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Gas pressure regulation station for hydrogen

Research on suitability of natural gas station as hydrogen station

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Colophon

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Summary

The Dutch Gas Distribution System Operators want to determine the suitability of existing – or possibly limited adapted – gas pressure regulating stations for natural gas (L_{gas})[1] for use for pure[2] hydrogen (H_2).

At present it is not known whether the current natural gas pressure regulating stations are suitable for reducing hydrogen in pressure in a correct, reliable, and safe manner.

The aim of this project is to gain insight into the operation and suitability of a new gas pressure regulating station, by means of practical tests, when hydrogen is used instead of natural gas.

Main research question: is the natural gas pressure regulating station technically suitable for use with hydrogen?

On behalf of the network operators a gas pressure regulating station has been provided by Rendo for carrying out the tests. The capacity of the gas pressure regulating station is 750 m^3_n/h (**natural gas**) at the minimum inlet pressure of 3 bar[3]. The nominal inlet pressure is 8 bar and the nominal outlet pressure is 100 mbar. The gas pressure regulating station complies with NEN 1059 (the Dutch version of the European standard for gas pressure regulation installations EN12186).

For the execution of the tests a measurement protocol was developed specifying the steps, conditions, and measurements to be taken for all tests. In addition to the measurement protocol, vibration and pulsation measurements were performed.

The gas pressure regulating station was first tested with **natural gas** up to a maximum of 750 m^3_n/h. The gas pressure regulating station was subsequently tested with **hydrogen** up to a maximum flow rate of 2,250 m^3_n/h.

Conclusion

Based on the measurements, as presented in this report, the main conclusion is:

THE TESTED GAS PRESSURE REGULATING STATION DESIGNED FOR **NATURAL GAS** CAN BE USED WITH **HYDROGEN** WITHOUT MODIFICATION

Note:

- The conclusion only concerns the technical functioning. No statement can be made about long-term behavior.

[1] ~~Het~~ L_{gas} (low calorific gas) consists of 86 vol% methane + 14% nitrogen.
[2] Hydrogen purer than 99%.
[3] Overpressures are stated in this report (8 bar corresponds to 9 bar absolute).

Recommendations

In addition to the investigation in the context of the HyDelta work packages, it is recommended to investigate (existing) stations with (significantly) other configuration as well as stations with other frequently used types of gas pressure regulators.

Explanation:

- An installation in a housing with a volume of approximately 0.5 m^3 was investigated. Installations with other configuration are, for example, installations in a cabinet (2 by 1 m) and a free-standing building. But also a high pressure delivery station.
- By researching the most common combinations of configurations and pressure regulators, the occurrence or non-occurrence of resonances can be determined for those combinations.

Other recommendations are:

- Investigation of the cause and effect of the unstable outlet pressure (high frequency pressure fluctuations) is advised if it occurs again.
- Further research into the functioning of directional control valves under hydrogen conditions.
- Further research into the functioning of safety shut-off valves under hydrogen conditions.

Contents

1 Introduction

1.1 Reason
The Dutch regional network operators want to establish the suitability of existing - or possibly slightly modified - gas pressure regulation stations for natural gas (L_{gas})[1] for use with pure[2] hydrogen (H_2).

1.2 Problem statement
At present it is not known whether the current (natural) gas pressure regulation stations are technically suitable for reducing the pressure of hydrogen in a correct, reliable, and safe manner.

Explanation:
- Hydrogen has different physical properties to natural gas and to deliver the same amount of energy as natural gas, the gas velocity of the hydrogen must be increased by a factor of three[3]. It is necessary to examine whether these factors have an impact on the technical operation of the station.

1.3 Objective
The objective of this study is to gain insight, by means of practical tests, into the operation and suitability of a new gas pressure regulation station if, instead of natural gas, the medium hydrogen is used. Specifically, the following aspects are being investigated:
- The external leakage rate of the whole pressure regulator station when using hydrogen.
- The correct operation of the components when using hydrogen.
- The internal leakage of the valves and safety devices.
- The operation of the safety devices.
- The operation / control behavior of the controller.

As explained above, to supply the same amount of energy as with natural gas, the speed of the hydrogen in the gas network and thus also in the gas pressure regulation stations must be higher. This is expected to be achievable with the same components and pressures. This study must determine, by means of practical tests, what effects increasing the speed has on the complete operation of the (natural) gas pressure regulation station.

In summary, the research question is: is the natural gas pressure regulation station technically suitable for use with hydrogen?

1.4 Approach
Rendo has made a gas pressure regulation station available on behalf of the network operators for the performance of the tests, consisting of a regulator, a safety shut-off valve (VA) and a safety shut-off valve (VAK) and associated shut-off valves and piping. The capacity of the gas pressure regulating station is 750 $m^3{}_n/h$ (**natural gas**) at a minimum inlet pressure of 3 bar[4]. The nominal inlet pressure is 8 bar and the nominal outlet pressure is 100 mbar. The gas pressure regulating station complies with NEN 1059:2019.

Due to the size of the hydrogen flows released during these tests, the tests were carried out at the Twente Safety Campus in Enschede for licensing reasons.

For the performance of the tests, a measurement protocol was drawn up and discussed with representatives of Netbeheer Nederland, in which the steps to be taken, conditions and measurements for all tests are specified. About the prescribed temperatures, it was established in advance that these cannot be influenced, or can hardly be influenced, as the gases are supplied from cylinder packs and the measurements take place in the open air (no laboratory conditions). The ambient temperature and the

[1] The Lgas (low calorific gas) consists of 86 vol% methane + 14% nitrogen.
[2] Hydrogen purer than 99%.
[3] Energy density: natural gas 38 MJ/kg - hydrogen 120 MJ/kg.
Calorific value: natural gas 31.7 MJ/m3n - hydrogen 10.8 MJ/m3n.
[4] Overpressures are mentioned in this report (8 bar corresponds to 9 bar absolute).

gas temperature during the measurements deviate from the temperatures as prescribed in the measuring protocol. This has no significant effect on the conclusions.

The gas pressure regulating station was first tested with natural gas up to a maximum flow rate of 750 m^3_n/h. Next, the gas pressure regulating station was tested with hydrogen up to a maximum flow rate of 2,250 m^3_n/h.

During the test with the maximum flow rate of hydrogen, a gas velocity of more than 60 m/s was reached in the outlet pipe (100 mbar), which made it possible to determine with sufficient reliability whether the pressure measured at the header is representative of the 'network pressure'. To this end, a buffer tank has been installed on the outlet side which significantly reduces the flow speed of the gas. This simulates the presence of a gas distribution network.

The measurement protocol is included in chapter 3.

In addition to the planned tests in accordance with the measurement protocol, vibration and pulsation measurements were carried out by TNO during the pressure stabilization measurements, test 8 of the measurement protocol.

For some of the measurements, the standard test system for gas pressure regulation installations, the PLEXOR test system, was used (see the measurement protocol, chapter 3). The measurements with ~~the~~ PLEXOR test system were performed by employees of Wigersma & Sikkema.

2 Gas pressure regulation station

2.1 Gas pressure regulation station

Figure 1 shows the gas pressure regulation station where the test was carried out.
Nominal inlet pressure is 8 bar, nominal outlet pressure is 100 mbar and minimum capacity at 3 bar is 750 m^3_n/h natural gas (L_{gas}).

Figure 12: Gas pressure regulation station (district station)
A flow straightener has been installed as shown in the left picture

2.2 Construction of the gas pressure regulating station

This is a single-line district station housed in a stainless-steel enclosure (half cubic meter enclosure) consisting of the following components:

- Inlet valve which also serves as a safety valve (VA).
- Dust filter.
- Gas operated pressure regulator with attached safety device (safety shut-off valve (VAKAAN)).
- Exhaust valve type butterfly valve.

For a detailed description of the components used, see Annex II.

2.3 Gas pressure regulating station in the test setup

For a schematic and photos of the test setup, see Annex IIIand IV.

3 Measurement protocol

In this chapter the measurement protocol is given, points 1 to 11, preceded by some remarks.

Notes:

- Natural gas is referred to as CH4 in this measurement protocol.
- Tests 1 through 9 are performed with natural gas (CH_4) and H_2 (5.0), where the H_2 volume flow is 3x the natural gas volume flow.
- Natural gas means low calorific gas (86 vol% methane + 14% nitrogen).
- Pressure settings remain identical.
- Where relevant the tests are based on or derived from EN 334[1] and EN 14382[2].
- Tests 1 to 11 may be combined.
- The ambient temperatures listed below may not be attainable because the tests are performed outdoors.
- The same applies to the gas temperature because the gas is supplied from bottle packs whereby the pressure is reduced from max. 200 bar to 8 bar.
- The measurements with ~~the~~ PLEXOR were performed by employees of Wigersma & Sikkema.

1. Leak tightness (external)
   This test is carried out **once** with CH4 and with H_2
   Use of leak detector (CH_4 / H_2), 8 bar (100 mbar off)
   Ambient temperature 20 ^{0}C +/- 5 ^{0}C
   Preceded by soaping

   Criterion: according to NEN 7244, clause 4.4.3.4.4: the tested pipe section complies with the stipulated requirements if it has been observed during the test that the pipe is leak tight (for pipe section and pipe, station should be read here)

2. Leak tightness (internal)
   This test shall be carried out **once** with CH_4 and with H_2
   a. Inlet valve (VA)
   b. Exhaust valve
      Inlet pressure 8 and 3 bar (100 mbar out)
      Ambient temperature 20 ^{0}C +/- 5 ^{0}C
      Pressure measurement +/- 1 mbar
      Pressure monitoring for 15 minutes with 8 bar and with 3 bar inlet pressure and closed regulator, and for 15 minutes 100 mbar with open regulator

   Criterion: the acceptance criteria in accordance with NEN-EN12266-1-2012, rate C (see annex IV).

[1] Gas pressure regulators for inlet pressures up to 100 bar.
[2] Safety devices for gas pressure regulating stations and installations - Gas safety shut-off valves for inlet pressures up to 100 bar.

3. Pressure loss over the filter (element)
This test is carried out once with CH_4 and with **H_2 at 750 m^3_n/h** - CH_4 and **2,250 m^3_n/h - H2**
Inlet pressure 8 bar
Accuracy pressure loss +/- 1 mbar

Criterion: according to NEN 1059, article 8.3.2.2: the pressure loss of the ~~dust~~ filter may not influence the stability of the pressure control system in a negative way

4. Activating pressure of safety devices (without flow)
This test is carried out **three times** with CH_4 and with H_2
Ambient temperature 20 ^{0}C +/- 5 ^{0}C
Executed with test ~~case~~test system (PLEXOR)
Accuracy pressure measurement +/- 0,1 mbar

Criterion: according to NEN 1059, clause 9.31: The pressure protection system shall automatically come into operation if, in the event of failure of the pressure control system, the pressure in the downstream system exceeds the permissible limits. The expected deviations of the pressure protection system to the set values (accuracy class (AC)) shall be considered. The AC of the VAK is 2.5 and the AC of the VA command valve is 1 (Rendo specification)

5. Closing time of the VA
This test is carried out **three times** with CH_4 and with H_2
Executed with PLEXOR test system
Pressure change rate 0,5 - 2 mbar/s

Criterion: according to NEN 1059, article 9.3.2: the reaction time of a pressure safety device must be sufficiently short to prevent a (temporarily) too high pressure in the downstream system.

6. Leak tightness (internal) of activated safety devices
This test is carried out **once** with CH_4 and with H_2
Inlet pressure 8 and 3 bar (100 mbar out)
Ambient temperature 20 ^{0}C +/- 5 ^{0}C
Executed with PLEXOR test system
Pressure monitoring for 15 minutes with 8 and with 3 bar inlet pressure and closed regulator, and for 15 minutes 100 mbar with open regulator

Criterion: the acceptance criteria in accordance with NEN-EN12266-1-2012, rate C (see annex IV).

7. Closing pressure when closing the exhaust valve
This test is carried out twice with CH_4 and with H_2
Manually closing the exhaust valve in 1 to 2 seconds at an initial flow of 100 +/- 20 m^3_n/h CH_4 and 300 m^3_n/h H_2
Inlet pressure 3 +/- 0.1 bar
Initial outlet pressure 100 mbar
Outlet volume > 0.2 m^3 between regulator and control valve

Criterion: no significant difference in closing pressure in the application with CH_4 and H_2

8. Outlet pressure and pressure stability (resonances[1]) during increase and decrease of flow
This test is carried out **twice** with CH_4 and with H_2
Inlet pressure 8 bar

[1] Small, rapid vibrations that can lead to (accelerated) wear of components.

Ambient temperature 20 ^0C +/- 5 ^0C
Gas temperature 15 ^0C +/- 5 ^0C
Pressure measurement +/- 1 mbar
Flow rate increase/decrease controlled **10 - 750** m^3_n/h **- CH_4** and **10 - 2.250 m^3_n/h - H_2**
Rate of flow change 10 +/- 1 m^3_n/h
Pressure and flow rate electronically recorded with a time resolution better than 5 s^{-1}
Average flow rate (once) per 10 s, accuracy better than +/- 15 %
Regulator valve manually operated

Criterion: No significant difference in exhaust pressure and pressure stability when using CH_4 and H_2

9. Noise emission during test 8
This test is carried out **twice** with CH_4 and with H_2
Measured with db(A) meter, at 1 m distance from closed housing at 1 m height

Criterion: the noise emission of a hydrogen station shall not be significantly higher than that of a natural gas station

10. Temperature measurement of pressure regulator body and outlet pressure for up to 30 minutes at approx. **750 m^3_n/h H_2** (temperature change by Joule / Thompson effect)
This test is performed **once** with H_2
Thermocouple in inlet pipe (8 bar section)
Thermocouple in outlet pipe (100 mbar section)
Thermocouple on the outside of regulator
Accuracy temperature +/- 0.5 ^0C
Accuracy pressure measurement +/- 1 mbar
Additional visual and audible observation and (subjective) assessment

Criterion: no greater temperature change than in the case of reduction of natural gas

11. Temperature measurement of the pressure regulator body and the outlet pressure for a maximum of 30 minutes at approx. **1,500 m^3_n/h H_2** (temperature change partly due to Joule / Thompson effect)
This test is performed **once** with H_2
See at 10
Remark: because any temperature change at 1,500 m^3_n/h is sufficiently visible and in order to somewhat limit the amount of hydrogen to be discharged, this flow rate has been chosen for this test instead of 2,250 m^3_n/h

Criterion: no greater temperature change than in the case of reduction of natural gas

4 Measurement results

The measurement results are listed whereby the paragraph numbering corresponds to the test numbering of the measurement protocol.

4.1 Leak tightness (external)

No external leaks have been identified with the application of **natural gas**.
No external leaks have been detected in the application of **hydrogen**.

Conclusion: the external leak-tightness meets the requirements.

4.2 Leak tightness (internal)

4.2.1 Inlet shut-off valve (VA safety shut-off valve)

Natural gas
The average leakage rate over the entire 15-minute period is 0.9 mbar/min. This equates to a leakage of 44.3 ± 10% mm^3/s.

Hydrogen
The average leakage rate over the entire 15-minute period is 1.2 mbar/min. This equates to a leakage of 58.8 ± 10% mm^3/s.

Notes:

- For the acceptance criteria in accordance with NEN-EN12266-1-2012 and the calculation of the internal leakage, see Appendix IV.
- The inlet valve complies with Rate C (3.0 * DN = 150 mm^3/s).
- Based on the theory that the leakage with hydrogen would be approximately 1.5 to 3 times[1] as high as with natural gas, the result of the measurement is that the leakage with hydrogen is smaller than expected. It should be borne in mind that the shut-off valve was operated between the two tests and may have been pressed slightly further shut during the test with hydrogen than during the test with natural gas.

Conclusion: the internal leak-tightness of the inlet valve meets the requirements.

4.2.2 Outlet valve

Natural gas
The average leakage value over the stable measuring time of 10 minutes is 126.5 ± 10% mm^3/s.

Hydrogen
The average leakage value over the stable measuring time of 10 minutes is 39.0 ± 10% mm^3/s.

Notes:

- For the acceptance criteria in accordance with NEN-EN12266-1-2012 and the calculation of the internal leakage, see Appendix IV.
- The inlet valve complies with Rate C (3.0 * DN = 150 mm^3/s).
- Based on the theory that the leakage with hydrogen would be approximately 1.5 to 3 times as high as with natural gas, the result of the measurement is that the leakage with hydrogen is smaller than expected. It should be borne in mind that the shut-off valve was operated between the two tests and may have been pressed slightly further closed during the test with hydrogen than during the test with natural gas.

Conclusion: the internal leak-tightness of the outlet valve meets the requirements.

[1] Depending on the pressure difference and the shape of the leakage opening, leakage with hydrogen is 1.5 to 3 times greater than with natural gas.

4.3 Pressure drop over the filter (element)

See paragraph 4.8.

Figure 3 (natural gas) and Figure 5 (hydrogen) show that the measurement contains noise (only the positive values are shown). The average measurement values as indicated by the thick orange line are at best indicative. It is possible that the flow along the measuring nipples causes an unstable static pressure at these measuring points.

The **conclusion** is that the pressure loss through the filter (element) at 750 m^3_n/h **natural gas is** approximately equal to the pressure loss through the filter (element) at 2,250 m^3_n/h **hydrogen**.

4.4 Tripping pressure of safety devices

The tripping pressures - and for the VA also the closing time - are shown in the tables below.

Table 12: response pressure and closing time VA

Safety valve VA - Set value is 190 mbar*)			
Medium	Tripping pressure**) mbar]	Closing time [s]	Inlet pressure (nominal) [bar]
Natural gas	206,0***)	< 1	3
	192,0	< 1	3
	192,0	< 1	8
	188,0	< 1	8
Hydrogen	198,9	< 1	3
	195,2	< 1	3
	195,6	< 1	8
	186,0	< 1	8

*) The safety devices are set according to the pressure read on the manometer of the gas line concerned. This contains a certain inaccuracy compared to the calibrated manometer during the tests. In view of the (average) measuring results for natural gas, a set value for the VA of 190 mbar is assumed.

**) The response pressure was determined four times, twice at 3 bar and twice at 8 bar.

***) This higher value is probably due to some 'stickiness'.

Table 34: tripping pressure VAK(AAN)

Safety shut-off valve VAKAAN - Set value is 190 mbar*)	
Medium	**Tripping pressure [mbar]**
Natural gas	186,8
	188,6
	187,8
Hydrogen	190,7
	188,7
	184,9

*) The safety devcies are set according to the pressure read on the manometer of the gas line concerned. This contains a certain inaccuracy compared to the calibrated manometer during the tests. In view of the (average) measuring results for natural gas, a set value for the VAKAAN of 188 mbar is assumed.

From Table 1 the tripping pressure for the VA at natural gas varies between 188.0 and 206.0 mbar, but if the value from the first test is disregarded the variation is between 188.0 and 192.0 mbar. This almost meets the AC 1 (permissible deviation ± 1.9 mbar). For **hydrogen** the response pressure varies between 186.0 and 198.9 mbar. This variation is significantly greater; no explanation has been found. It is possible that the ambient conditions played a role in this.

It is recommended that further research is carried out into the functioning of the pilots under hydrogen conditions.

Table 3 shows that the tripping pressure for the VAKAAN with natural gas varies between 186.8 and 188.6 mbar. This complies with AC 2.5 (permissible deviation ± 4.7 mbar). For **hydrogen,** the tripping pressure varies between 184.9 and 190.7 mbar. The variation in the case of **hydrogen** is also greater here (it is possible that the ambient conditions have also played a role here), but also meets the AC 2.5. It was assumed that the VAKAAN tripping pressure was set at 188.0 mbar.

It is recommended that further research is carried out into the functioning of safety shut-off valves under hydrogen conditions because the variation in the tripping pressure is greater with **hydrogen** than with natural gas.

Conclusions:

- The closing time meets the standard.
- The variation in closing pressure is greater for both the command valve (of the VA) and the VAKAAN with **hydrogen** than with natural gas. The command valve does not (in this test) meet the AC for **hydrogen** (set for natural gas).

4.5 Closing time of the VA

See section 4.4, Table 1.

4.6 Leak tightness (internal) of activated fuses

4.6.1 Safety valve

For the VA, see section 4.2.1.

4.6.2 Safety shut-off valve

Natural gas

The average leakage value over the entire 15-minute period is
-0.1 mbar/min.

Hydrogen
The average leakage value over the entire 15-minute period is
0.0 mbar/min.

Conclusion: the internal leak-tightness of the safety shut-off valve meets the requirements.

4.7 Closing pressure when closing the pressure regulator

See Annex Vand VIfor the graphs on the determination of the closing pressures.

The closing pressures are shown in Table 5.

Table 56: Closing pressures

Medium	Inlet pressure [bar]	Closing pressure*) mbar]
Natural gas	8	116,7
	8	107,5
	3	113,3
	3	118,2
Hydrogen	8	108,1
	8	103,2
	3	104,1
	3	104,2

*) The closing pressure was determined four times, twice at 3 bar and twice at 8 bar.

Remark:

- The differences in closing pressure may have been caused by variations in the closing speed of the manually operated control valve (item No 13, Annex III).

Conclusion: the closing pressure (in the tests) for **natural gas** is on average higher (9 mbar) than the closing pressure for **hydrogen**.

4.8 Outlet pressure and pressure stability (resonances) during increase and decrease of flow rate

Figure 3 shows the result of the measurement with **natural gas** and Figure 5 with **hydrogen** where the flow rate was gradually increased for five minutes and then decreased again in five minutes. The measurement was carried out twice in the same way. See Annex VIIfor the graphs of the second measurement.

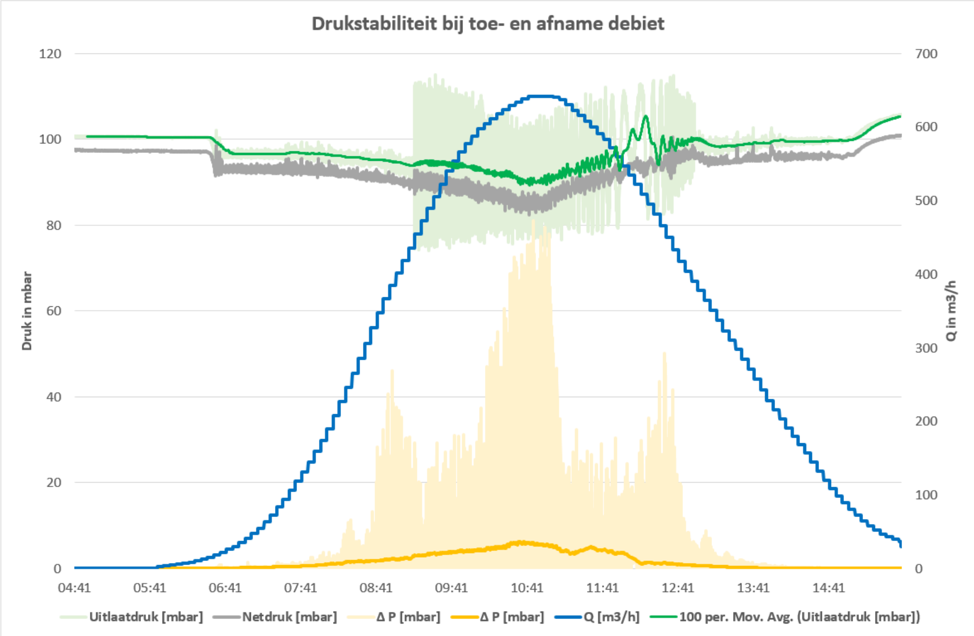


*Figure 34: Pressure stability with increase and decrease of flow rate - **natural gas***

<u>Explanation of the graph:</u>

- The **blue** line is the flow rate per five seconds, the flow rate is given on the secondary y-axis.
- The thin **orange** line is the measured pressure difference per 0.1 second (due to the many measuring points, a line is not visible). This pressure is measured in the 8 bar section, the pressure fluctuates roughly between 7,92 and 8,08 bar.
  The thick **orange** line is the measured pressure difference over the filter. This line is the average over 400 measurements (= 40 seconds). See paragraph 4.3.
- The thin **green** line is the measured value per 0.1 second. (Due to the many measuring points, a line is not visible everywhere).
  The thick **green** line is the exhaust pressure measured at the header of the station. This line is the average over 100 measurements (= 10 seconds).
- The **grey** line is the 'net pressure', the pressure measured per 0.1 second at the buffer vessel DN 400.

<u>Notes</u>:

- The somewhat fluctuating progression of the flow rate is caused by the fact that a value was stored every five seconds.
- There is no explanation for the (large) noise of in particular the exhaust pressure with **natural gas**. The second measurement with **natural gas** also shows this noise, even more pronounced. It is recommended that the cause and possible effect of this noise be further investigated.

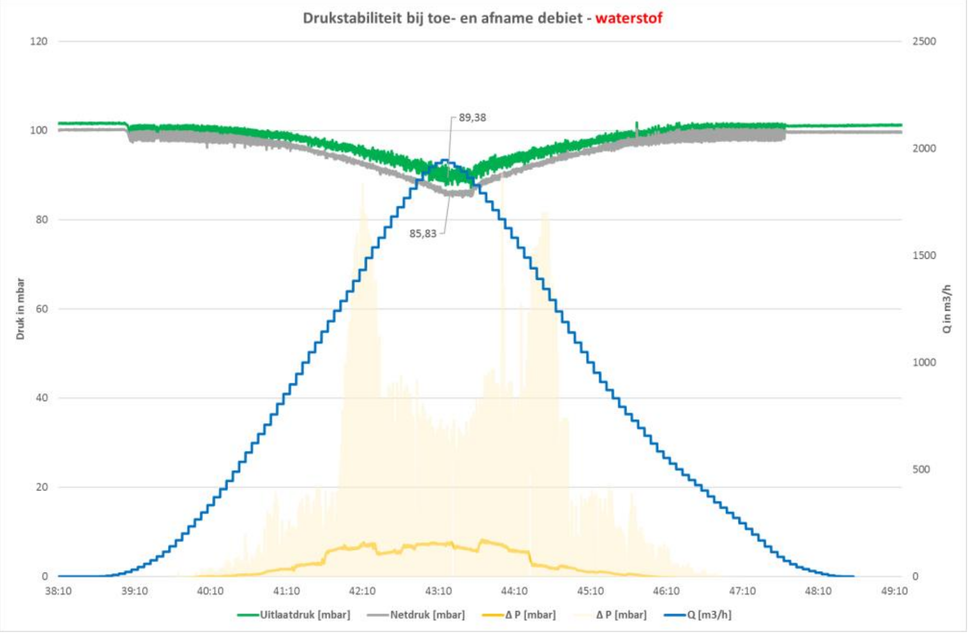


*Figure 5: Pressure stability with increase and decrease of flow rate - **hydrogen***

Conclusions:

- The pressure stability is not (negatively) influenced by the application of **hydrogen**.
- The pressure measured at the header is representative of the grid pressure.

For the explanation of the figure see Figure 3.

4.9 Noise emission

Figure 6 shows the noise emissions of the first measurement with **natural gas** and **hydrogen**, the results of the second measurement are included in Annex VIII.

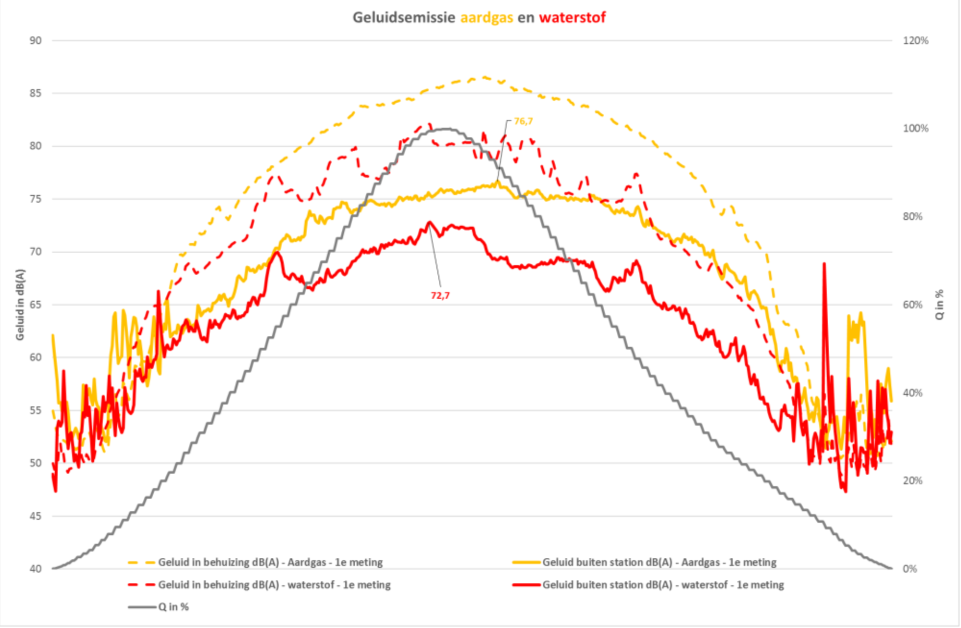


*Figure 67: Noise emissions from **natural gas** and **hydrogen***

Notes:
- The somewhat fluctuating progression of the flow rate was caused by a value being stored every five seconds.
- The flow rate is given in percentage terms (100% **natural gas** corresponds to 750 $m^3{}_n/h$, 100% **hydrogen corresponds** to 2,250 $m^3{}_n/h$) so that the noise emissions of **natural gas** and **hydrogen can** be compared more easily.
- The peaks at the beginning and end of the measurement are caused by environmental noise. The noise from the surroundings then dominates the noise from the gas pressure regulation station.

Conclusion: the noise emission for the application of **hydrogen** (at a flow rate of 2,250 $m^3{}_n/h$) is 3.9 dB(A) lower than for **natural gas** (at a flow rate of 750 $m^3{}_n/h$).

4.10 Temperature measurement pressure reduction at 1,000 $m^3{}_n/h$

The Figure 8shows the temperature of the **hydrogen** on the inlet and outlet sides, i.e., before and after the pressure reduction from 8 bar to 100 mbar at a flow rate of approximately 1,000 $m^3{}_n/h$ (instead of 750 m3n/h as stated in the measurement protocol).
The results of the temperature measurement of the pressure regulator are given in Annex IX.

Figure 89: Inlet and outlet temperature at ca. 1.000 $m^3{}_n/h$ - **hydrogen**

Explanation:
- The **red** line is the inlet temperature (for the regulator, pressure 8 bar).
- The **green** line is the outlet temperature (after the regulator, pressure 100 mbar).
- The **blue** line is the flow rate.

Remark:
- The smooth lines (polynomial) has been added to better compare the inlet and outlet temperatures of the **hydrogen**.
- The inlet temperature drops in almost equal degree to the temperature drop during the pressure reduction from a maximum of 200 bar to 8 bar. The difference between the **red** and **green** lines, respectively the inlet and outlet temperature, is decisive for this test. There is some temperature increase. Based on the theory, a temperature increase of 0.03 ºC per bar pressure reduction would occur, a pressure reduction from 8 bar to 0.1 bar leads to a temperature increase of approximately 0.25 ºC.

Conclusion: the temperature increase due to pressure reduction is negligible.

4.11 Temperature measurement pressure reduction at 1,600 m^3_n/h

The Figure 10the temperature of the **hydrogen** on the inlet and outlet sides, i.e. before and after the pressure reduction from 8 bar to 100 mbar, at a flow rate of approximately 1,600 m^3_n/h (instead of 1,500 m^3_n/h as stated in the measurement protocol).
The results of the temperature measurement of the pressure regulator are given in Annex IX.

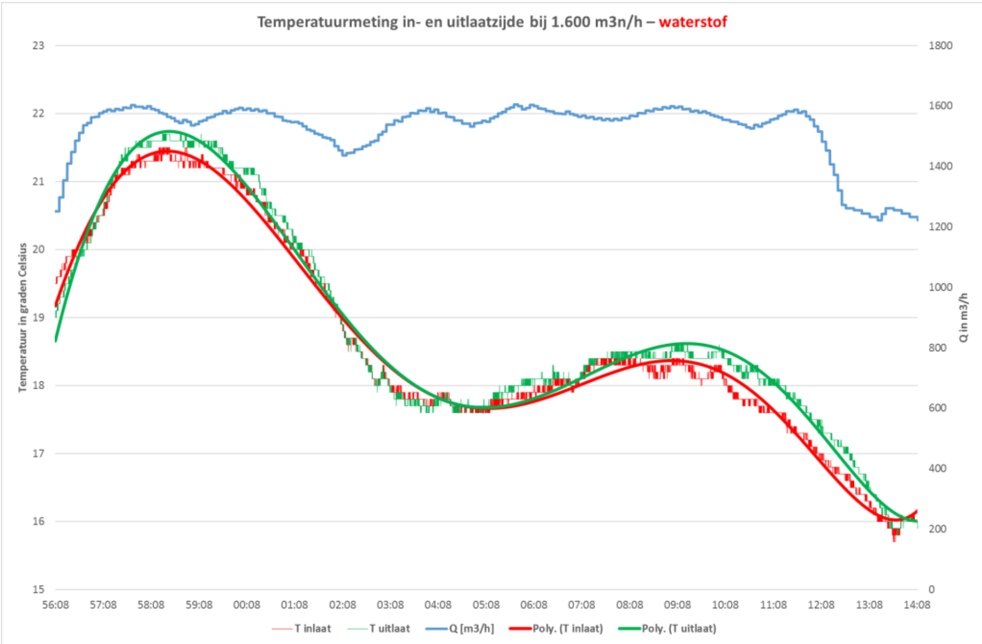


*Figure 1011: Inlet and outlet temperature at ca. 1,600 $^{m3n/h}$ - **hydrogen***

Remark:

- The smooth line (polynomial) has been added for better comparison of the inlet and outlet temperatures of the **hydrogen**.

Conclusion: the temperature increase due to pressure reduction is negligible.

4.12 Vibration and pulsation in natural gas and hydrogen

Simultaneously with the measurements of the pressure stability, the occurring vibrations and pulsations were measured by TNO at various places in the gas pressure regulation station and the exhaust line. The results of these measurements are included in appendix X.

Findings from the tests are (for location of P1 and A3 see Appendix X):

- In general, the overall levels of vibration, pulsation and noise are equivalent for both situations.
  - Therefore, noise production does not increase with hydrogen.
  - In the hydrogen tests, the inlet pressure varied much more, so there was also more variation on the measurement signals, especially on the inlet side (see e.g. P1).
  - The conditions at the exhaust side were more stable during the hydrogen tests.
  - The vibrations in the exhaust line are slightly lower in the hydrogen tests.
  - Results of the measurement at location A3 are not always reliable. This is probably caused by very high frequency contributions (>>10kHz) due to locally very high gas velocities and in the pressure regulator. This can cause disturbances in the measuring signal.
- The frequency content of the hydrogen test is different from that of the natural gas test: there is more contribution from high frequency, tonal components. This is mainly due to the lower density/high gas velocity and the higher sound velocity of hydrogen.

Conclusion: the overall levels of vibrations and pulsations for **natural gas** and **hydrogen** are similar.

Note: In Germany, an incident occurred in which the bolts of a flange connection of a pipeline carrying a mixture of natural gas and hydrogen were loosened[1]. The investigation into the cause of the vibrations determined that a risk arises when acoustic vibrations coincide with the mechanical natural frequencies (resonance) of the station. This should be taken into account during the (gradual) conversion from natural gas distribution to hydrogen distribution and investigated if necessary. The incident occurred with a high-pressure transmission line. See also annex XI.

For the sake of completeness: no changes in vibrations were observed during the tests at this pressure regulator station (see conclusion above).

1 *"Wasserstoff in Erdgasanlagen. Schwingungstechnische Aspekte und Lösungen zum Betrieb"* uit GWF Gas+Energie van april 2020.

5 Conclusions

Based on the measurements, as presented in this report, the main conclusion is:

THE TESTED GAS PRESSURE REGULATION STATION DESIGNED FOR NATURAL GAS CAN BE APPLIED WITH HYDROGEN WITHOUT MODIFICATION.

Remark:

- The conclusion concerns only the technical functioning. No statement can be made about the long-term behavior.

The partial conclusions are summarized in Table 7.

Table 78: Sub-conclusions

Topic	Natural gas	Hydrogen	Note
Leak tightness external	0	0	
Leak tightness internal valves	0	0	
Pressure loss over filter	0	0	Indicative measurement
Tripping pressure VA and VAK	0	0	Medium has no influence
Closing time VA	0	0	Medium has no influence
Leak tightness internal VA and VAK	0	0	
Closing pressure	0	0	Difference possibly caused by variation in closing speed of manually operated control valve
Pressure stability	0	0	
Noise emission	0	+	Hydrogen causes less noise emission
Temperature influence pressure reduction	-	0	Hardly any influence
Vibrations and pulsation	0	0	

Explanation:

- If the measurement results for **hydrogen** are (almost) the same as for **natural gas**, this is indicated by '0'.
- If the measuring results for **hydrogen** are more favorable than for **natural gas**, this is indicated by '+'.
- The temperature influence in the pressure reduction of **natural gas** has not been determined.

6 Recommendations

Within the framework of the HyDelta work packages, a work package Gas Stations has also been included, see Annex XII. In addition to the research in the HyDelta programme it is recommended to investigate (existing) stations with (clearly) different configurations and stations with other common types of regulator.

<u>Explanation</u>:

- An installation in an enclosure with a volume of approximately 0.5 ^{m3} has been investigated. Stations with a different configuration include installations in a cabinet station (2 by 1 m) and a free-standing building. But also a high pressure supply station HAS.
- By examining the most common combinations of configurations and controllers, the occurrence or non-occurrence of resonances can be determined for those combinations.

Further recommended:

- Further investigate the cause and possible effect of exhaust pressure noise should it occur again.
- Conduct further research into the functioning of command valves under hydrogen conditions.
- Further investigation of the functioning of safety shut-off valves under hydrogen conditions.

I Glossary

Concept	Description / explanation
Lgas (low calorific gas)	86 vol% methane + 14% nitrogen
Overpressure	Pressure above atmospheric (8 bar corresponds to 9 bar absolute)
m^3_n	One m^3 at 1013.25 mbar(a) and 0 ^{0}C
VA	Safety valve
VAK	Safety shut-off valve
VAKAAN	VAK built on a controller
CH_4	Methane
H_2	Hydrogen. The tests were carried out with hydrogen 5.0 (purity 99.999%)
PLEXOR	Test system for functional testing of pressure regulator stations
Closing pressure	Output side pressure of the regulator at zero flow
Closing pressure class (CP)	Maximum pressure increase in percentage of nominal output pressure that may occur when the delivery flow rate is reduced to zero
Accuracy Class (AC)	The accuracy with which the VA or a VAK(ON) takes effect.

II Components used in the gas pressure regulation station

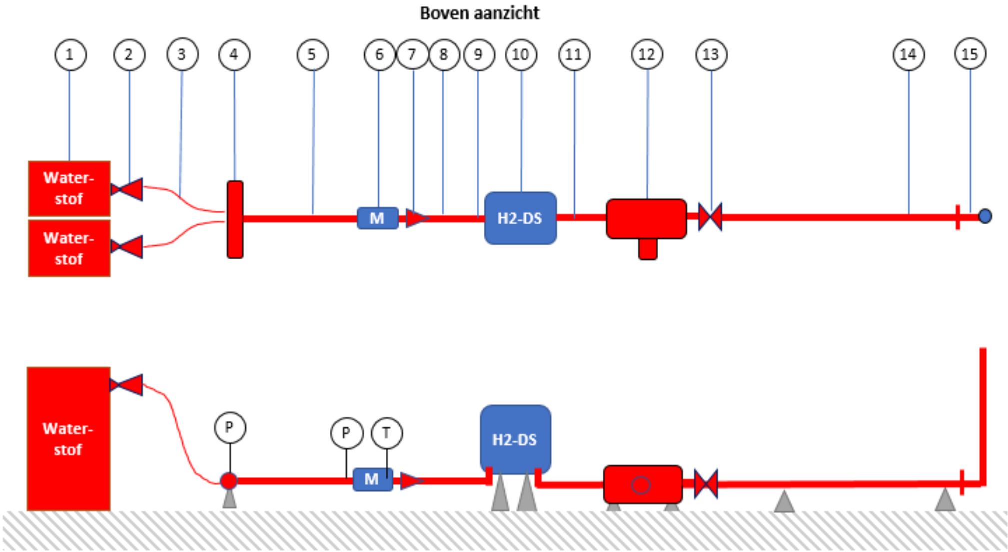
DISTRICTSTATION 1/2 m3 2"-4" (8bar > 100 mbar)		opmerking
bouwjaar	2020	zelfbouw RENDO
inlaatflens	2" DN 50	
inlaatleiding	2" (ST 60,3 X 3,2 mm)	
inlaatafsluiter	Kogelkraan DN 50 KSN 75 (fabrikant G-BEE)	
draaicilinder	AKP 75 (G-BEE)	2e veiligheid:
commandoventiel	stuurventiel SP-2000 LD, bereik 30-320 mbar (G-BEE)	
stoffilter	DN 50/50 - 150 (behuizing ST 168,3)	
filterelement	G 1 1/2"	
regelaar	W&S Regelaar type RS350	zie capaciteits-overzicht
	keuze uit klepgrootte 17,5, 22,5 of 27,5 mm (*)	(onderaan)
	aangebouwde veiligheidsafslagklep S100 MD	1e veiligheid:
	stuurdrukregelaar 300 SP 400	
uitlaatleiding	4" (ST 114,3 x 3.6 mm)	v= 20 m/s (bij 750 m3/h)
geluidsdemping	gerperforeerde buis (L = 30 cm)	
uitlaatafsluiter	vlinderklep EVML DN 100 (fabr. Wouter Witzel)	
uitlaatflens	4" DN 100	
diversen	W&S meetaansluiting LD-BMA 10	
	W&S meetaansluiting HD-BMA 04	
	W&S diagnoseaansluiting BDA 10	
	manometer 63 mm 0-10 bar	
	manometer 100 mm 0-250 mbar	
behuizing	RVS gaskast 1/2 m3 afm. 1000 x 500 x 1000 mm	
	RVS variabele fundatie 1/2 m3 kast	
	geluidsisolatie	

Capaciteitsoverzicht W&S regelaar in m3(n)/h			
Druk (bar)	klep 17,5	klep 22,5	klep 27,5
2	278	660	960
3	370	880	1280
4	463	1100	1600
5	555	1320	1920
6	648	1540	2240
7	740	1760	2560
8	833	1980	2880

(*) The regulator was equipped with a 22.5 mm valve.

III Schematic of the test setup

A schematic representation of the test setup is shown below with the designation of the various components.



Pos nr.	Aantal	Omschrijving
1	2	Flessenpakket H2 of (CH4)
2	2	Reduceer - 200 bar - 8 bar - DN 25 (1") - Qmin 500 nm3/h
3	2	Slangen DN 25 (1")
4	1	Manifold DN 100 met 4 DN 25 (1") draadaansl. en DN 100 flensaansl.- PN 16
5	1	Pijpstuk DN 100 - PN 16 - L = 12 m
6	1	Rotormeter G250 met EVHI / Mass Flow Meter
7	1	Verloop DN 100 - DN 50
8	1	Slang met flenzen DN 50
9	1	Stalen bocht DN 50 met flensaansl. - PN 16
10	1	H2-DS
11	1	Stalen uitlaatpijpstuk DN 100 - PN 16 - L = 1 m
12	1	Stalen buffervat DN 400 L = 1,7 m - met header DN 50 met meetnippel 1/4" BSP
13	1	Regelafsluiter DN 100 - PN 16
14	1	PVC uitlaatleiding DN 100 - L = 50 m
15	1	Stalen afblaaspijp DN 100 met ondersteuning en mogelijkheid tot aarden

Remark:

- The capacity of the buffer tank(item no. 12) is approx. 0.2 m^3. EN 334 prescribes that the closing pressure is determined with a pipe length of 10 x DN, where DN is the outlet diameter of the regulator. As this concerns a district station it was decided to use a larger one.

Below some pictures of the test setup in practice.


RENDO

IV Calculation leakage valves

This appendix includes a table of the acceptance criteria (Table A.5) from NEN-EN12266-1-2012 *Industrial valves - Testing of metallic valves - Part 1: Pressure tests, test procedures and acceptance criteria - Mandatory requirements*.
Scope of the standard:
This European Standard specifies requirements for tests, test procedures and acceptance criteria for production testing of industrial valves made of metallic materials. The specified tests may also be used as type tests or acceptance tests.

In addition, the calculations of the leakages are included.

Table A.5 — Maximum allowable seat leakage for each leakage rate

Unit: mm^3/s

Test fluid	Rate A	Rate B	Rate C	Rate D	Rate E	Rate F	Rate G
Liquid	No visually detectable leakage for the duration of the test	0,01 × DN	0,03 × DN	0,1 × DN	0,3 × DN	1,0 × DN	2,0 × DN
Gas		0,3 × DN	3,0 × DN	30 × DN	300 × DN	3 000 × DN	6 000 × DN

NOTE 1 The leakage rates only apply when discharging to room temperature.

NOTE 2 Table A.1 shall be used to establish the equivalent DN number for those valves which are designated other than by DN.

NOTE 3 "No visually detectable leakage" means no visible weeping or formation of drops or bubbles. If leakage rate measurements are carried out by automatics means, this should be qualified by the manufacturer's quality system.

Calculation of internal gas tightness of the inlet valve for **natural gas**.

P start = 1089.9 mbar

P end = 1103.4 mbar

Volume* = 13,0 dm^3

This is the content of the control set from inlet valve to outlet valve.

$$Internal\ leakage\ = 13{,}0 - \frac{1089{,}9 * 13{,}0}{1103{,}4} = \ 0{,}16\ dm^3\ /\ 60\ s = 44{,}3\ mm^3/s$$

Calculation of internal gas tightness of the outlet valve for **natural gas**.

P start =	1018.5 mbar
P end =	1120.7 mbar
Volume* =	214,5 dm³

* This is the volume from the outlet valve of the control set to the control valve (pos. no. 13 on the diagram in Annex III).

$$Internal\ leakage\ = 214{,}5 - \frac{1018{,}5 * 214{,}5}{1120{,}7} = \ 0{,}46\ dm^3\ /\ 60\ s = 126{,}5\ mm^3/s$$

Calculation of internal gas tightness of **hydrogen** inlet valve.

P start =	1089.9 mbar
P end =	1107.9 mbar
Volume* =	13,0 dm³

This is the content of the control set from inlet valve to outlet valve.

$$Internal\ leakage\ = 13{,}0 - \frac{1089{,}9 * 13{,}0}{1107{,}9} = \ 0{,}21\ dm^3\ /\ 60\ s = 58{,}8\ mm^3/s$$

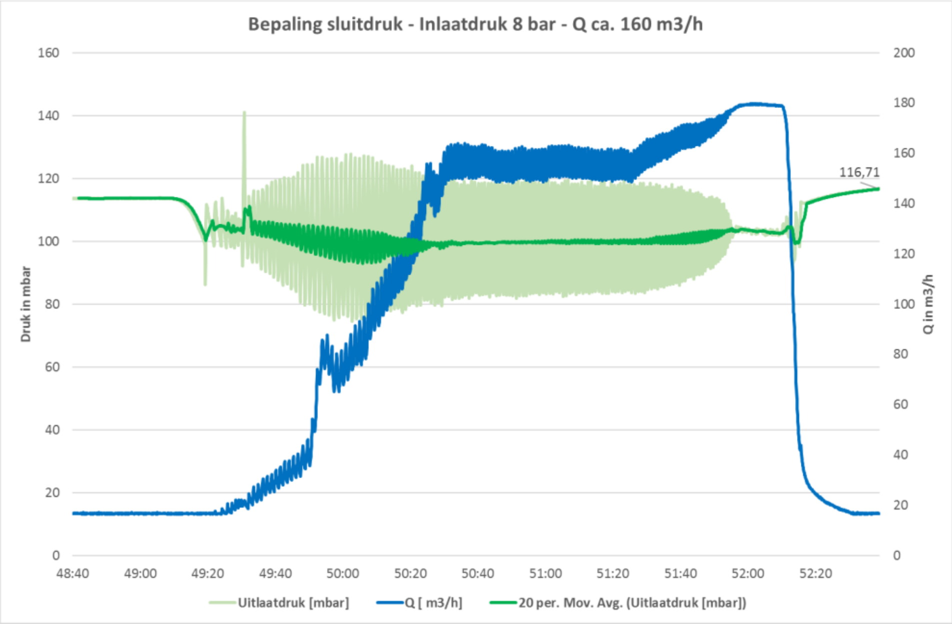
Calculation of internal gas tightness of the exhaust valve for **hydrogen**.

P start =	1018.3 mbar
P end =	1119.0 mbar
Volume* =	214,5 dm³

* This is the volume from the outlet valve of the control set to the control valve (pos. no. 13 on the diagram in Annex III).

$$Internal\ leakage\ = 214{,}5 - \frac{1018{,}3 * 214{,}5}{1119{,}0} = \ 0{,}14\ dm^3\ /\ 60\ s = 39{,}0\ mm^3/s$$

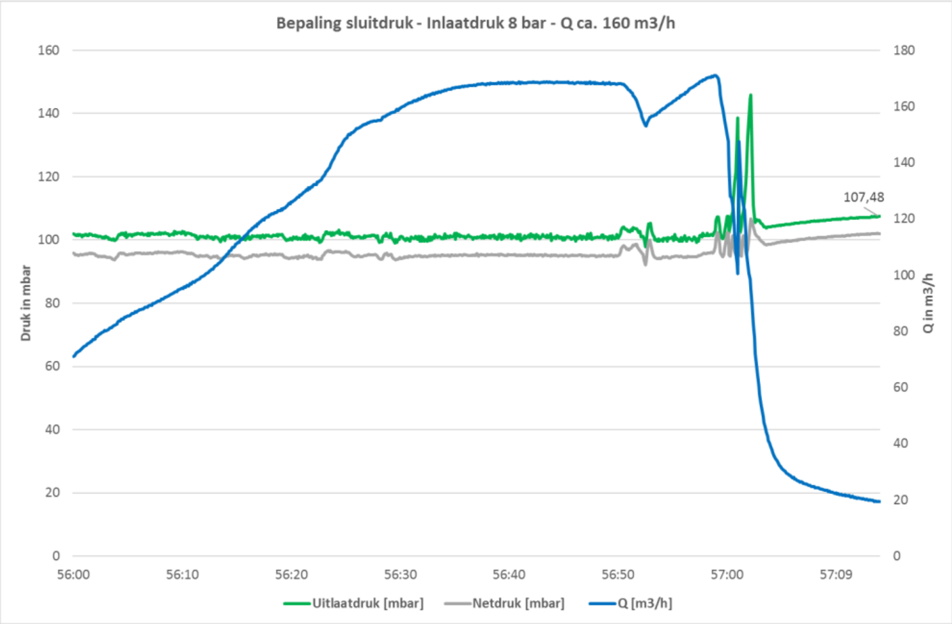
V Graphs natural gas closing pressure



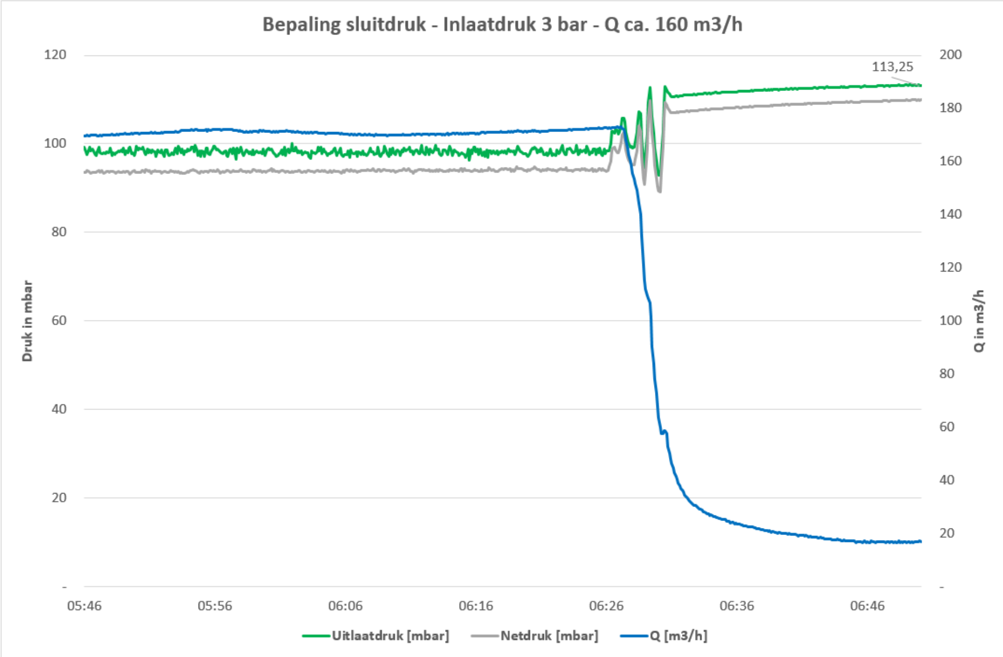
*Test 1: Determination of closing pressure **of natural gas***

Explanation:

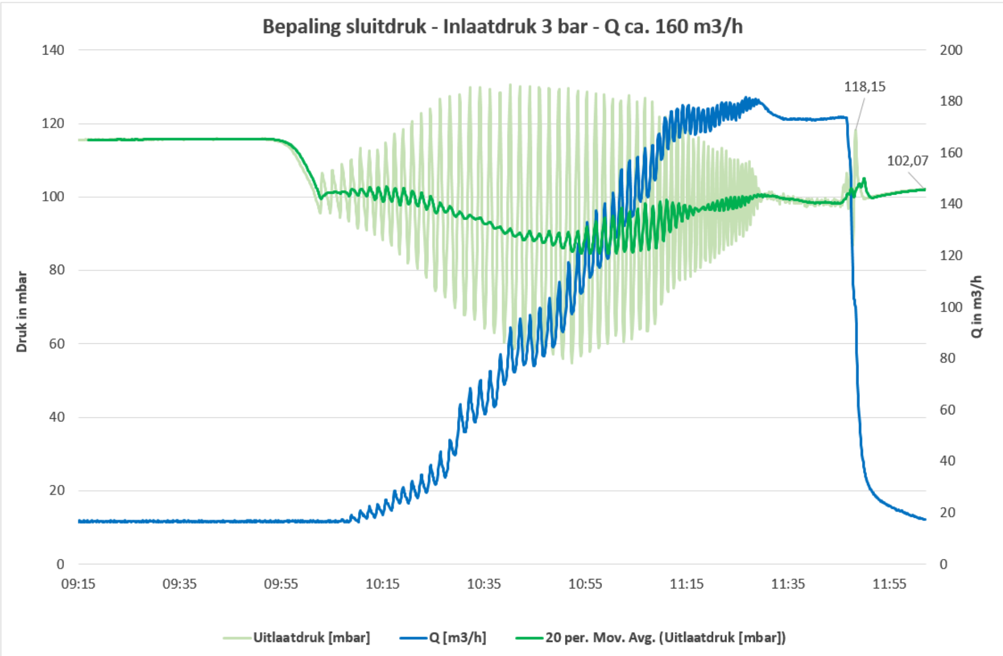
- The **blue** line is the flow rate.
- The **green** line is the outlet pressure at the header of the station. This line is constructed over the average of 20 measurements (= 2 seconds). The light **green** line is the measured value per 0.1 second.
- The **grey** line is the 'mains pressure', the pressure measured per 0.1 second at the buffer vessel DN 400.



*Test 2: closing pressure **of natural gas***

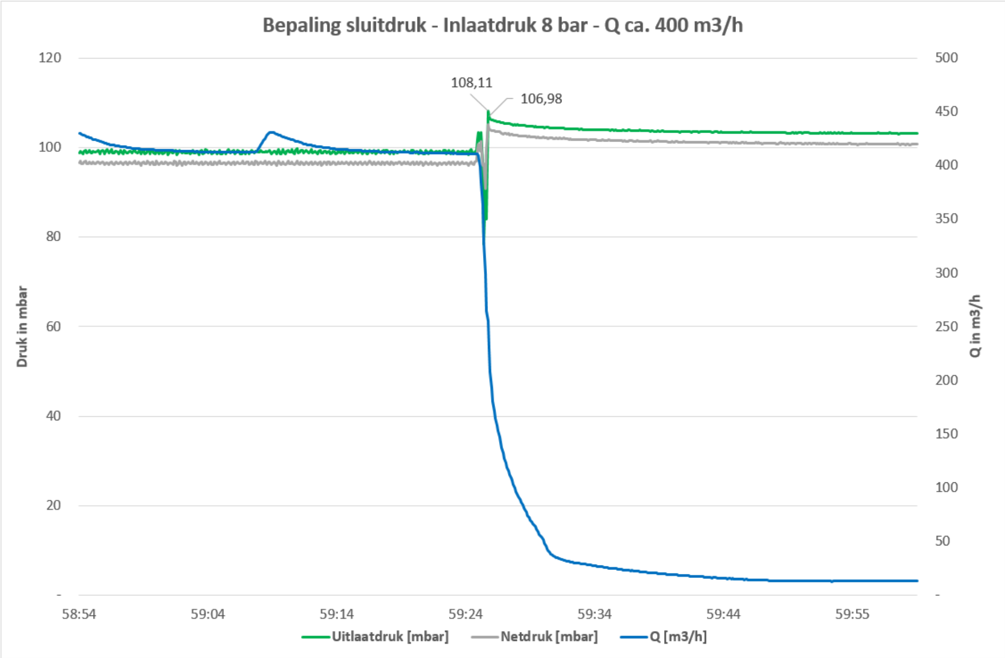


Test 3: closing pressure of natural gas

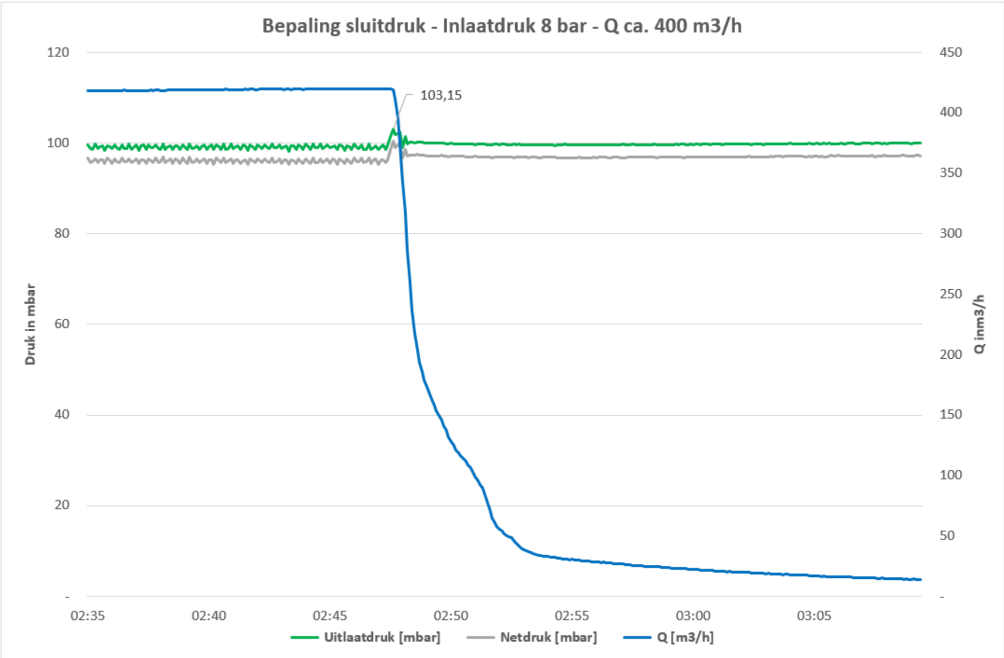


Test 4: closing pressure of natural gas

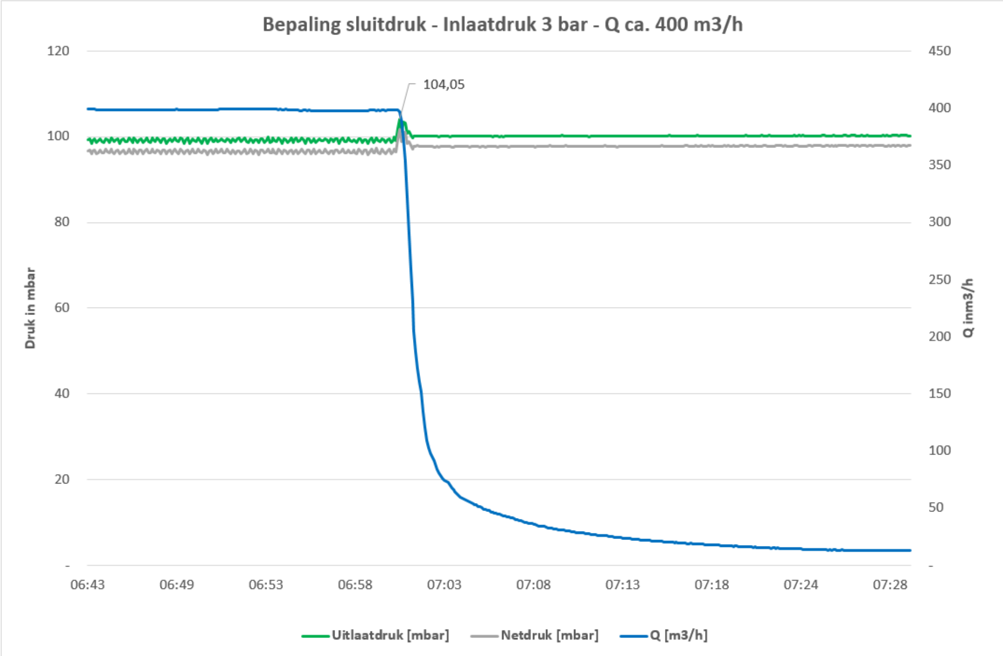
VI Graphs hydrogen closing pressure



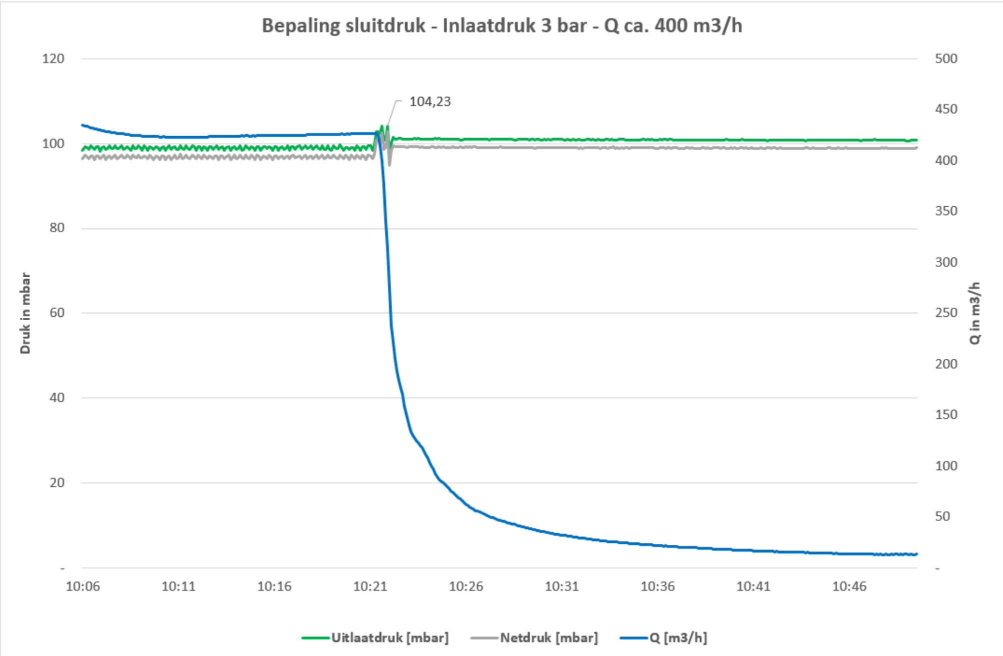
*Test 1: **hydrogen** closing pressure*



*Test 2: **hydrogen** closing pressure*

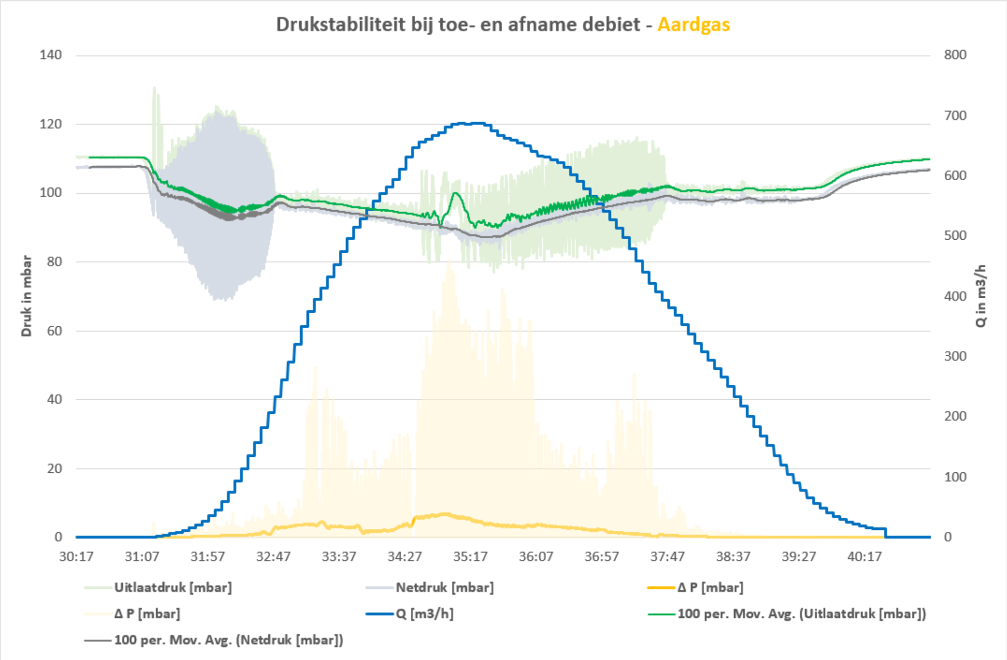


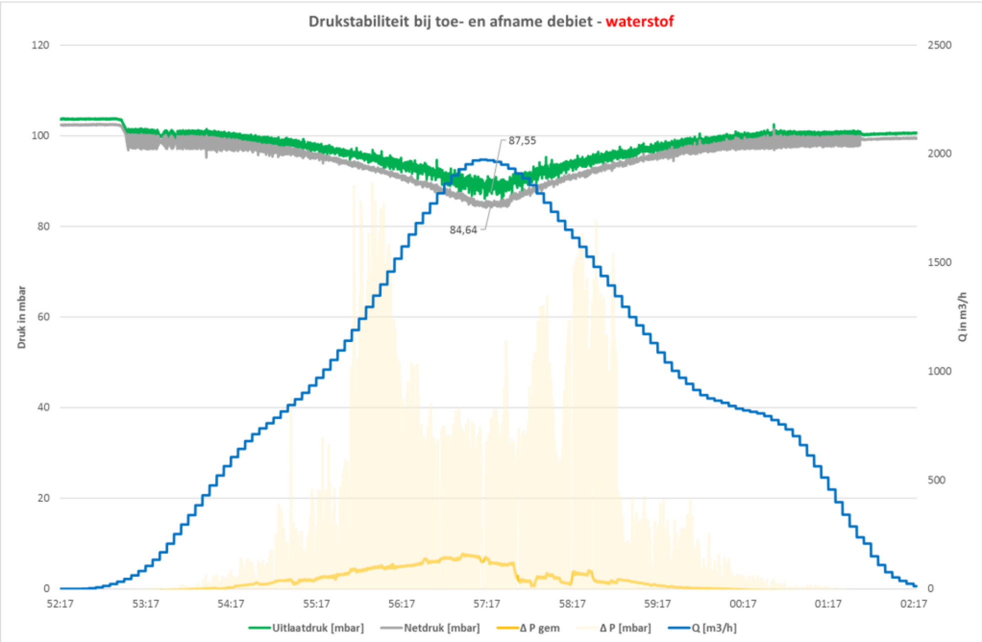
*Test 3: **hydrogen** closing pressure*



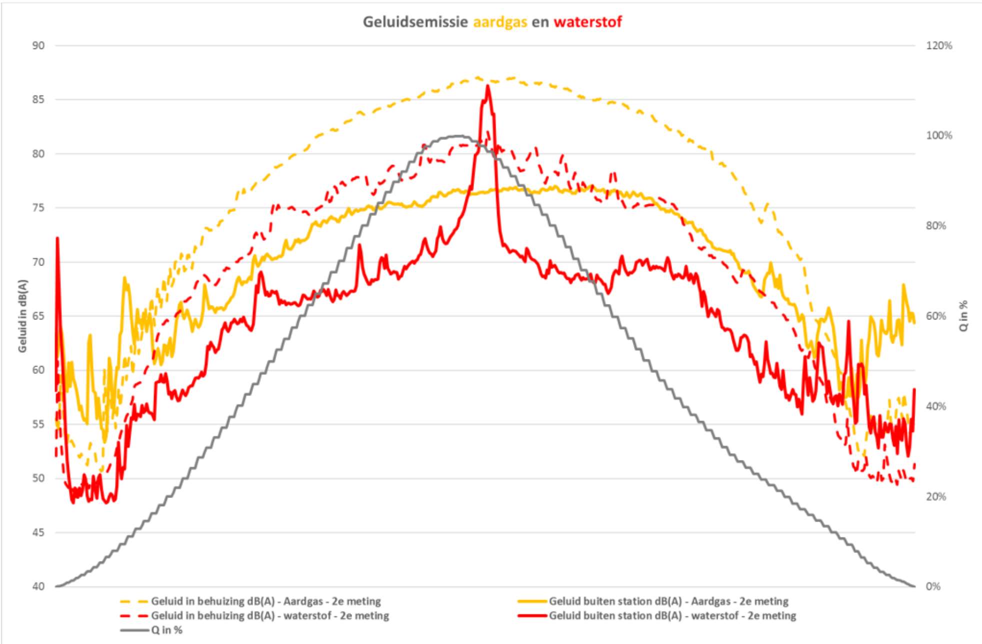
*Test 4: **hydrogen** closing pressure*

VII Graph of pressure stability (second measurement)





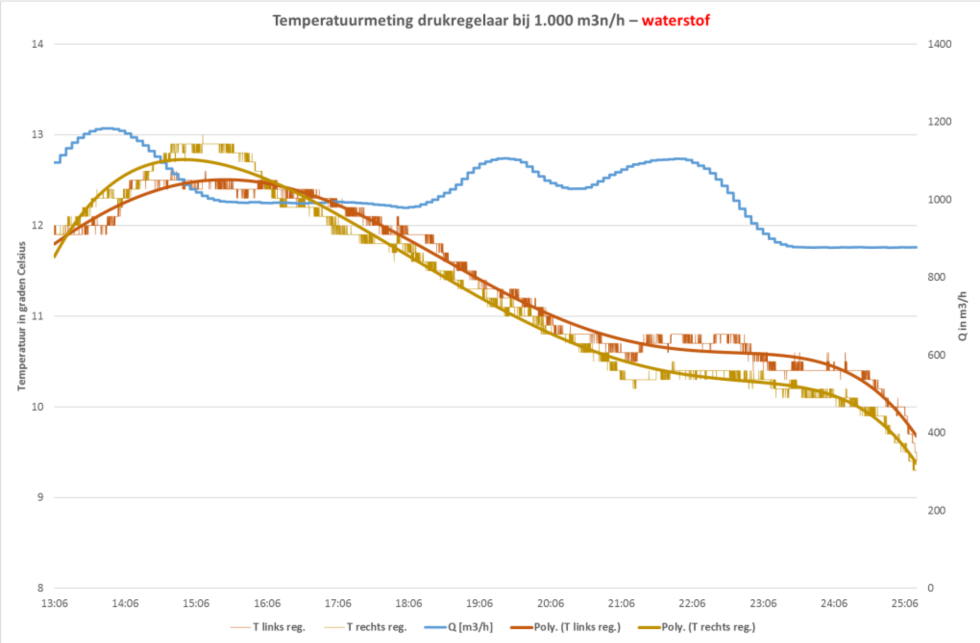
VIII Graph of noise emission (second measurement)

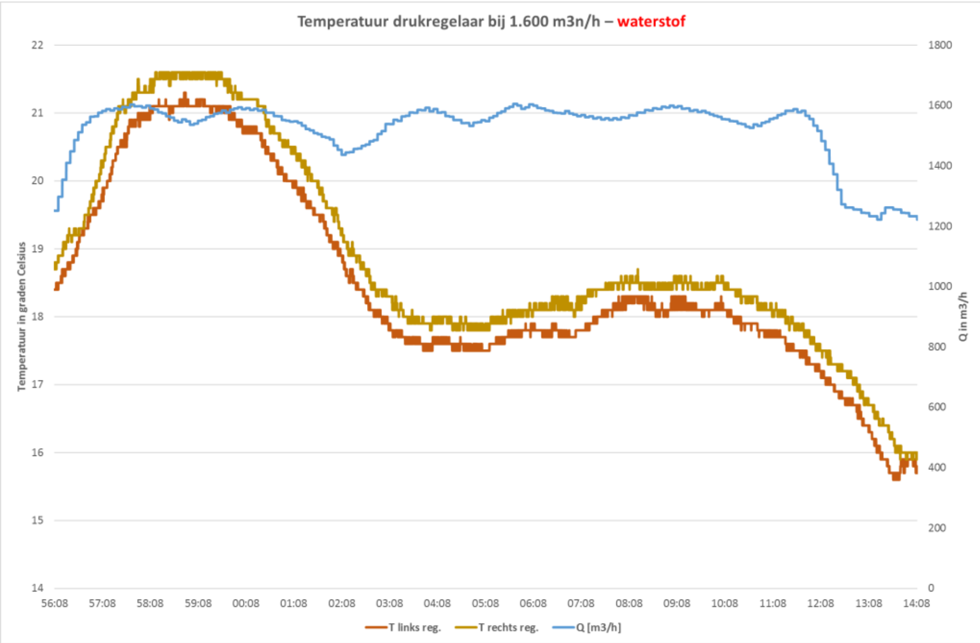


<u>Notes</u>:

- The somewhat fluctuating progression of the flow rate was caused by a value being stored every five seconds.
- The flow rate is given as a percentage to facilitate comparison of the noise emissions of **natural gas** and **hydrogen**.
- The peaks at the beginning and end of the measurement are caused by environmental noise. The noise from the surroundings then dominates the noise from the gas pressure regulation station.
- The peak at **hydrogen** is (also) clearly caused by ambient noise, as this peak does not occur inside the enclosure.

IX Graphic temperature measurement pressure regulator

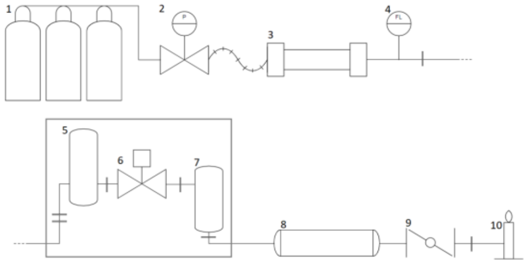




X Vibrations and pulsations

MEETPROGRAMMA

- TNO heeft metingen verricht bij de volgende tests:
  - 2 runs met een flow sweep van aardgas (0 → max debiet → 0).
  - 2 runs met een flow sweep van waterstof (0 → max debiet → 0).
- Tijdens de tests zijn door Kiwa o.a. de temperaturen, drukken en debiet gemeten.
- Schematisch zag de meetopstelling er als volgt uit:

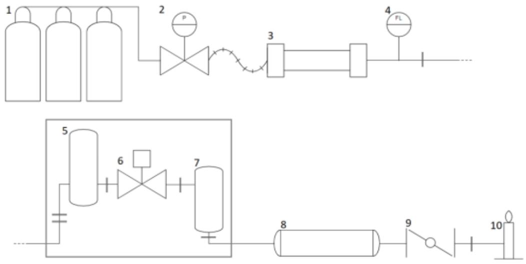


1	Gas cylinders	200 barg
2	Pressure reducer, manually adjusted	200 to ± 8 barg
3	12 m steel pipe	8 barg
4	Flow meter	8 barg
5	Filter	8 barg
6	Pressure reducer	8 to 0.1 barg
7	Damper	0.1 barg
8	Damper / boundary condition	0.1 barg
9	Butterfly valve	0.1 barg
10	Flare	0 barg

TNO innovation for life 3

MEETPROGRAMMA

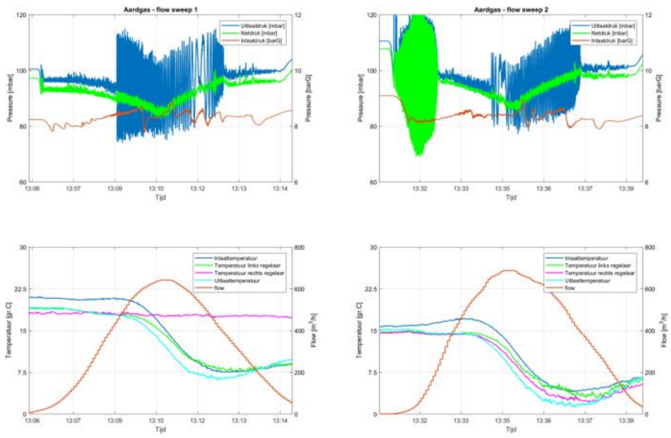
- TNO heeft metingen verricht bij de volgende tests:
  - 2 runs met een flow sweep van aardgas (0 → max debiet → 0).
  - 2 runs met een flow sweep van waterstof (0 → max debiet → 0).
- Tijdens de tests zijn door Kiwa o.a. de temperaturen, drukken en debiet gemeten.
- Schematisch zag de meetopstelling er als volgt uit:



1	Gas cylinders	200 barg
2	Pressure reducer, manually adjusted	200 to ± 8 barg
3	12 m steel pipe	8 barg
4	Flow meter	8 barg
5	Filter	8 barg
6	Pressure reducer	8 to 0.1 barg
7	Damper	0.1 barg
8	Damper / boundary condition	0.1 barg
9	Butterfly valve	0.1 barg
10	Flare	0 barg

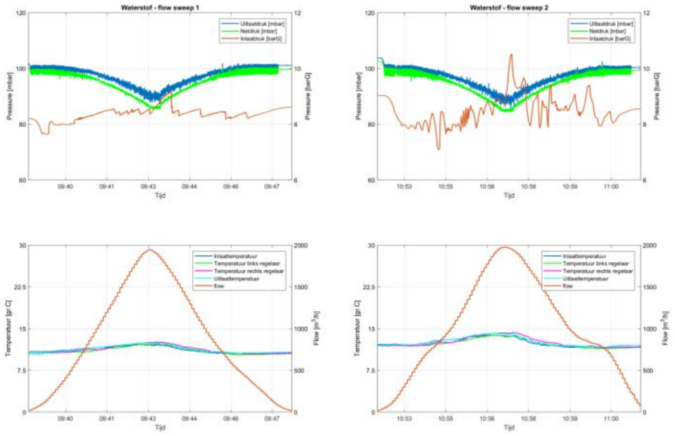
TNO innovation for life 3

MEETPROGRAMMA – PROCESS CONDITIES



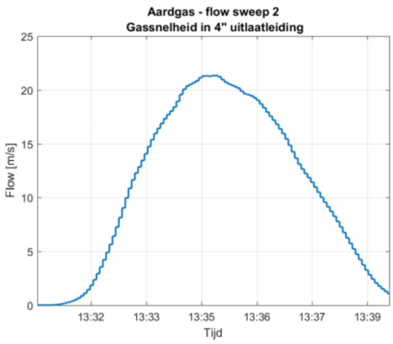
TNO innovation for life 4

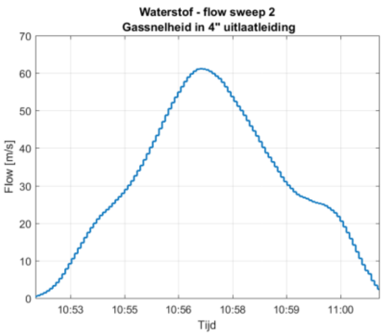
MEETPROGRAMMA – PROCESS CONDITIES



MEETPROGRAMMA

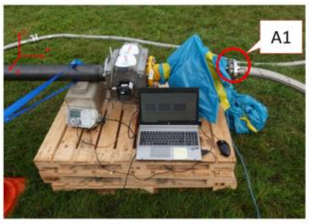
- Het waterstof volumedebiet was tijdens de tijdens de tests bijna 3x hoger dan aardgas. Hierdoor was de gassnelheid ook 3x hoger, met snelheden tot ruim 60 m/s.



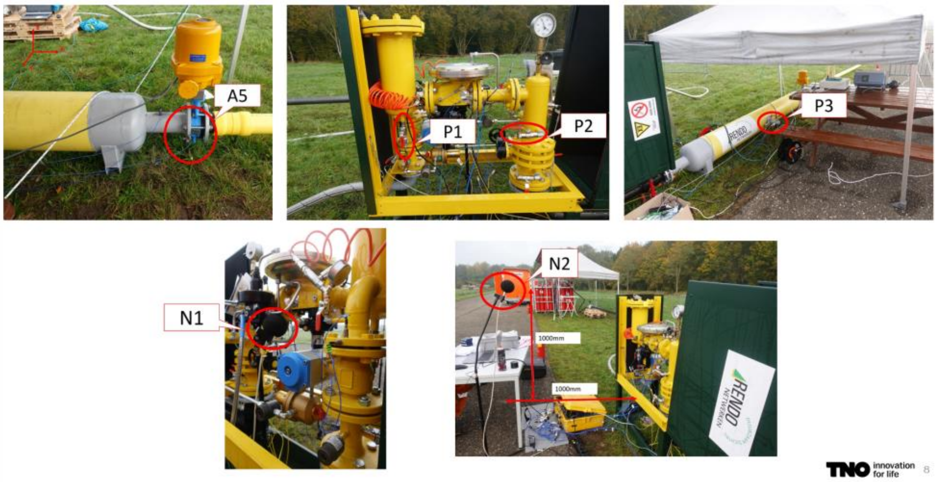


MEETLOCATIES

- TNO heeft het volgende gemeten:
  - Trillingen (A), 5 locaties & 3 richtingen per locatie.
  - Pulsaties (P), 3 locaties.
  - Geluid (N), 2 locaties (in districtstation en op ongeveer 1m afstand).
- De meetsignalen zijn continu opgenomen, op een sample frequentie van 20kHz.



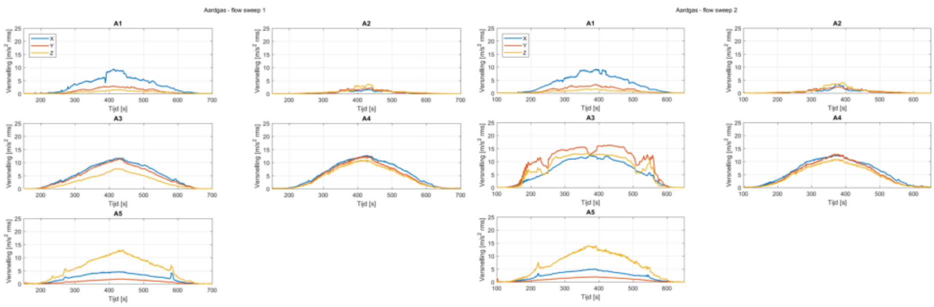
MEETLOCATIES



TNO innovation for life 8

MEETRESULTATEN – TRILLINGEN

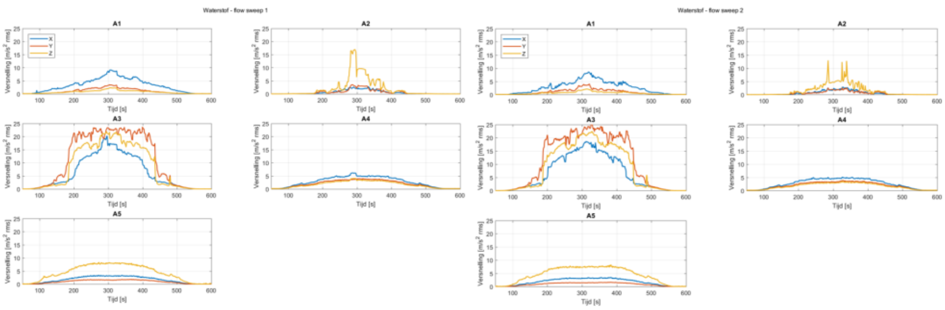
- Overall versnellingen op A1 t/m A5 in m/s^2 tijdens de aardgas tests: rms (root mean square) waarde per seconde.



TNO innovation for life 9

MEETRESULTATEN – TRILLINGEN

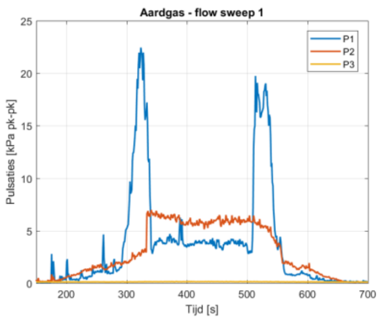
- Overall versnellingen op A1 t/m A5 in m/s^2 rms tijdens de waterstof tests.

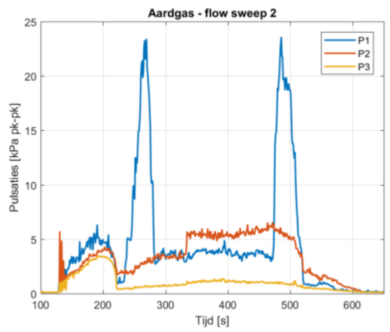


TNO innovation for life 10

MEETRESULTATEN – PULSATIES

- Overall pulsaties op P1 t/m P3 in kPa tijdens de aardgas tests: pk-to-pk waarde per seconde.
  De opslingering bij P1 wordt veroorzaakt door een lokale, akoestische resonantie in de meetbuis.

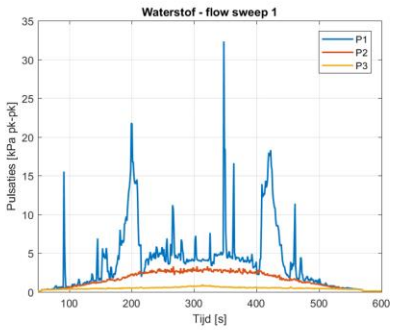


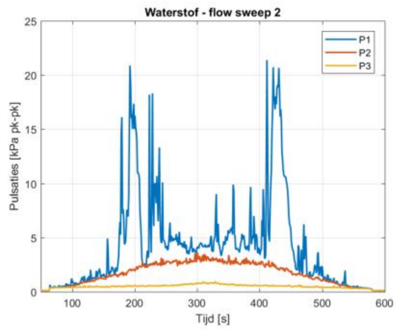


TNO innovation for life 11

MEETRESULTATEN – PULSATIES

- Overall pulsaties op P1 t/m P3 in kPa rms tijdens de waterstof tests.

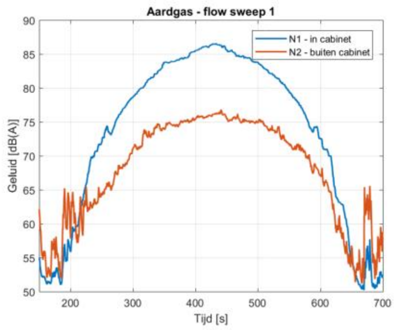


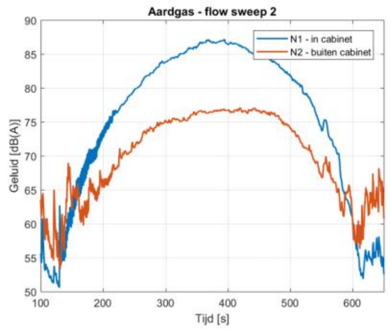


TNO innovation for life 12

MEETRESULTATEN – GELUID

- Overall geluidniveau op N1 en N2 in dB(A) tijdens de aardgas tests.

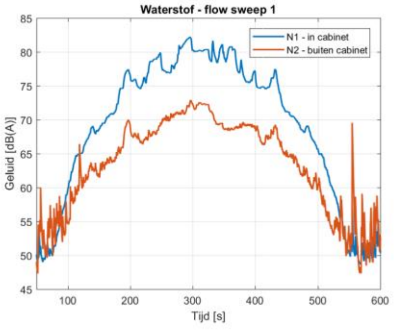


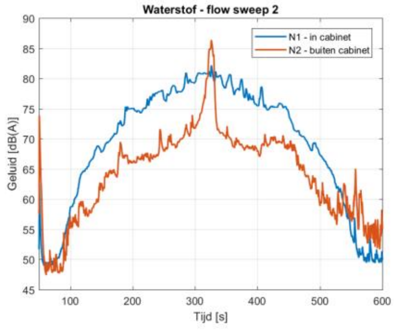


TNO innovation for life 13

MEETRESULTATEN – GELUID

- Overall geluidniveau op N1 en N2 in dB(A) tijdens de waterstof tests.
  Let op: piek in geluid op microfoon N2 bij max. flow veroorzaakt door externe bron (op geen enkel ander signaal zichtbaar).

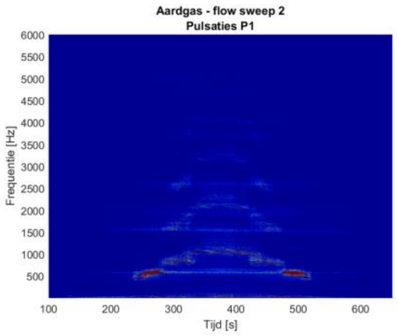


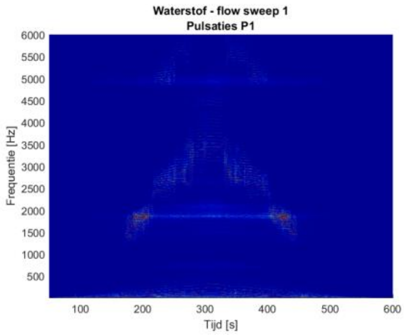


TNO innovation for life 14

MEETRESULTATEN – FREQUENTIESPECTRA

- Enkele karakteristieke frequentiespectra (spectrogrammen) van de pulsaties tijdens de tests.
  De opslingering bij 600Hz en 1900Hz voor resp. aardgas en waterstof komt overeen met een lokale resonantie in de meetbuis (kwart-golflengte resonantie van een eenzijdig afgesloten zijtak).

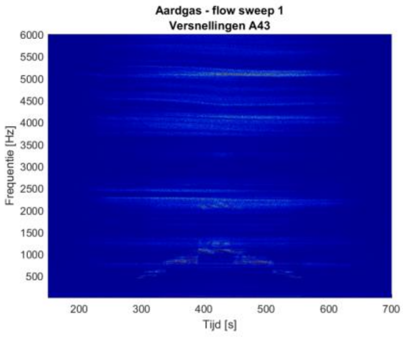


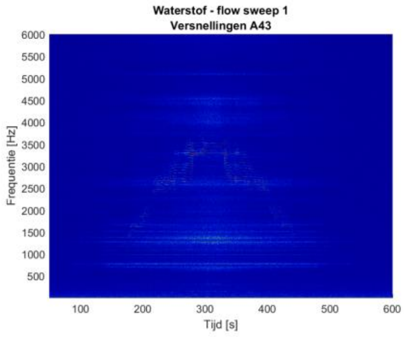


TNO innovation for life 15

MEETRESULTATEN – FREQUENTIESPECTRA

- Enkele karakteristieke frequentiespectra (spectrogrammen) van de trillingen tijdens de aardgas tests.

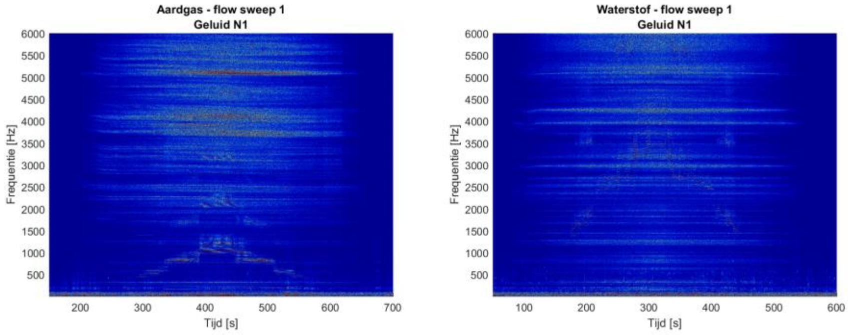




TNO innovation for life 16

MEETRESULTATEN – FREQUENTIESPECTRA

- Enkele karakteristieke frequentiespectra (spectrogrammen) van het geluid tijdens de aardgas tests.



TNO innovation for life 17

BEVINDINGEN UIT DE TESTS

- Hoge gassnelheden tot > 60 m/s in de 4 inch uitlaatleiding tijdens de waterstof tests.
  Let op: direct na de klep lokaal nog hogere snelheden, want daar is de diameter < 4 inch.
- Over het algemeen zijn de overall niveaus van de trillingen, pulsaties en het geluid voor beide situaties gelijkwaardig.
  - Het geluidproductie neemt dus niet toe bij waterstof.
  - Bij de waterstof tests varieerde de inlaatdruk veel meer, waardoor er ook meer variatie op de meetsignalen was, met name aan de inlaat zijde (zie bijv. P1).
  - De condities aan de uitlaatzijde waren tijdens de waterstof tests juist stabieler.
  - De trillingen in de uitlaatleiding zijn bij de waterstof tests iets lager.
  - Resultaten meetlokatie A3 niet altijd betrouwbaar. Dit komt waarschijnlijk door zeer hoogfrequente bijdragen (>>10kHz) door lokaal zeer hoge gassnelheden en in de regelklep. Dit kan voor verstoringen van het meetsignaal zorgen.
- De frequentie-inhoud bij de waterstof test is anders dan bij de aardgas tests: er is meer bijdrage van hoogfrequente, tonale componenten. Dit komt met name door de lagere dichtheid / hoge gassnelheid en de hogere geluidsnelheid van waterstof.
- Bij de waterstof tests bleef de temperatuur constanter dan bij de aardgas tests. Dit komt door de verschillen bij de vulling vanuit hoge druk flessen.

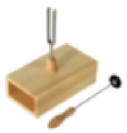
TNO innovation for life 18

XI Incident due to resonances

Below is the summary of an incident due to resonances in Germany published in GWF Gas+Energie of April 2020: *"Wasserstoff in Erdgasanlagen. Schwingungstechnische Aspekte und Lösungen zum Betrieb."*

Trillingen in gasstations door waterstof

Risico's kunnen ontstaan wanneer akoestische trillingen samenvallen met de eigenfrequentie van het station.

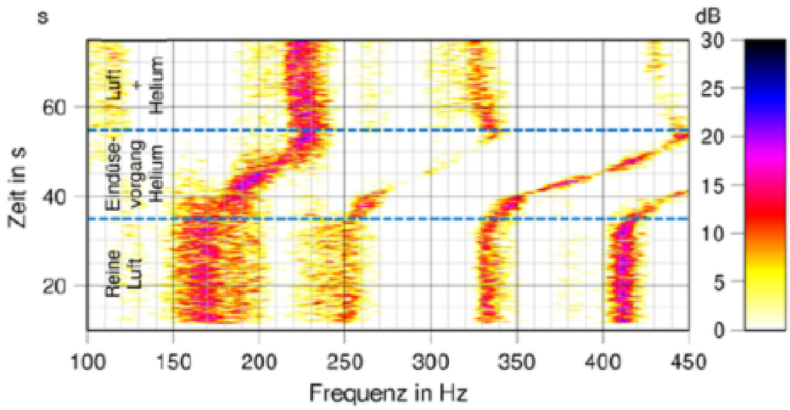


Michiel van der Laan, oktober 2020.
Naar verwachting zal in de toekomst steeds meer waterstof worden gedistribueerd in de Duitse gasnetwerken. Er zijn nog veel vragen te beantwoorden over bijvoorbeeld het materiaalgedrag en de lekdichtheid van de bestaande infrastructuur bij de toepassing van waterstof. Een onderwerp dat nog niet zo veel aandacht heeft gekregen is het trillingsgedrag van waterstof in gasstations. In Duitsland heeft dit meer aandacht. Dat komt onder andere door een ongeval uit 2002 waarbij een aardgas hogedrukleiding in een verdeelstation brak met een grote gasbrand tot gevolg. De waarschijnlijke oorzaak was dat de bouten van een flensverbinding zijn losgeraakt door trillingen. Het bedrijf Kötter Consulting Engineers (KCE) heeft sindsdien veel onderzoek gedaan aan trillingen in stations. Er ontstaat een risico wanneer akoestische trillingen samenvallen met de mechanische natuurlijke frequenties (resonantie) van het station.

Trillingsinvloed door waterstof

Dit artikel is een samenvatting van het artikel "Wasserstoff in Erdgasanlagen. Schwingungstechnische Aspekte und Lösungen zum Betrieb." uit GWF Gas+Energie van april 2020.

Bij de overstap van aardgas naar een mengsel van aardgas en waterstof of naar 100% waterstof in bestaande aardgasinfrastructuur, moet aandacht geschonken worden aan het trillingsgedrag van stations.
Door het lage molecuulgewicht van de waterstof die aan het aardgas wordt toegevoegd, verandert de geluidssnelheid van het gas aanzienlijk. Dit verandert ook de akoestische omstandigheden in de pijpleidingen en de voorwaarden voor akoestische resonantie. KCE heeft in haar laboratorium een leidinggedeelte met een luidspreker blootgesteld aan diverse mogelijke omgevingsgeluiden. Bij de gemeten drukschommelingen binnen het buisgedeelte worden "staande golven" gevormd, die als frequenties met verhoogde amplitudes in het spectrum zichtbaar zijn. De positie van deze individuele frequenties wordt voornamelijk beïnvloed door de geometrie (afstand tussen de reflectiepunten) van de pijpleiding en de geluidssnelheid van het medium. Door 10% waterstof aan het aardgas toe te voegen, veranderen de akoestische frequenties in het systeem. Wanneer deze samenvallen met de eigenfrequentie, kunnen resonantietrillingen niet worden uitgesloten. Afhankelijk van het type systeem worden verschillende procedures aanbevolen om ervoor te zorgen dat het gasstation vanuit trillingsoogpunt probleemloos werkt.



Figuur 1. Metingen aan gasstations bij verschillende gassen (in dit geval lucht en helium). De trillingsfrequentie is afhankelijk van de gebruikte gassen.

Voorgestelde acties

De auteurs van het artikel stellen een aantal acties voor. Bij nieuwe stations zou een pulsatiestudie uitgevoerd moeten worden om de individuele akoestische frequenties en de eigenfrequenties van de constructie te berekenen. Met de invloed van waterstof kan tot in detail rekening worden gehouden en kan het systeem zo worden opgezet dat er geen problemen ontstaan.
Voor bestaande gasstations waardoor in de toekomst aardgas een verhoogd aandeel waterstof wordt getransporteerd, is online monitoring van de trillingen aan te bevelen. Er wordt gezocht naar een pilotproject om de effectiviteit van de trillingsmonitoring aan te tonen.

Geplaatst op: 19-10-2020

XII HyDelta work package Gas stations

The HyDelta work packages also include a work package on gas stations. Research is being carried out based on the following research questions:

Material resistance:

- Can the soft components of gas pressure regulators and safety devices used in the distribution of natural gas be adversely affected when hydrogen gas is distributed? (NBN, question 207)
  Note: this was not investigated in the present study.

Functioning of the station:

- Are the present stations suitable for the safe reduction of hydrogen gas (station as a whole)?' (NBN, question 206)
  Remark: in this investigation, this has been examined for one configuration and one type of gas pressure regulator.
- What effects does increasing the speed have on the complete operation of the station? (NBN, question 213)
  Note: this was investigated for one configuration and one type of gas pressure regulator in this study.
- Are any modifications to the housing necessary for safe use with hydrogen and if so, what are they? (Ventilation & Earthing) (NBN, question 212)
  Remark: this was not investigated in this research.
- To what extent does the higher speed of hydrogen affect the behavior in pipelines and measuring and control stations (noise, dust and dirt in the pipeline, leaks, friction at discharge and consequently the risk of ignition) (NBN, question 71)?
  Note: this was not investigated in this study.

Working safely on and with hydrogen-powered stations:

- Which control measures (VWI) are necessary to start up and shut down a station? (NBN, question 208)
  Note: this was not investigated in this study.
- Can the pressure be safely equalized if a safety risk has been created? (NBN, question 209, part of question 208)
  Note: this was not investigated in this examination.
- Is there a need for more intensive inspection of filters in gas pressure regulators? This section specifically concerns filters: the increased gas velocity can lead to more dirt being carried along and this can lead to greater strain on the filters (NBN, question 173).
  Note: this was not investigated in this examination.

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