38	4.1.2
6	DN 100	1.09	4.1.3
7	DN 100	1.00	4.1.3
Consideration	DN 100		4.1.4
1	DN 200	0.19	4.2.1
2	DN 200	0.20	4.2.1
3	DN 200	0.40	4.2.2
4	DN 200	0.40	4.2.2
5	DN 200	0.82	4.2.3
6	DN 200	0.82	4.2.3
7	DN 200	0.95	4.2.4
8	DN 200	0.97	4.2.4
Consideration	DN 200		4.2.5

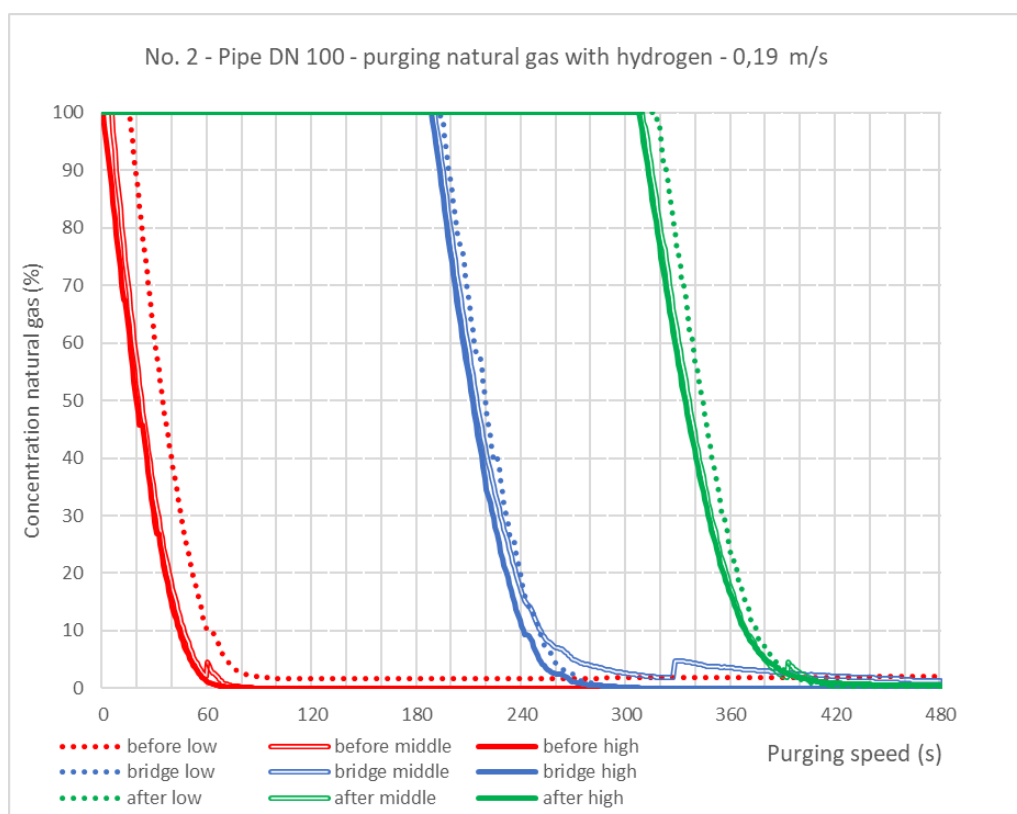
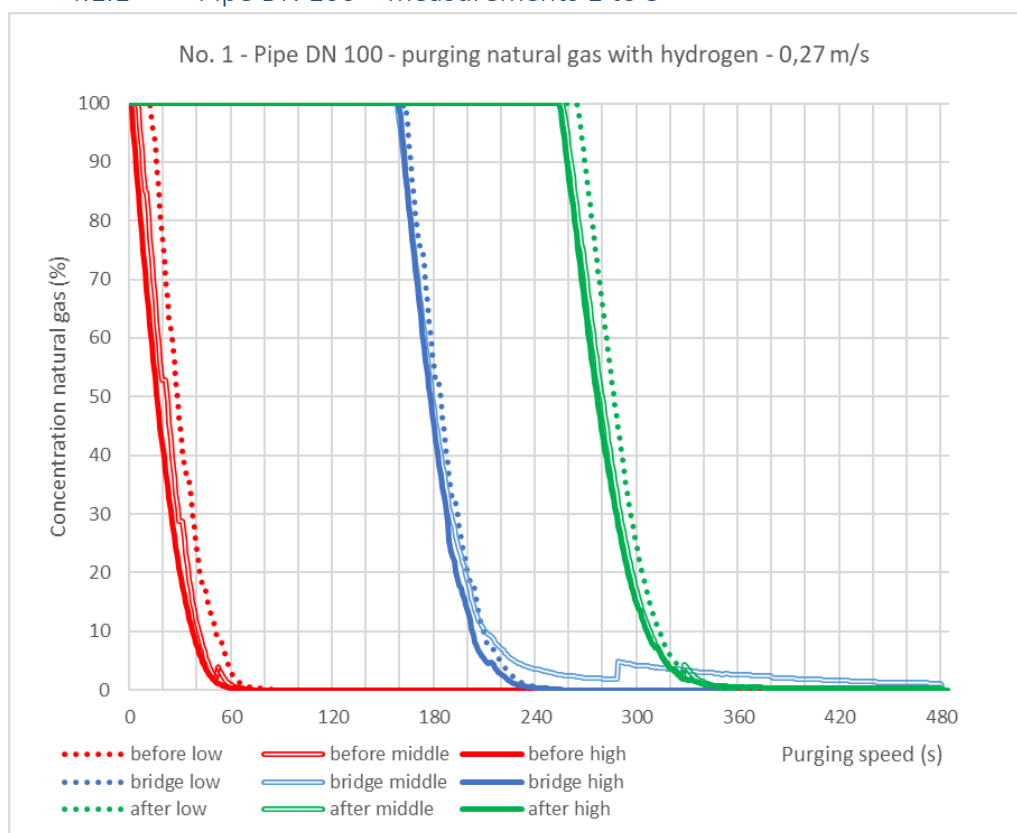
**The initial purging speed is the speed set at the beginning of the test. Particularly for the DN 200, the speed increases during the measurement. See section 3.4 for further explanation. The charts in 4.1 and 4.2 show the initial purging speeds.*

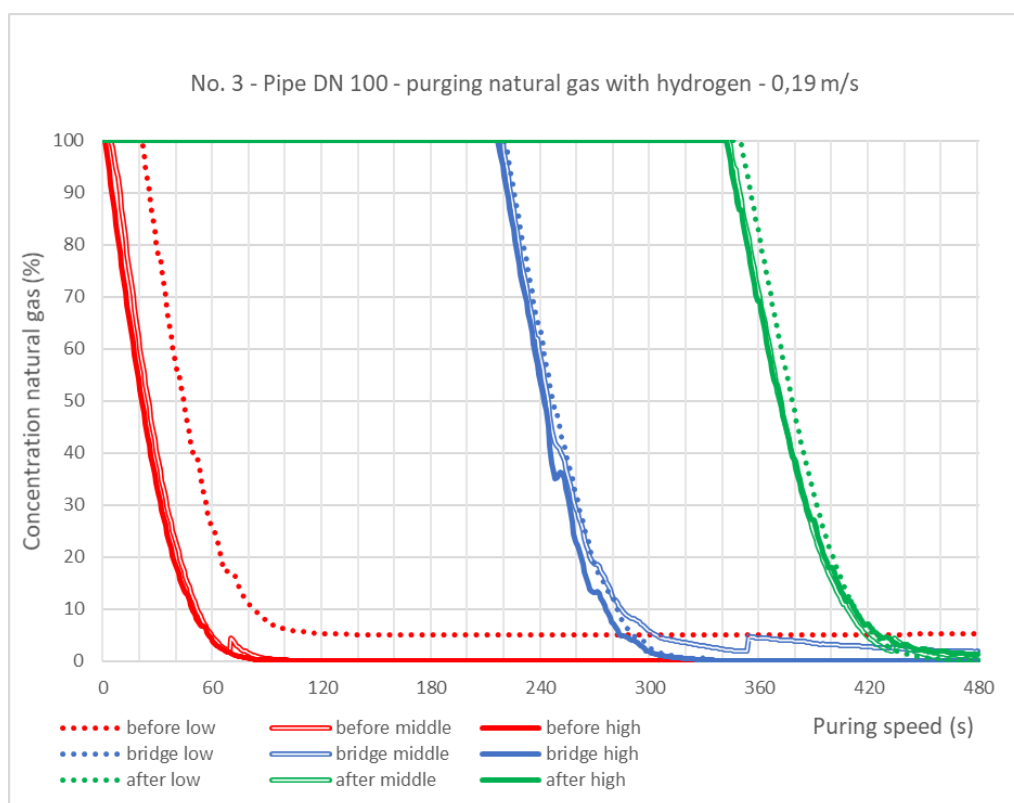
Points of attention:

- Sections 4.1.4 and 4.2.5 give an explanation for the sharp rise in the natural gas concentration observed in all measurements at the moment that virtually all the natural gas has been displaced.
- Section 4.3 explains the shift of a few metres in the zero point that was observed.
- Section 4.4 explains how the speeds were determined.
- Section 4.5 describes the results of flaring.

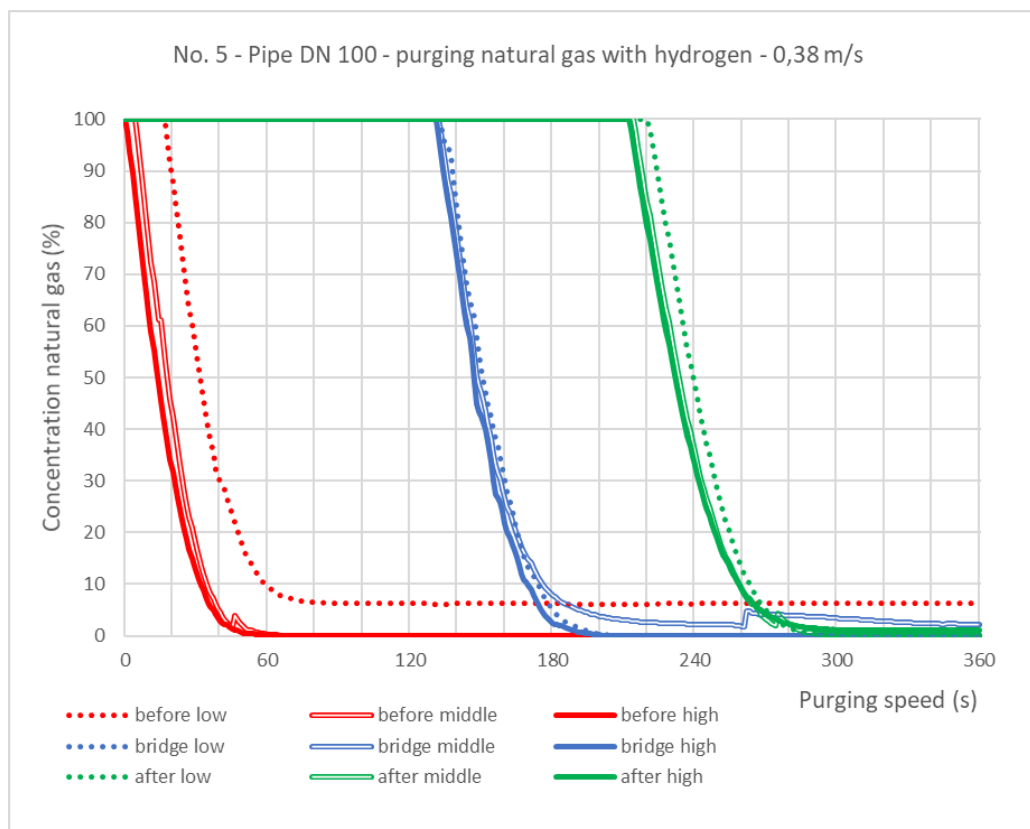
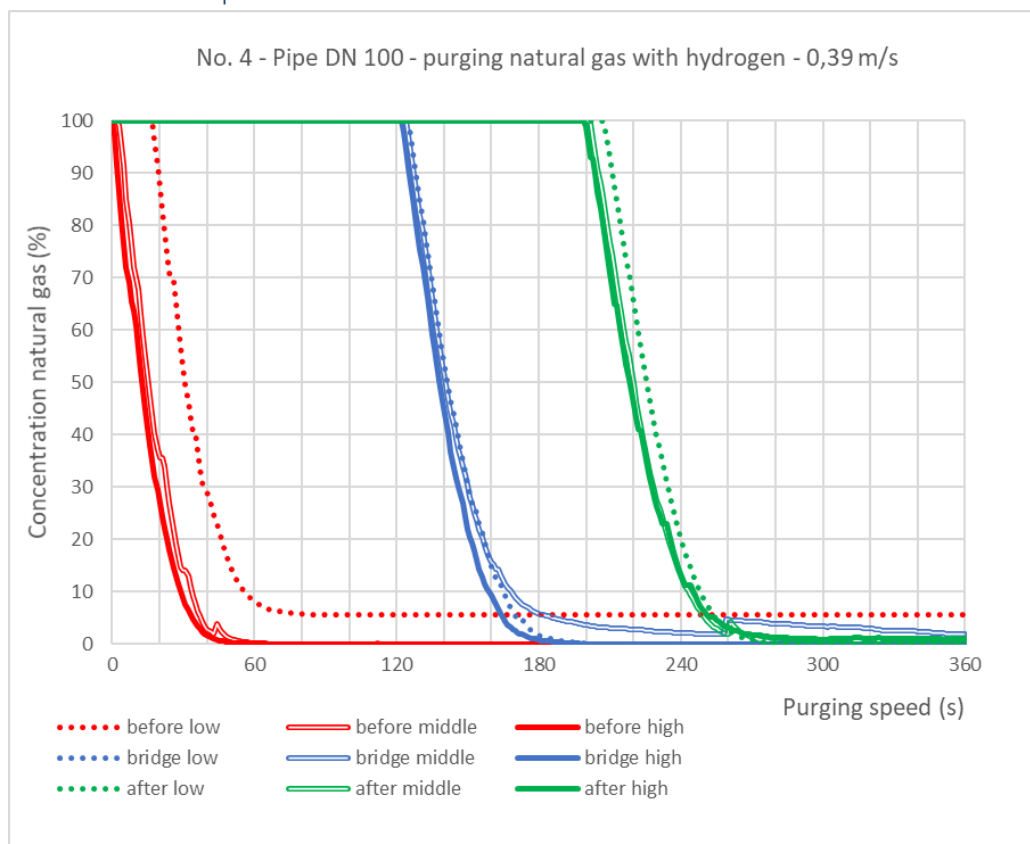
4.1 Purging measurements on DN 100 pipe

4.1.1 Pipe DN 100 – measurements 1 to 3

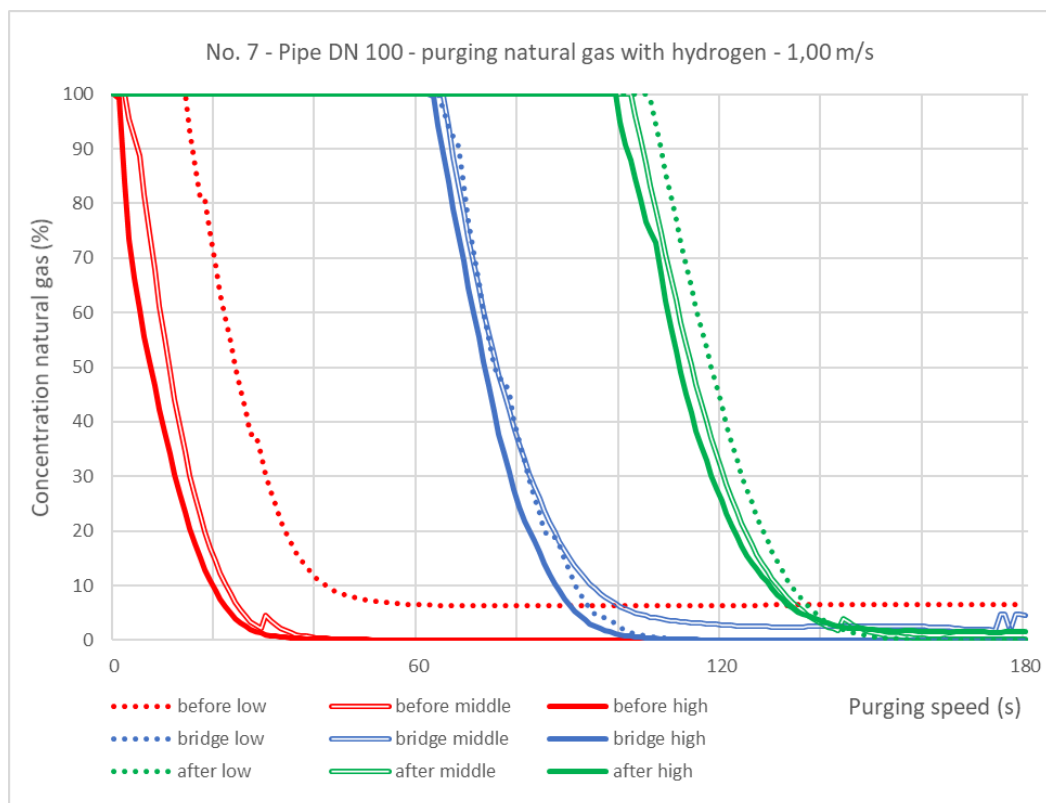
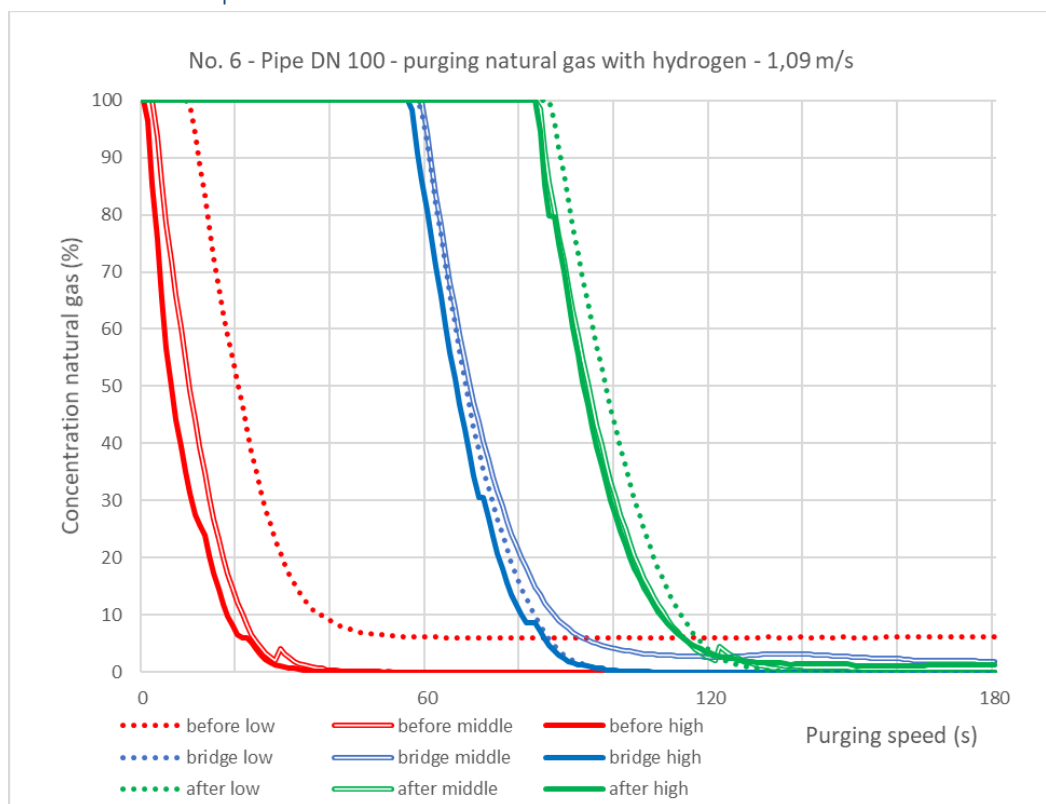




4.1.2 Pipe DN 100 – measurements 4 and 5



4.1.3 Pipe DN 100 – measurements 6 and 7



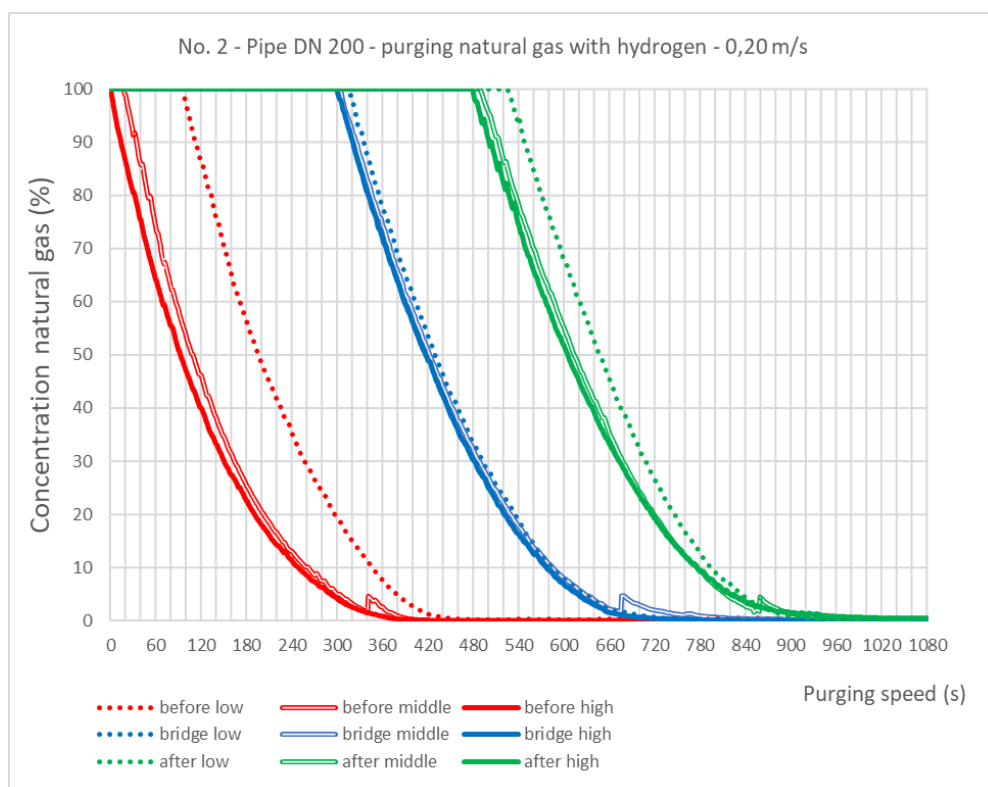
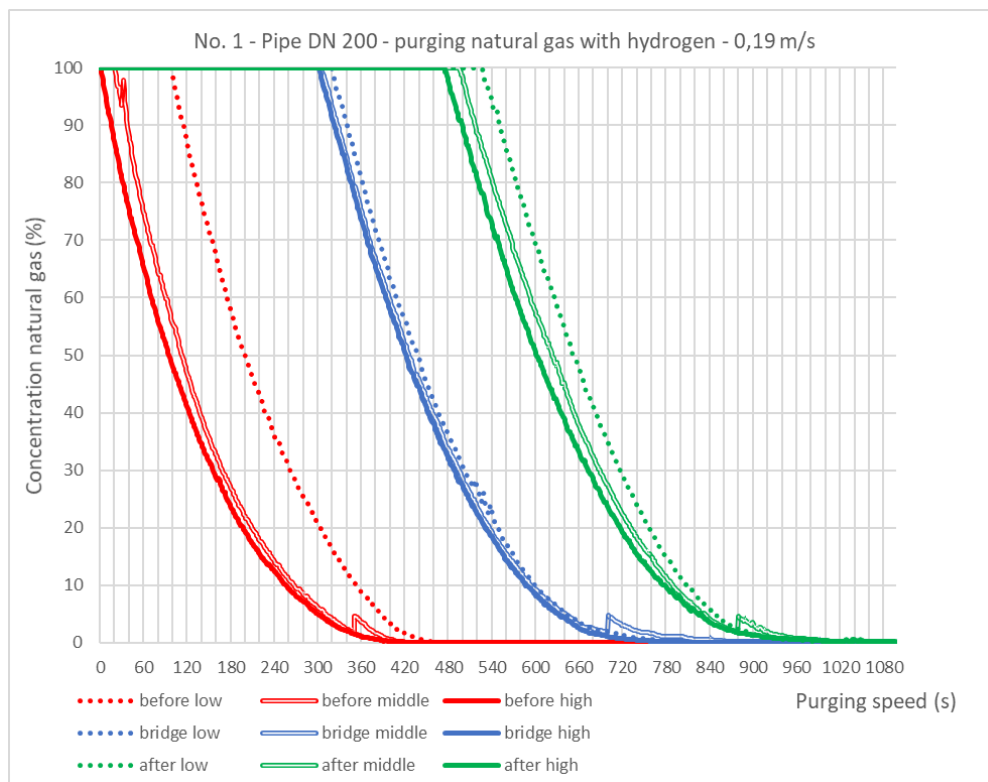
4.1.4 Consideration of results DN 100

The graphs in 4.1.1 to 4.1.3 show the following:

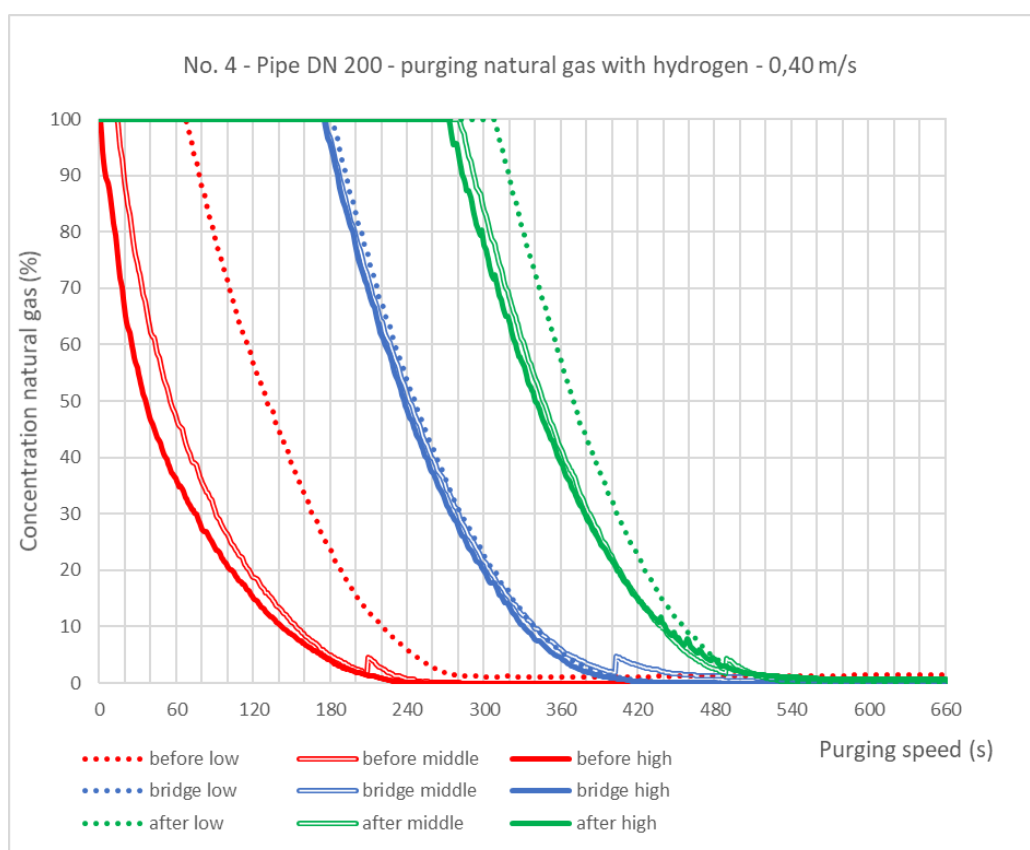
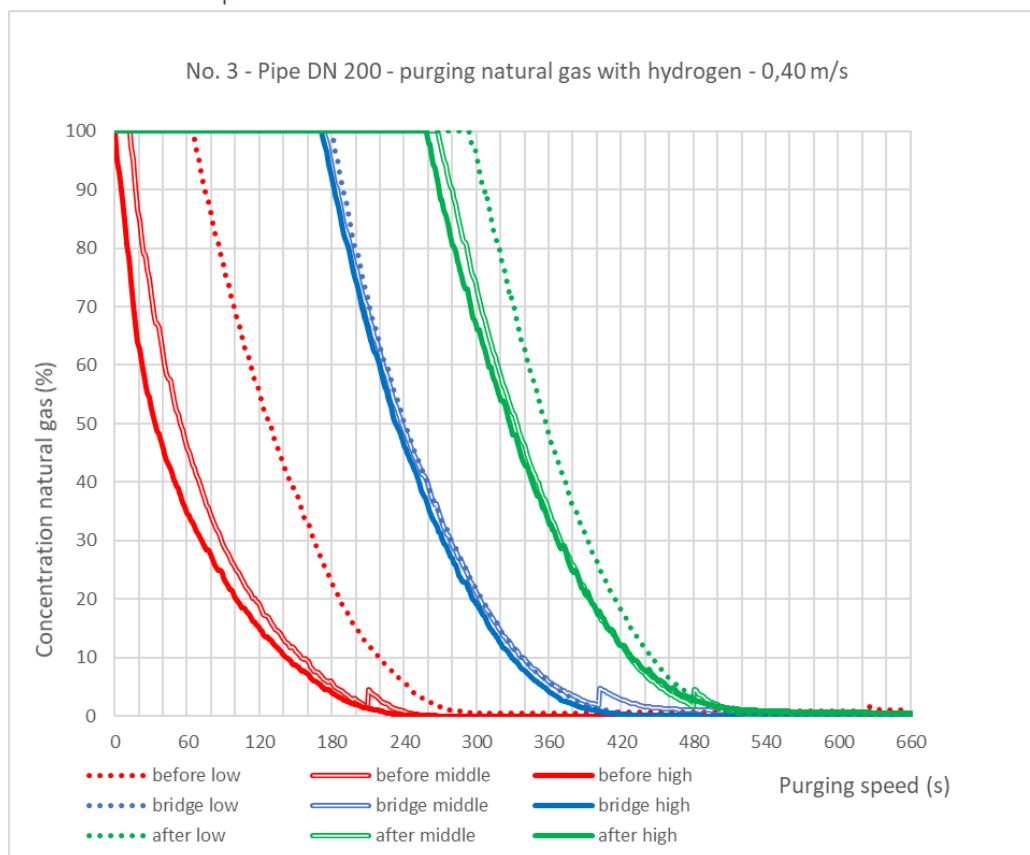
- At measurement 1, hydrogen completely displaces natural gas. In the other graphs it appears that some natural gas remains at measurement point “before-low”. The zero point has not been reached correctly (see below and section 4.3)
- In all measurements, the concentration of natural gas first decreases in the top of the pipe. This happens at every position in the test pipeline (before the bridge, on the bridge and after the bridge) and at all purging speeds. The concentrations at the three measurement points on the bridge lie closer together than at the measurement points before and after the bridge.
- The zero point of the natural gas detector connected to measuring point “before-low” shifts during the measurements. The zero point of the natural gas detector connected to measuring point “bridge-middle” is reached late or not at all, and it shifts slightly during the measurements. The zero point of the natural gas detector connected to measuring point “bridge-high” shifts slightly during the measurements. See section 4.3 for a more detailed explanation.
- The three measuring points in the middle of the pipes at all positions (before the bridge, on the bridge and after the bridge) show a sudden increase of a few percent when the concentration of natural gas drops below 5%. A possible explanation for this is a change from turbulent to laminar flow. During the purging process, the natural gas is slowly displaced by hydrogen gas. As a result, the concentration of natural gas gradually decreases and that of hydrogen gas increases. Due to the difference in physical properties (density and viscosity), the flow behaviour of natural gas at the applied speeds is mainly turbulent and that of hydrogen laminar. At the interface of natural gas and hydrogen gas, vortices (the transition from turbulent to laminar) will cause mixing. A small amount of natural gas is mixed back into the hydrogen gas as a result, causing a small peak in the graph that is visible just before the natural gas concentration reaches zero.

4.2 Purging measurements on DN 200 pipe

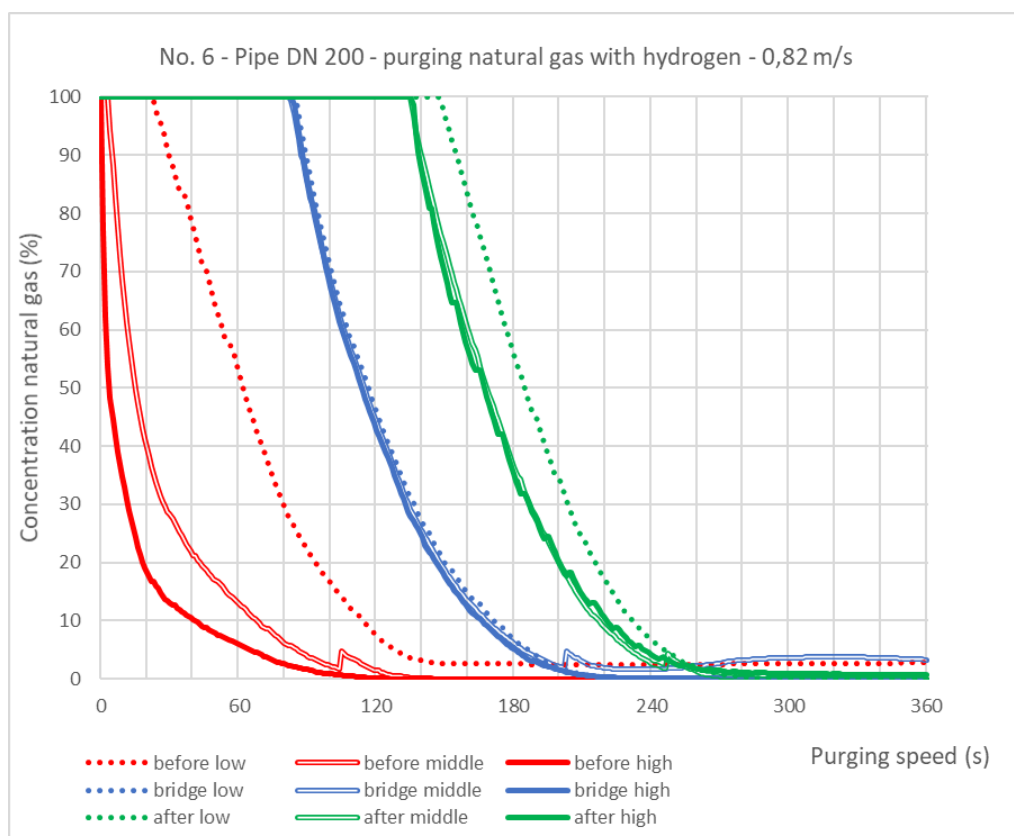
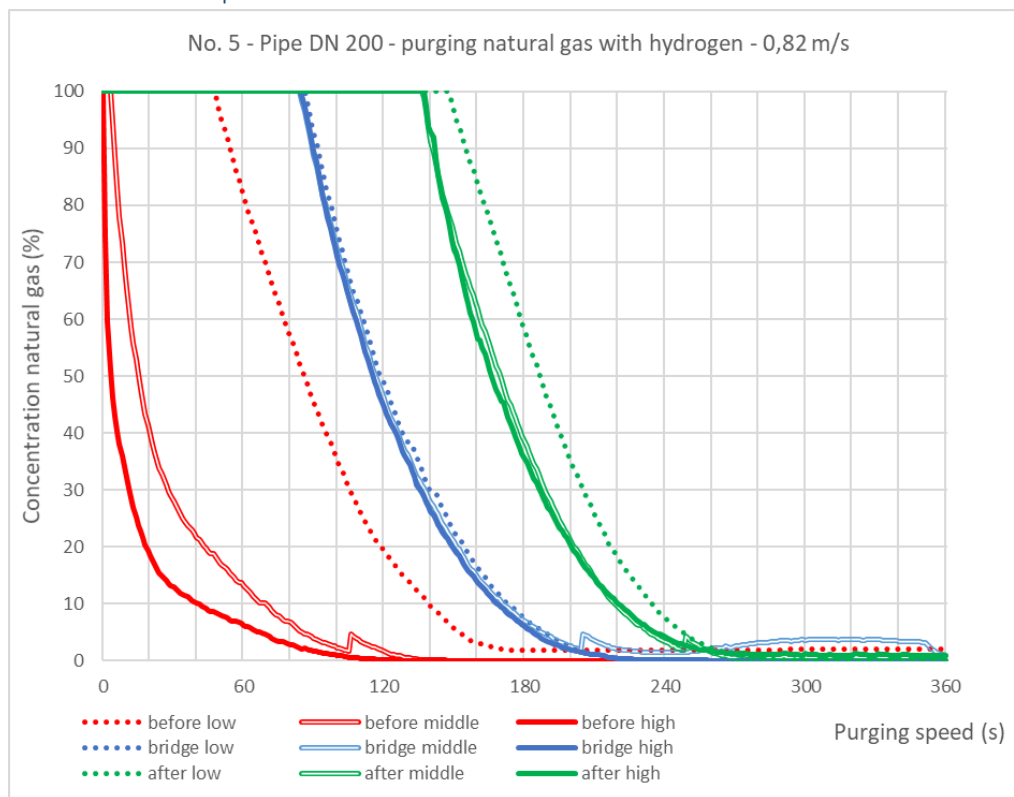
4.2.1 Pipe DN 200 – measurements 1 and 2



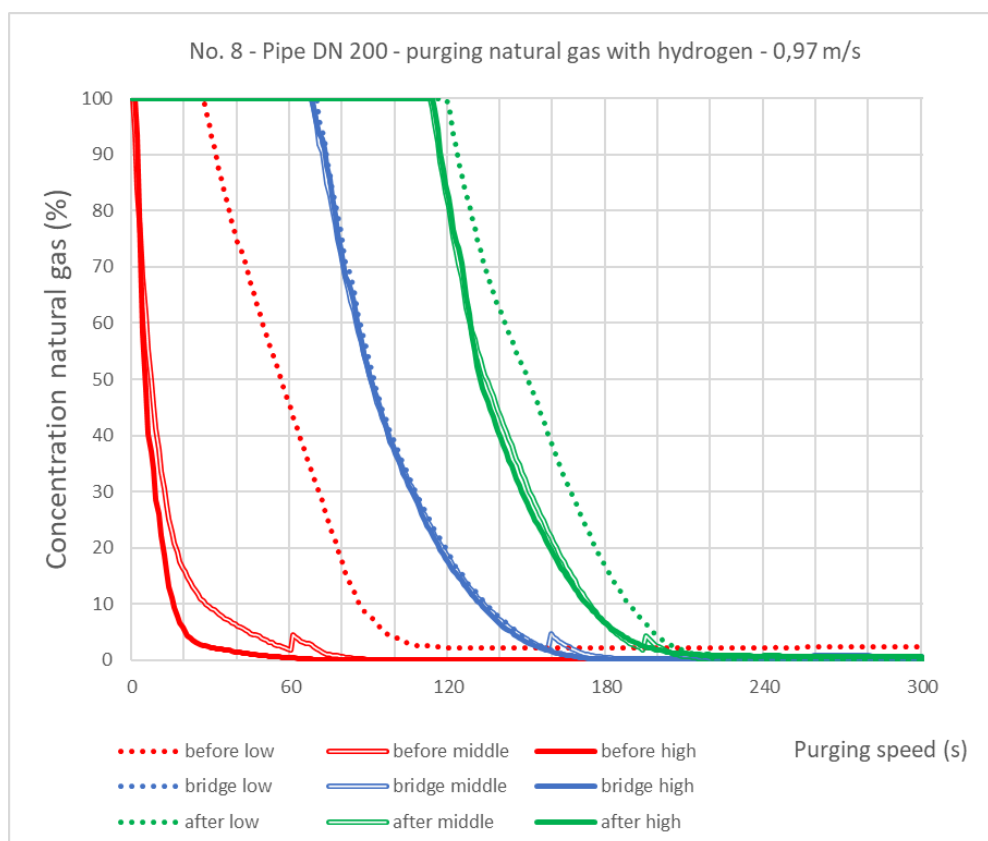
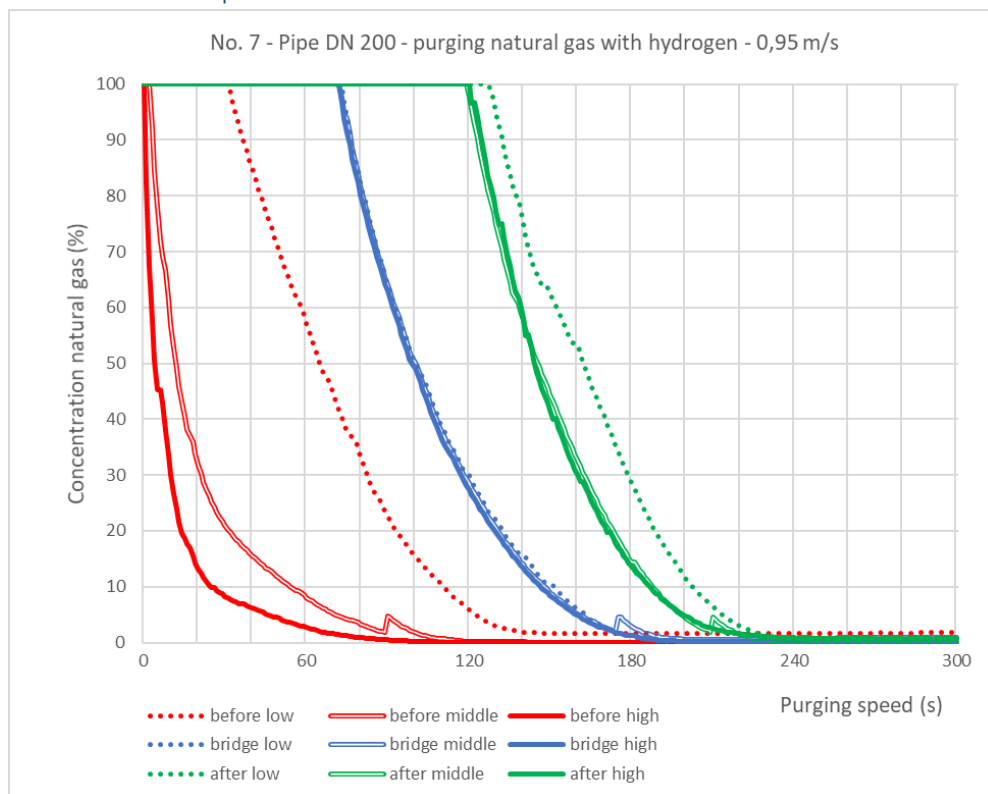
4.2.2 Pipe DN 200 – measurements 3 and 4



4.2.3 Pipe DN 200 – measurements 5 and 6



4.2.4 Pipe DN 200 – measurements 7 and 8



4.2.5 Consideration of results DN 200

The graphs in 4.2.1 to 4.2.4 show the following:

- At measurement 1 and 2, hydrogen completely displaces natural gas. In the other graphs it appears that some natural gas remains at measuring point “before-low”. The zero point has not been reached correctly (see below and section 4.3).
- In all measurements, the concentration of natural gas first decreases in the top of the pipe. This happens at every position in the test pipeline (before the bridge, on the bridge and after the bridge) and at all purging speeds. The concentrations at the three measurement points on the bridge lie closer together than at the measurement points before and after the bridge.
- The zero point of the natural gas detector connected to measuring point “before-low” shifts during the measurements. The zero point of the natural gas detector connected to measuring point “bridge-middle” is reached late or not at all, and it shifts slightly during the measurements. The zero point of the natural gas detector connected to measuring point “bridge-high” shifts slightly during the measurements. See section 4.3 for a more detailed explanation.
- The three measuring points in the middle of the pipes at all positions (before the bridge, on the bridge and after the bridge) show a sudden increase of a few percent when the concentration of natural gas drops below 5%. A possible explanation for this is a change from turbulent to laminar flow. During the purging process, the natural gas is slowly displaced by hydrogen gas. As a result, the concentration of natural gas gradually decreases and that of hydrogen gas increases. Due to the difference in physical properties (density and viscosity), the flow characteristics of natural gas is mainly turbulent and that of hydrogen laminar. At the interface of natural gas and hydrogen gas, vortices (the transition from turbulent to laminar) will cause mixing. A small amount of natural gas is mixed back into the hydrogen gas as a result, causing a small peak in the graph that is visible just before the natural gas concentration reaches zero.

4.3 Shift of zero point in relation to complete displacement of natural gas

As mentioned in 4.1.4 and 4.2.5, the zero points of the natural gas detectors shift during the measurements. These movements occur at the following measuring points;

- before-low
- bridge-middle
- after-high

This is visible in both the series of measurements in pipeline DN 100 and in pipeline DN 200. Based on the measured concentrations at measuring points “after-low” and “after-middle”⁵, as well as at the first measurement on pipe DN 100 with a low purging speed and the first two measurements on pipe DN 200 with a low purging speed, it can be concluded that the hydrogen does not flow over the bottom layer of natural gas, but that it displaces it completely.

The supplier of the detection equipment has indicated that drifting around the zero point can occur with infrared sensors and that this is usually caused by humidity. As dry gas was offered, however it is unlikely that this is the case.

In these measurements, the pipe is refilled with natural gas after being purged with hydrogen gas. Every measurement starts with 100% natural gas (all meters indicated this as well).

⁵ All 15 measurements at measuring point “after-low” and “after-middle” indicate a measured concentration of 0.0% of natural gas at the end of each measurement.

The shift of the zero point is an effect that occurs with three of the nine sensors and increases over time (measuring day). It is theoretically conceivable that, in the measurements at low speeds, natural gas stays behind and that the hydrogen flows over it, but it is at these low speeds that the measuring point “before-low” reaches the zero point. These concerned measurements taken at the start of the day. It can therefore be stated that hydrogen does not flow over natural gas.

The zero point that shifts the most is the measurement point “before-low”. This point gradually moves to 6.5% natural gas during the measurements on the DN 100 pipe, and moves to 2.5% natural gas during the measurements on the DN 200. The measurements on the DN 100 pipe were carried out on 2 March and the measurements on the DN 200 pipe were carried out on 3 March. On 2 March, the day started colder and ended warmer than on 3 March. This may be a reason for the observed difference.

4.4 Measured speeds

The hydrogen flow rate was set at the start of the measurement and monitored during the measurements. The speed was determined at the start and at the end of the measurement based on these flow rates (operating conditions). The speed is also determined by the time between the first decrease in natural gas concentration (position “high”) between the first and last measuring point. This results in the following speeds.

Table 2. Speeds in pipe DN 100

Measurement	Speed calculated according to initial flow rate I	Speed calculated according to final flow rate II
	(m/s)	(m/s)
1	0.27	0.28
2	0.19	0.20
3	0.19	0.19
4	0.39	0.40
5	0.38	0.38
6	1.09	1.10
7	1.00	1.01
I = Based on flow rate value at inlet at start of measurement		
II = Based on flow rate value at inlet at end of measurement		

Table 3. Speeds in pipe DN 200

Measurement	Speed calculated according to initial flow rate I (m/s)	Speed calculated according to final flow rate II (m/s)
1	0.19	0.19
2	0.20	0.20
3	0.40	0.42
4	0.40	0.42
5	0.82	0.99
6	0.82	0.99
7	0.95	1.31
8	0.97	1.34
I = Based on flow rate value at inlet at start of measurement		
II = Based on flow rate value at inlet at end of measurement		

Comparison of values I and II

When measuring the DN 100 and DN 200 pipes, the same flaring installation is used. The pipe diameter between the saddle and the flaring installation is DN 32 and has a length of 10 metres. The diameter of the connection point at the flaring installation that is mounted on the saddle is 29.8 mm. The borehole diameter on the DN 100 pipe is 28 mm and the DN 200 pipe has a borehole diameter of 37 mm.

Table 1 shows that the flow rate (and therefore the purging speed) of the DN 100 hardly changes during the measurement. Table 2 shows that the flow rate (and therefore the purging speed) of the hydrogen flowing through the DN 200 increases during the measurements, starting from a purging speed of approximately 0.8 m/s. This can be explained by the difference in flaring installation's resistance in the DN 100 measurements and the DN 200 measurements. The resistance of the flaring installation is low with the purging flow rate in the DN 100 pipe, which means the influence of the natural gas still present is limited. In the DN 200 pipe, the differences between the starting and end speeds are greater. Compared to the DN 100 pipe, more gas must pass through the same flaring installation in the DN 200 pipe to achieve the same purging rate. Natural gas encounters more resistance compared to an equal flow rate of hydrogen. The amount of natural gas in the pipe decreases during the measurement, therefore the resistance of the flaring device decreases and the speed of the hydrogen supply increases.

Establishing the purging speed in practice, for example, can be done by measuring the differential pressure across a flange (restriction) or with a gas meter.

4.5 Determining total displacement of natural gas and flaring

Annex VIII contains a reference to the video recordings of the flaring process at various purging rates.

The transition from natural gas to hydrogen is clearly visible in all measurements through the flaring installation. The flame colour in all measurements evolves from a fully orange colour to a flame with patches of orange and then to a completely colourless flame. The transition from a natural gas flame to a hydrogen flame is smooth. The hydrogen flame remains intact in all measurements. A hydrogen detector was placed at the flaring installation; the purging process was stopped as soon as the meter indicated 100% hydrogen.

5. Estimation of costs

If it is determined that the main pipelines for natural gas in their existing state are also suitable for distributing hydrogen, these pipelines can be safely commissioned by means of purging the natural gas directly with hydrogen.

The estimated costs of purging main pipelines with hydrogen are shown below per kilometre.

Guiding principles:

- PVC main pipe, max DN 200
- Work carried out by three employees (digging 2 holes and purging).
- Work duration: 3 hours.
- Hourly rate: € 65.
- Material: 2 saddles.
- Material costs per saddle: € 50.

The costs for purging one kilometre of pipe therefore comes to:

$$[9 \times € 65] + [2 \times € 50] = € 685$$

The amounts mentioned are exclusive of VAT and are limited to the actual purging of the main pipelines. The preparation costs for the work (e.g. drawings, switching plans, KLIC reports) and the conversion to hydrogen in the homes, etc. have not been taken into account, as these are very specific for different sections of the network.

Purging with hydrogen will take place shortly before a conversion from a natural gas network to a hydrogen network. After this is done, it must be ascertained that the connected appliances in homes are also compatible with hydrogen. Further elaboration on how this transition and conversion is implemented at the homes and businesses of consumers is needed when answering question 55 (after answering all the sub-questions in this work package). The most logical course of action is to close the main valves of all consumer premises when purging the main pipelines. After completing the purging process of the main pipeline, the connecting pipes and indoor installations of homes and businesses will need to be purged.

6. Conclusions and answers to research question

The research study shows that hydrogen can be used to displace natural gas from existing natural gas pipelines. It proves that a natural gas distribution pipeline can be recommissioned as a hydrogen distribution pipeline after the natural gas has been displaced.

Furthermore, the study shows that purging natural gas with hydrogen including flaring is safe and technically feasible. However, when flaring hydrogen, one must be aware that a hydrogen flame is not as easily visible. There are no additional risks than when purging natural gas pipelines using the conventional methods.

The estimated cost of purging main gas pipes with hydrogen are € 685 (excl. VAT) per kilometre. These costs do not include the costs for work preparation and conversions in homes.

Purging DN 100 pipe

Natural gas is completely displaced by hydrogen at all purging speeds of 0.2 - 0.4 and 1.0 m/s. Flaring is feasible at all purging speeds used. During the transition from natural gas to hydrogen, the flame on the flaring installation remains intact at the purging speeds used.

Purging DN 200 pipe

Natural gas is completely displaced by hydrogen at all purging speeds of 0.2 - 0.4 - 0.8 and 1.0 m/s. Flaring is feasible at all purging speeds used. During the transition from natural gas to hydrogen, the flame on the flaring installation remains intact at the purging speeds used.

With a purging speed of 0.2 m/s in both the DN 100 and the DN 200, the natural gas is completely displaced by hydrogen. However, the conditions in practice when purging pipelines may be less favourable compared to purging the test pipes. For this reason, a safety factor of two is applied to be absolutely sure that the pipes have been completely purged. The minimum purging speed is therefore 0.4 m/s. This is in line with the report “Spoelen van waterstofleidingen” (Kiwa Technology GT-200289).

To reduce the duration of purging, a speed of 1.0 m/s is recommended. This also shortens the duration of an open flame (flaring). The advised purging speed of 1 m/s, as mentioned in report GT-200289, also applies in case of direct purging of natural gas with hydrogen. The minimum purging speeds and flow rates for diameters other than DN 100 and DN 200 are presented in Appendix IX. This statement complies fully with Kiwa Technology report GT-200289.

References

- [1] A.J. Kooiman, C. Lock en C.J.A. Pulles, "Spoelen van waterstofleidingen", Kiwa Technology, rapport GT-200289, maart 2021
- [2] C.J.A. Pulles, J.C. de Laat en C. Lock, "Affakkelen en afblazen van waterstof", Kiwa Technology, rapport GT-200096, april 2021.

I List of questions HyDelta WP1C

The following questions are addressed in this work package.

- Question number HyDelta 187: Research into the safe commissioning and decommissioning of pipeline sections in hydrogen distribution during the conversion to a hydrogen network and the associated costs.
- Question number HyDelta 124: Research into the performance of strength and density tests.
- Question number HyDelta 135: What is the effect of the existing gas network on the quality of hydrogen in distribution and transport? (Such as dust and dirt and THT)
- Question number HyDelta 185: Home pressure regulator: What are the risks if it is not modified?
- Question number HyDelta 101: Investigation of risks related to existing gas installations (at the customers) when converting from natural gas to 100% hydrogen.
- Question number HyDelta 61: How is it ensured that the developments of all components suitable for 100% hydrogen are integrated - in the distribution network (incl. connections), in the indoor installation and in the gas consumption appliances in homes and businesses - so that the entire chain is compatible?
- Question number HyDelta 55: What will a conversion to a hydrogen network look like?

II List of participants in the guidance group and sparring group

sub-question 187

Table 4. Composition of guidance group and sparring group

Name	Employer	Guidance group	Sparring group
D. Nieuwenhuizen	Stedin		V
H. Smit	Enexis		V
W. Koppenol	Enexis	V	V
W.R. Nispeling	Alliander		V
R. den Hartog	Westland Infra	V	V
J. Jonkman	Rendo	V	V
R. Scholten	Rendo	V	V
C. Lock	Kiwa Technology	V	V
S. Lueb	Kiwa Technology	V	V
The guidance group has been assigned a more active role in the implementation of the sub-study compared to the sparring group. The sparring group is involved in setting up the test programme and in assessing the concept reports.			

III Risk assessment and evaluation by Kiwa

Bestemd voor: Sparringgroep WP1c
Betreft: Spoelen HL, AL en GMO bij de ombouw van
aardgasdistributie naar waterstofdistributie.
Risico's
Van: Cees Lock, Kiwa Technology
Datum: 3 februari 2021

Bij het benoemen van risico's bij de ombouw van de hoofd- en aansluitleidingen en gasmeteropstellingen van aardgasdistributie naar waterstofdistributie is de methode van Fine en Kinney gebruikt.

Onderstaande inleiding op de RI&E is een citaat uit de RI&E Gastechnische risico's (versie 2, d.d. 02-12-2019) zoals deze is geactualiseerd door werkgroep VIAG 2019. Zie voor de volledigheid www.beviag.nl onder 'overige documenten'.

RI&E volgens Fine en Kinney

Bij het opstellen van de RI&E is de methode volgens Fine en Kinney voor de diverse gastechnische activiteiten toegepast. Bij deze methode wordt de risico-index bepaald d.m.v. het toekennen van een waarde voor de **kans** op het risico, de **frequentie** van de blootstelling aan het risico en het **effect** van de schade. **Voor de bepaling van het effect is uitgegaan van het potentieel gevolg. (worst case scenario).** De tabel van Fine en Kinney is op de laatste pagina van deze bijlage toegevoegd.

Er is gekeken naar de algemene gastechnische risico's als brand, explosie, verstikking en vlaminslag (bij affakkelen). Indien andere voor de hand liggende, specifiek met de betreffende gastechnische activiteit verbonden risico's aanwezig zijn, zijn deze ook opgenomen.

Voor elke gastechnische activiteit is een initiële risicoscore bepaald ervan uitgaande dat de werkzaamheden door een niet deskundige persoon worden uitgevoerd. Vervolgens zijn conform de arbeidshygiënische strategie bronmaatregelen (incl. technische- en organisatorische maatregelen) bepaald welke vooral de kans op het risico reduceren. In een beperkt aantal gevallen wordt tegelijkertijd het effect beperkt. Hierna is opnieuw een risico weging gemaakt. Als tweede stap zijn beschermende maatregelen in kaart gebracht welke vooral het effect van het risico reduceren en is ook hier een resterende risicoweging gemaakt. In een beperkt aantal gevallen wordt hierbij ook de kans beperkt.

Risico's van activiteiten niet direct gerelateerd aan de uit te voeren gastechnische activiteiten zijn niet meegenomen. Hiervoor wordt verwezen naar de Arbocatalogus Netwerkbedrijven, relevante normen en bedrijfseigen voorschriften/procedures en risico inventarisaties.

Toelichting op de wijze van bepaling van de risicoweging:

1. De kans op het initiële risico is gebaseerd op het uitvoeren van de gastechnische activiteit door een ondeskundig persoon. Een belangrijke bronmaatregel is de deskundigheid van personeel (opleiding, aanwijzing en instructie).
2. De blootstelling / frequentie is gebaseerd op de activiteiten door één persoon of één ploeg (Netbeheerder of uitbested) die deze werkzaamheden standaard/continue uitvoert. Dit is gedaan om te voorkomen dat voor elke activiteit "voortdurend" ingevuld wordt, daar de activiteiten verspreid over de verschillende verzorgingsgebieden van de netbeheerders dagelijks en dus voortdurend voorkomen.
3. Het initiële effect is gebaseerd op het worst case scenario zonder dat de medewerker beschermende maatregelen heeft genomen (bijv. PBM's.)
4. De gastechnische activiteiten conform de onderverdeling zoals gebruikt in de VWI's gas zijn beoordeeld. In de leeswijzer zijn daarbij uitgangspunten opgenomen. Deze uitgangspunten kunnen ook gehanteerd worden bij activiteiten die niet in een VWI zijn vastgelegd.

Voor het opstellen van een complete RI&E moeten de volgende stappen worden doorlopen:

1. Inventariseren en valideren risico's.
2. Taak-risico analyse. Op te stellen indien
 - a. Werkzaamheden met een hoog risico moeten worden uitgevoerd die niet of niet geheel volgens de reeds bestaande procedures of werkinstructies kunnen worden uitgevoerd.
 - b. Procedures opgesteld of geëvalueerd moeten worden.
 - c. Werkzaamheden voor het eerst worden uitgevoerd, waarvan de risico's en ongewenste gevolgen (nog) niet bekend zijn.

In deze bijlage wordt alleen stap 1 voor gastechnische activiteiten doorlopen. Stap 2 wordt in deze bijlage niet doorlopen.

Risico-index volgens Fine en Kinney:

Kans van het risico: K

Waarde	Omschrijving
0,1	Bijna niet denkbaar (nooit van gehoord)
0,2	Praktisch onmogelijk (nooit van gehoord binnen bedrijfstak en branche)
0,5	Denkbaar, maar onwaarschijnlijk (wel van gehoord binnen bedrijfstak, maar niet binnen bedrijf zelf)
1	Onwaarschijnlijk, maar mogelijk in grensgeval (in laatste 10 jaar niet binnen bedrijf voorgekomen)
3	Ongewoon, maar mogelijk (in de laatste jaren binnen het bedrijf wel eens gebeurd)
6	Zeer wel mogelijk (enkele keren per jaar binnen het bedrijf gebeurd)
10	Te verwachten (komt vaak/vaker voor binnen het bedrijf)

Blootstellingfrequentie van het risico: B

Waarde	Omschrijving
0,5	Zeer zelden (1x per jaar)
1	Zelden (jaarlijks)
2	Soms (maandelijks)
3	Af en toe (wekelijks)
6	Geregeld (dagelijks)
10	Voortdurend

Effect van het risico: E

Waarde	Omschrijving
1	Gering: letsel zonder verzuim (EHBO) of hinder
3	Belangrijk: letsel en verzuim
7	Ernstig: irreversibel effect (invaliditeit)
15	Zeer ernstig: één dode (acuut of op termijn)
40	Ramp: enkele doden (acuut of op termijn)

Risicoscore: $R=K*B*E$

Klasse	Risicoscore	Actie
5	$R \leq 20$	Geen (risico aanvaardbaar)
4	$20 < R \leq 70$	Aandacht vereist (mogelijk risico)
3	$70 < R \leq 200$	Maatregelen vereist (belangrijk risico)
2	$200 < R \leq 400$	Directe verbetering vereist (hoog risico)
1	$R > 400$	Werkzaamheden stoppen (zeer hoog risico)

Gasdistributienet ombouwen van aardgasdistributie naar waterstofdistributie																
NR	ACTIVITEIT	GEVAAR/ARBO-RISICO	K	B	E	Risico index	Maatregel ter voorkoming	K	B	E	Risico index	Maatregelen ter bescherming	K	B	E	Risico index
	LD-Hoofdleidingen ombouwen (uit (aardgas)bedrijf nemen en in (waterstof)bedrijf nemen. Spoelen van hoofdleidingen (vermaasd)	<ul style="list-style-type: none">Niet alle aardgas is vervangen door waterstof ¹⁾H2-toestel veroorzaakt brand, explosie	6	3	7	126	<ul style="list-style-type: none">Waterstoftoestellen die door hun constructie veilig functioneren of naar een veilige toestand gaan en/of beveiligd zijn tegen aardgas-waterstofmengsel (ter info: de H2-ketel die in de Kiwa/Liander-woning is geïnstalleerd voldoet hieraan)Opstellen van een uitvoeringsplanOpleiding, aanwijzing en instructies	0,5	3	7	10,5	<ul style="list-style-type: none">Geen	0,5	3	7	10,5
G20	LD-Hoofdleidingen ombouwen (uit (aardgas)bedrijf nemen en in (waterstof)bedrijf nemen. Affakkelen of afblazen	<ul style="list-style-type: none">Brand, explosie, bedwelming en verstikking, potentiaal verschillen	10 10	3 6	15 15	450	<ul style="list-style-type: none">Voldoende ventilatieVoorkomen van ontstekingsbronnenOpleiding, aanwijzing en instructiesAfbakenen werkplek (i.v.m. concentratie medewerker en veiligheid omstanders/dieren)Voorkomen vrije gasuitstromingWerken onder <10% LEL concentratieWerken met minimaal twee personenOpstellen van een uitvoeringsplanAffakkel- afblaasinstallatie<ul style="list-style-type: none">Met RVS afblaaspijpAardenBorgen tegen omvallen	0,5 0,5	3 6	15 15	22,5	<ul style="list-style-type: none">GassignaleringsapparatuurZuurstofmeterAntistatische/vlamvertragend/nauwsluitend werkkledingBrandblusser ABC 6kg, blusdekenGasuitstroming naar een bewaakte, veilige plek	0,5 0,5	3 6	3 3	4,5
	LD-Aansluitleidingen en Gasmeteropstelling ombouwen (uit (aardgas)bedrijf nemen en in (waterstof)bedrijf nemen. Spoelen	<ul style="list-style-type: none">Niet alle aardgas is vervangen door waterstofH2-toestel veroorzaakt brand, explosieWaterstof-luchtmengsel in binneninstallatie ²⁾	6	3	7	126	<ul style="list-style-type: none">Waterstoftoestellen die door hun constructie veilig functioneren of naar een veilige toestand gaan en/of beveiligd zijn tegen aardgas-waterstofmengsel en tegen waterstof-luchtmengsels (ter info: de H2-ketel die in de Kiwa/Liander-woning is geïnstalleerd voldoet hieraan)Opleiding, aanwijzing en instructies	0,5	3	7	10,5	<ul style="list-style-type: none">Geen	0,5	3	7	10,5
G13	LD-Aansluitleidingen en Gasmeteropstelling ombouwen (uit (aardgas)bedrijf nemen en in (waterstof)bedrijf nemen. Affakkelen of afblazen	<ul style="list-style-type: none">Brand, explosie, bedwelming en verstikking, potentiaal verschillen	6 6	3 6	15 15	270	<ul style="list-style-type: none">Voldoende ventilatieGecontroleerde gasuitstromingVoorkomen van ontstekingsbronnenAarding / vereffeningGebruik gecertificeerde antistatische halfgeleidende slang type Ω (Ohm)Opleiding, aanwijzing en instructiesWerken met twee personenAfbakenen werkplek (i.v.m. concentratie medewerker en veiligheid omstanders/dieren)	0,5 0,5	3 6	15 15	22,5	<ul style="list-style-type: none">Gasuitstroming naar een bewaakte, veilige plekBrandblusser ABC 6kg / blusdekenGassignaleringsapparatuurZuurstofmeter (bij toepassing van inert gas)Antistatische/vlamvertragend/nauwsluitend werkkleding	0,5 0,5	3 6	3 3	4,5
	Ombouw algemeen - binneninstallatie	<ul style="list-style-type: none">Niet vervangen aardgastoestel veroorzaakt brand, explosie	3	3	15	135	<ul style="list-style-type: none">Inventarisatie van de toestellen bij alle om te bouwen gebruikers	0,5	3	15	22,5	<ul style="list-style-type: none">Geen	0,5	3	15	22,5
	Ombouw algemeen - distributienet	<ul style="list-style-type: none">Lekhoeveelheid neemt toe ³⁾	10	10	3	300	<ul style="list-style-type: none">Lekzoekronde voor en na ombouw	1	10	3	30	<ul style="list-style-type: none">Lekzoekronde herhalen 1 maand na ombouw	0,5	10	3	15
Opmerking		Optionele extra maatregelen ter voorkoming: de uitstroomopening van de affakkel- afblaasinstallatie (-slang) voorzien van een waterstof-vlamdover.														
Toelichting		Continue bewaking van de gasuitstroom en mogelijkheid tot bediening affakkel- afblaasinstallatie (-slang). Dit dient continue gelijktijdig plaats te kunnen vinden.														
		¹⁾ Bijvoorbeeld door een (dode) aftakking die over het hoofd is gezien, onjuist spoelplan. ²⁾ T.b.v. het ontluchten van de AL en GMO wordt de verbinding GMO-binneninstallatie losgekoppeld en na het spoelen weer gemonteerd. Hierbij wordt een geringe hoeveelheid lucht ingesloten. ³⁾ De lekkage met waterstof is maximaal factor drie groter. Bij kleine lekkages (bijv. door corrosie) zal het risico nauwelijks toenemen echter bij grotere lekkages (vanaf ca. 100 l/h) zal het risico toenemen (zie Gedrag van waterstof bij lekkages in het gasdistributienet - DNV-GL 2020 en Kiwa-Veilig Sectioneren Waterstofnetten GT-200231 (nog concept)) <ul style="list-style-type: none">De rood gekleurde waarden gelden bij de toepassing van waterstofDe oranje gekleurde waarden gelden bij de toepassing van aardgas (vermeld om gemakkelijk te kunnen vergelijken, zo is ook het nummer van VWI Gas vermeld)De rode tekst zijn de extra maatregelen i.v.m. de toepassing van waterstof														

IV Memo test programme - sub question 187 purging

Memo



Bestemd voor: Sparringsgroep deelvraag 187 WP1C
onderwerp: Testprogramma deelvraag 187 spoelen
van: Begeleidingsgroep deelvraag 187 WP1C
datum: 5 februari 2021

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Uitgangspunt bij dit onderzoek: De functie van een bestaande aardgasleiding wordt omgebouwd naar een waterstofleiding waarbij het aardgas rechtstreeks verdrongen wordt door waterstof.

Doelstelling bespreking 3-2-21 begeleidingsgroep: opstellen van het testprogramma t.b.v. deelvraag 187 aan de hand van:

- Beschreven risico's door leden van de sparringsgroep
- (Concept) rapport afblazen/affakkelen waterstof.
- (Concept) rapport spoelen waterstof, hierin is vastgelegd welke spoelsnelheid noodzakelijk is voor het verdringen van stikstof door waterstof.

Aan het eind van deze memo is het voorstel voor het testprogramma opgenomen.

Doelstelling bespreking 10-2-21 sparringsgroep: vaststellen van het testprogramma t.b.v. deelvraag 187 aan de hand van:

- Beschreven risico's door leden van de sparringsgroep
- (Concept) rapport afblazen/affakkelen waterstof.
- (Concept) rapport spoelen waterstof, hierin is vastgelegd welke spoelsnelheid noodzakelijk is voor het verdringen van stikstof door waterstof.

Aangeleverde risico's mbt vraag 187 – Spoelen WP1C

Deze zijn tijdens de bespreking van 3-2-2021 besproken en daar waar nodig aangevuld.

- Kiwa - memo - risico inventarisatie van 12-1-21 (vervangen door 3-2-21).
Opmerkingen/oordeel 3-2-21: in een enkele cel moet de kleur aangepast.

Daarnaast (aanlevering Johan Jonkman, Walter Koppenol en Rob Nispeling);

- Extra stof door 3x hogere snelheid van het gas.
Opmerkingen/oordeel 3-2-21: Door de hogere snelheid kan er stof losraken en verderop in het terech komen. Dit effect wordt onderzocht bij vraag 173 WP1B. Dit risico is niet van invloed op de risico's bij het verdringen van aardgas rechtstreeks door waterstof waarbij het gas wordt afgefakkeld, zie ook verderop.
- Waterstof voldoet niet aan kwaliteit door achterblijvende "restanten" van aardgas
Opmerkingen/oordeel 3-2-21: beschouwing bij vraag 135 WP1C.
- Problemen bij affakkelen van het gas doordat de samenstelling in fases veranderd van aardgas naar waterstof.
Opmerkingen/oordeel 3-2-21: het affakkelen onderdeel laten zijn van de metingen. Er is geen inslag te verwachten omdat er geen lucht wordt bijgemengd (bleek ook bij recente ervaringen met het waterstofhuis bij Kiwa).
- Niet voldoen aan veiligheidsworkinstructies (VIAG) wanneer in verband met bovenstaande punt gekozen wordt voor afblazen i.p.v. affakkelen.
Opmerkingen/oordeel 3-2-21: dit werd gesteld met de gedachte dat afblazen niet is toegestaan, dit bleek niet juist. Volgorde in VIAG is leegbufferen, dan affakkelen of afblazen. Bij het verdringen van aardgas rechtstreeks door waterstof is affakkelen de beste optie.





- Spontaan ontbranden van waterstof.
Opmerkingen/oordeel 3-2-21: zelfontbranding zal niet optreden, er is altijd een externe ontstekingsbron nodig. Bij het afblazen van waterstof kan meegevoerd stof mogelijk tot ontbranding van de waterstofwolk leiden. Dit is, naast het voorkomen van milieubelasting door afblazen aardgas/waterstof, een extra beweegreden om te kiezen voor affakkelen.
- Onvoldoende kwaliteit van het gas (waterstof) meteen na de ombouw. Door de hogere snelheid wordt de voorgestelde ondergrens van 98% H₂ mogelijk niet gehaald. De hoge snelheid leidt mogelijk tot veel meer vervuiling.
Opmerkingen/oordeel 3-2-21: vervuiling zoals aardgascondensaat, water (extreem geval), THT dat met H₂ wordt meegevoerd. Vervuiling door THT, permeatie zuurstof, stikstof en waterdamp is onderdeel van vraag 135 WP1C. Stof en vuil is onderdeel van de beantwoording van vraag 173 in WP1B. De aanwezigheid van aardgascondensaat en grote hoeveelheden water komen naar verwachting niet vaak voor. Waterstof wordt weliswaar met een grote snelheid door de leidingen gevoerd, maar heeft ook een lagere dichtheid. Het is nog maar de vraag of de kracht voldoende is om meer aardgascondensaat en water mee te voeren dan dat dit het geval is bij aardgas. Dit aspect blijft in het kader van deze vraag (187) buiten beschouwing.
- Toestellen (o.a. cv-combi-ketels) krijgen een mengsel van waterstof en lucht te verwerken (wordt benoemd in de tabel van de Kiwa - memo - risico inventarisatie, zal ook aandachtspunt moeten zijn bij de beantwoording van vraag 101 WP1C)
Opmerkingen/oordeel 3-2-21: vanuit ervaringen Kiwa UK (project Hy4Heat) geven twee toestelfabrikanten aan dat toestellen niet kunnen ontsteken bij een mengsel van waterstof en lucht in de gasleiding. Dit omdat er bij deze voorgemengde toestellen nog eens lucht wordt bijgemengd, waardoor het buiten de ontstekingsgrenzen komt te liggen. O.b.v. ervaring Kiwa UK is het advies om geen vlamdovers voor cv-toestellen te plaatsen (geen meerwaarde, kan zelfs tot ongewenst verbrandingsgedrag leiden). Bovendien zal lucht bij het rechtstreeks verdringen met waterstof niet meegevoerd worden (tenzij er een bedieningsfout wordt gemaakt)
- Toestellen (o.a. cv-combi-ketels) ingesteld voor aardgas krijgen een mengsel van waterstof en aardgas te verwerken (Kiwa: indien vergeten is het toestel te wisselen). (Wordt benoemd in de tabel van de Kiwa - memo - risico inventarisatie, zal ook aandachtspunt moeten zijn bij de beantwoording van vraag 101).
Opmerkingen/oordeel 3-2-21: het is niet getest door Remeha (leverancier (aardgas- en waterstofketel waterstofhuis). Bij beantwoording vraag 101 nagaan of dit door andere fabrikanten wel is gedaan.
- Toestellen (o.a. cv-combi-ketels) krijgen een druk van 100 mbar te verwerken (door falende drukregelaar door meevoeren van bijvoorbeeld stof).
Opmerkingen/oordeel 3-2-21: dit is een aandachtspunt bij de beantwoording van vraag 101, falen drukregelaar is aandachtspunt bij vraag 185 in WP1C.

Aanvullende risico's benoemd tijdens overleg van 3-2-21:

- Gebrek aan ervaring.
- Gebruik van elektronische apparatuur. In de werkpakketomschrijving WP1C is een beschouwing gegeven m.b.t. het gebruik van gereedschap en meetapparatuur. Deze beschouwing heeft betrekking op het gebruik bij gasdetectie bovengronds lekzoeken. Vooralsnog wordt veronderstelt dat het gebruik van gereedschappen/meetapparatuur explosie-veilig moet zijn en dat nader onderzoek niet nodig is.

Is of komt er informatie uit pilots beschikbaar met betrekking tot het spoelen van aardgasleidingen met waterstof?

- Hoogeveen (Rendo); 80-100 woningen in een nieuwe wijk worden direct op waterstof aangesloten (dat wordt verwacht in 2022). Daarna wordt er een bestaande naastliggende wijk (Erflanden) overgezet van aardgas naar waterstof. Dat zal niet voor 2023 plaatsvinden
- Lochem (Alliander) Q4 2021 van start. Ca. 15 woningen. Inzet van het bestaande aardgasnet .
- Enexis wil in de zomer 2022 in Groningen pilot gaan draaien. Nog niet duidelijk of bestaand net omgezet gaat worden. Mogelijk nieuw aardgasnet en bestaand net ombouw naar H₂.



Wat zijn de ervaringen vanuit het project Uithoorn (Stedin)? Bestaand aardgasnet op waterstof? Of is een nieuw waterstofnet gelegd en is er alleen gebruik gemaakt van de bestaande binneninstallaties?

Beschikbare rapportages

- Rapport Kiwa GT200075; spoelen van aardgasleidingen.
Minimale vastgestelde snelheid (DN200) is 0,3 m/s, advies is 1 m/s
- Rapport Kiwa GT-200289-concept; spoelen van waterstofleidingen (nog niet definitief)
Minimale vastgestelde snelheid (DN200) is 0,4 m/s, advies is 1 m/s
- Rapport Kiwa GT-200096-concept; affakkelen en afblazen van waterstof (nog niet definitief).
Daarin wordt in tabel 1 v.d. samenvatting al ombouw aardgas naar waterstof benoemd. Hierin wordt alleen affakkelen benoemd (i.v.m. milieubelasting).

Voorstel voor testprogramma:

Spoelen met waterstof van PE-leidingen met diameter 110 mm en 200 mm gevuld met aardgas.

Spoelsnelheden 0,2 – 0,4 – 1,0 m/s. Metingen in duplo.

Afhankelijk van resultaten eventueel aanvullende snelheden.

Bij het spoelen met waterstof zal de snelheid uiteindelijk toenemen. Goed rekening houden met het feit dat snelheden tijdens het spoelen zullen veranderen.

Meetopstelling zoals beschreven in rapportage Kiwa GT-200289-concept: figuur 3 en Bijlage II.

Meting van concentratie aardgas (afname van concentratie tijdens het spoelen met waterstof). Meters zijn selectief voor aardgas. De meters voor waterstof zijn niet volledig selectief voor waterstof (kruisgevoelig voor de aanwezigheid van aardgas). Voorstel om wel 1 meetpunt net voor de affakkelininstallatie te plaatsen met een H₂ meting.

Loggen van meetgegevens iedere seconde.

Affakkelen, praktisch vaststellen of het affakkelen werkt bij de uit te voeren metingen (conform aanbevelingen/aanwijzingen uit bovengenoemd concept-rapport).

Ter discussie; wel / of niet experimenteren met afblazen?

Bij verdringing van aardgas door waterstof wordt geen vlamdover toegepast.

Met name het affakkelen wordt op film vastgelegd.

3-2-21 Walter:

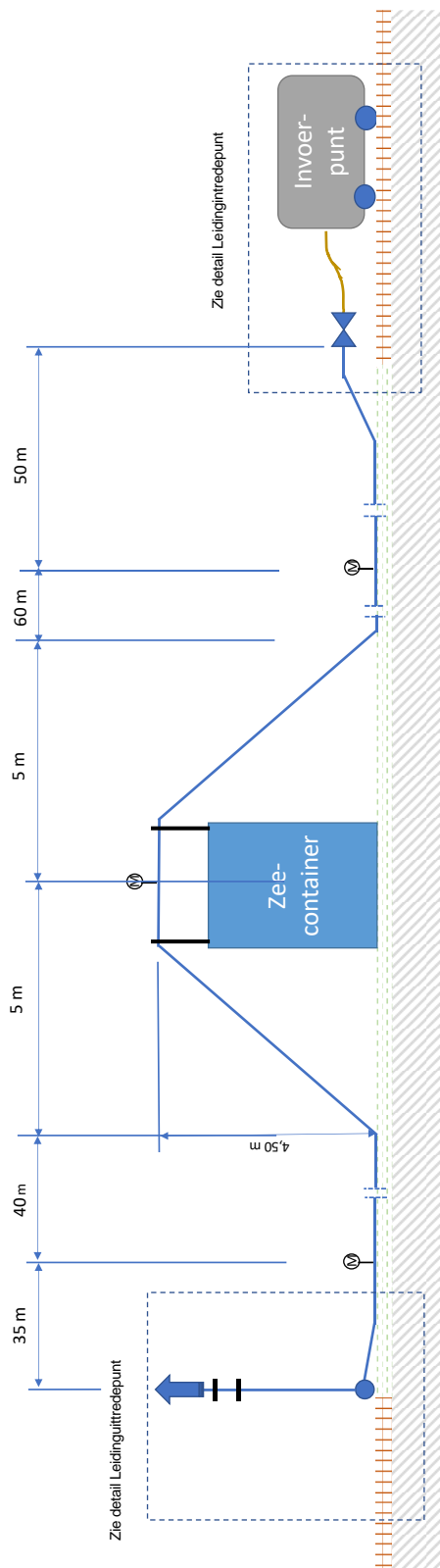
Kan 110 en 200 mm aan elkaar gekoppeld worden (parallel) om zodoende een simulatie te maken van een grotere leidinginhoud? Het advies van 1 m/s is in de praktijk mogelijk niet altijd (eenvoudig, met standaard apparatuur) haalbaar bij grote leidingdiameters (groot af te fakkelen volumes). Apparatuur (w.o. air-mover) kan dit niet altijd aan. Esders wel (tot DN 200), andere fabrikant(en) (nog) niet.

Hier rechtstreeks spoelen met 100 mbar H₂, dus geen air-mover nodig. Hier beperken tot het vaststellen van de minimaal benodigde spoelsnelheid. Overigens is de 1 m/s een advies, de minimaal benodigde snelheid ligt lager (zie eerder genoemde rapporten m.b.t. het spoelen).

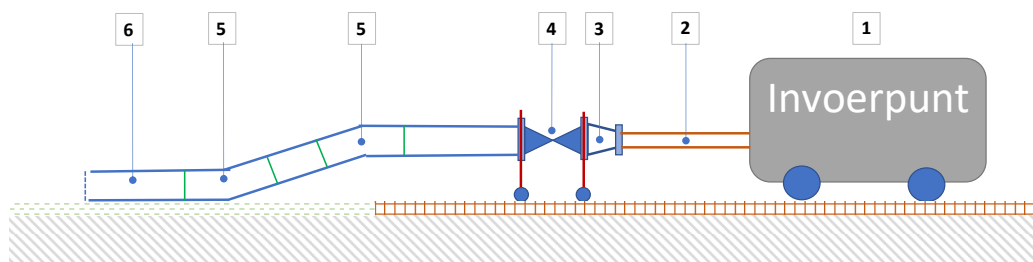
Mogelijk in de toekomst

Rapportage spoelen waterstof (rapport Kiwa GT-200289-concept) en op te stellen rapportage aardgas-waterstof met elkaar combineren.

V Detailed drawings of the test pipeline

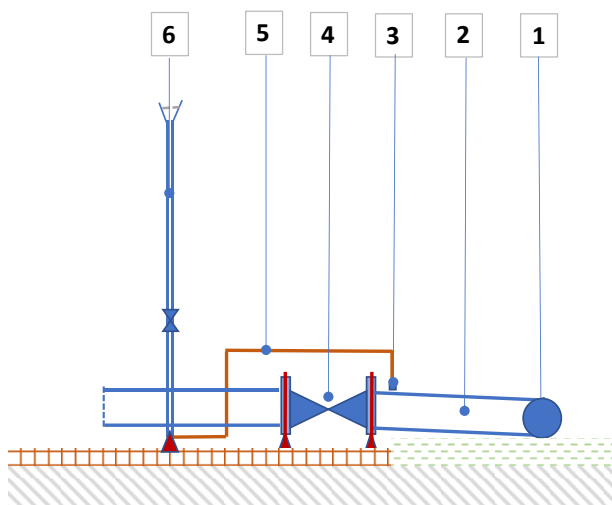


Detail of pipe entry point



- 1 Mobile district station
- 2 Flexible connection pipeline
- 3 Reducer 4 inch - 8 inch
- 4 Gate valve DN 200
- 5 Pipe bend 22 deg - R 3,5 D
- 6 PE 200 - SDR 17

Detail of pipe exit point



- 1 Pipe bend 200 - 90 deg - R 3,5 D
- 2 PE 200 - SDR 17
- 3 Saddle GF 200 for inflatable stopper
- 4 Gate valve DN 200
- 5 Flare hose
- 6 Flare stack (small)

A DN 100 test pipe was installed next to the DN 200 test pipe as shown above, with the same pipe layout. A flare stack with a diameter of 1½" (indicated in the drawing with no. 6) is used to flare the natural gas and hydrogen in both the DN 200 and DN 100 pipelines.

VI Photos of the test set-up



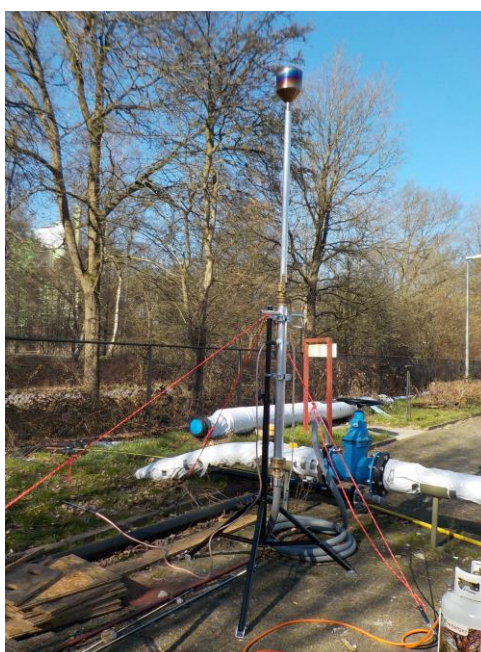
Entry points and inflow side of the bridge pipe



Bridge pipe and outflow side of bridge pipe



Exit points (red arrows) and flaring installation



VII Measuring equipment used

Description	Manufacturer and type	Kiwa no.
Natural gas detector	MultiRAE Lite IR	114033
Natural gas detector	MultiRAE Lite IR	114034
Natural gas detector	MultiRAE Lite IR	114036
Natural gas detector	MultiRAE Lite IR	114037
Natural gas detector	MultiRAE Lite IR	114038
Natural gas detector	MultiRAE Lite IR	114039
Natural gas detector	MultiRAE Lite IR	114040
Natural gas detector	MultiRAE Lite IR	114041
Natural gas detector	MultiRAE Lite IR	114043
Hydrogen detector	Riken Keiki NP 1000	114633
Gas meter	Elster - RVG G65	-
Electronic Volume Conversion Instrument	Wigersma Sikkema - Unigas 300	-

VIII Reference to video recordings of flaring

Below is a reference to the video recordings of the flaring process at various purging speeds:

<https://youtu.be/S2woOm4YrqY>

IX Purging speeds and flow rates at different pipe diameters

On the basis of the present report, the table below with explanations⁶ is also applicable to the displacement of natural gas with hydrogen.

Pipe diameter	Minimum required purging speed [m/s]	Required flow rate at the required purging speed [m ³ _n /h]	Required flow rate at the recommended purging speed of 1,0 m/s [m ³ _n /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

Remarks:

- The minimum required purging speed applies to all pipe materials.
- A purging speed of at least 0.4 m/s is required for pipes with a diameter smaller than or equal to DN 200. For pipes with larger diameters, the purging speed must be increased proportionally to the diameter.
- The nominal diameter is taken into account for the required flow rate, so for DN 200 an inside diameter of 200 mm is taken into account. For example, the required flow rate in a DN 200 PE pipe (inside diameter 177 mm) is lower (36 m³_n/h) and the flow rate in a DN 200 steel pipe (inside diameter 210 mm) is higher (50 m³_n/h).
- In areas where different pipe diameters in the pipeline route require purging, the purging speed of the largest pipe diameter should be used.

⁶ Source: Kiwa Technology report “Spoelen van waterstofleidingen GT 200289” – Reference [1]