HyDelta

WP 1C – Pipes and indoor installations (components)

D1C.4 – question 185 – domestic pressure regulators

Status: final

Dit project is medegefinancierd door TKI Nieuw Gas | Topsector Energie uit de PPS-toeslag onder referentienummer TKI2020-HyDelta.

Document summary

Corresponding author

Corresponding author	Sander Lueb
Associated with	Kiwa Technology B.V.
E-mail address	sander.lueb@kiwa.com

Document history

Version	Date	Author	Associated with	Summary of changes
1	03.08.2021	Arie Kooiman	Kiwa Technology	Concept final report
2	01.10.2021	Arie Kooiman	Kiwa Technology	Processing of various comments
3	21.10.2021	Arie Kooiman	Kiwa Technology	Processing of comments relating to version 2
4	24.01.2022	Arie Kooiman	Kiwa Technology	Minor linguistic changes

Distribution level

Distribution level		
PU	Public	X
R1	Restricted to • Partners including Expert Assessment Group • Other participants of the project including Sounding Board • External entity specified by the consortium	
R2	Restricted to • Partners including Expert Assessment Group Other participants of the project including Sounding Board	
R3	Restricted to • Partners including Expert Assessment Group	

Document assessment

Partner	Name
Kiwa Technology	Sander Lueb
Alliander	Rob Nispeling
Rendo	Johan Jonkman
Stedin	Dick Nieuwenhuizen
Enexis	Henk Smit
Enexis	Walter Koppenol
Westland Infra	Rick den Hartog
gAvilar	Pieter Klijs
gAvilar	Lianne Mostert
NEC, Kiwa Technology, DNV, TNO, NBNL, Stedin, Alliander	HyDelta Supervisory Group

Summary

A study was carried out on the risks involved in not replacing a domestic pressure regulator as part of the conversion from natural gas to hydrogen. The potential risks were inventoried and, in consultation with the guidance group and sparring group, the risks requiring further investigation were identified. A test programme has been determined based on the findings, also in consultation with the guidance/sparring group.

The distribution network operators have been removing pressure regulators from their networks, some due to complaints and some without complaints being received. 40 of these regulators were tested with hydrogen. Based on the findings, 10 regulators were selected and subsequently also tested with natural gas.

The general conclusion based on the studies is that there are no safety risks when the existing domestic pressure regulators are used in converting the pipeline network from natural gas to hydrogen. Nevertheless, there is a chance of more failures occurring due to the more sensitive (earlier) intervention of the UPSO (under-pressure shut-off) valve. The valve shut-off pressures will also increase by a few millibars when hydrogen is used.
This does not give an urgent reason to replace all pressure regulators, seeing as all hydrogen appliances will be equipped with a flame protection device that mitigates the safety risk. If a network operator chooses to replace the pressure regulators in homes as part of the conversion to hydrogen, there is no need to replace them immediately. New pressure regulators can be installed at a later stage and are not necessarily needed at the time of conversion.

- In a relatively large number of the regulators tested with hydrogen, the under-pressure protection (UPSO valve) closes prematurely. This occurs especially when lowering the inlet pressure to 17.5 mbar. It is worth noting that the failure behaviour of the UPSO valve during these tests was the same for natural gas and hydrogen. The minimum required supply pressure is 23.4 mbar, which in practice means that it is highly unlikely that the device is prematurely triggered because the inlet pressure is too low. Even if this were the case, closing the valve too soon will not lead to a dangerous situation. However, supply disruptions may occur sooner due to the more sensitive UPSO valve operation with hydrogen.
- The pre-closed UPSO valve can also open unintentionally in some regulators when the inlet pressure increases to 200 mbar. This could possibly be a safety issue in 200 mbar networks, were it not for the fact that the hydrogen systems will always have protection devices installed because of the requirement since 2010 that all new cookers must be fitted with a flame failure device[1].
- In all regulators that were tested with natural gas as well as with hydrogen, the regulating characteristics of hydrogen at inlet pressures of 37.5 mbar and 100 mbar were only a fraction (in the order of a few tenths of mbar) below the regulating characteristics of natural gas. No consequences are expected in practice from this marginal effect.
- No irritating noises or vibrations were discerned in any of the tested regulators. There are no indications that using hydrogen will cause more problems than when natural gas is used.
- No external leakage was observed in any of the regulators tested. If a regulator does not show external leakage with natural gas, it is also not likely that the same will happen with hydrogen.

[1] Whether this is an important safety issue for existing situations with 200 mbar natural gas supply should be further investigated. But this is beyond the scope of the present investigation.

- The shut-off pressure is several millibars higher with hydrogen than with natural gas. Only in highly exceptional cases could this lead to a higher chance that the gas valve of a hydrogen boiler doesn't open at start-up. (N.B. For most gas valve units, the manufacturer prescribes a maximum inlet pressure of 60 mbar).
- The probability of internal leaks from pressure regulators is greater with hydrogen than with natural gas. This effect translates into higher shut-off pressures.

The following is recommended to distribution network operators:
When converting to hydrogen, a choice should be made based on one's own considerations as to whether or not to replace the existing pressure regulators, with or without a UPSO valve that is or is not equipped with a bypass. This choice can be made using the decision tree in figure 6, based on the arguments for and against the various options given in table 11.

Table of contents

1. Reason

1.1. General

This study has been 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 hamper innovative hydrogen projects. The complete research programme is divided into work packages. For an explanation of the various work packages, please visit www.hydelta.nl

1.2. Problem definition

Like regulators at fuel stations, domestic pressure regulators can run into several issues if the existing pressure regulators are used for supplying hydrogen to homes. Some of the potential problems are:

- The lower density of hydrogen allows it to flow more easily past the control valve, which can affect the stability of the regulator.
- In order to deliver the same level of energy, three times the flow rate has to pass through the regulator. It is as yet unknown how this (significantly) higher gas flow rate will affect the regulating behaviour of the valve or the noise production of the regulator.
- Regulators can leak small amounts of gas through the vent orifice. It is not known by how much this will change when switching to hydrogen.
- Following the change to a different medium, the pressure regulators may become more sensitive to the shut-off pressure problem when combined with appliances without a pilot flame or with indoor installations that have smaller capacities.

There may also be other issues that have not yet been identified.

Domestic pressure regulators may need to be replaced already when converting to hydrogen, but it is also possible the study shows that the regulators can be replaced at a later stage after the conversion (i.e. not on the day of the conversion and only if required).

1.3. Research question 185

This report answers research question 185 from Work Package 1C: Piping and Indoor Installations. The research question is: What are the risks if a domestic pressure regulator is not replaced when converting from natural gas to hydrogen?

1.4. Objective

The aim of this study is to identify all potential problems of using the existing pressure regulators in homes after converting from natural gas to hydrogen, and to quantify those issues through experimental testing. This will lead to a recommendation for follow-up (whether the current domestic pressure regulators need to be modified or whether additional research is needed).

2. Method

2.1. General working method

The implementation of this study was coordinated together with a guidance group and sparring group. Both groups consist of participants from network operators and suppliers/manufacturers (see appendix II).

The risks associated with using domestic pressure regulators for hydrogen were presented by the participants in the sparring group. Full details of the risk assessment are in appendix III. Notes were subsequently compared and, using previously available reports as the basis (see section 2.2), the guidance group formulated a proposal for a test programme, which has been adopted by the sparring group. The test programme can be found in chapter 3 and its details in appendix IV.

2.2. Available information

Kiwa has carried out various studies in recent years into the operational risks of domestic pressure regulators in the natural gas network. More recently, gAvilar, the largest supplier of domestic pressure regulators in the Netherlands, conducted research into the regulating behaviour and noise production of their regulators with helium as the medium [7]. Since 2019, domestic pressure regulators of gAvilar are covered by a declaration from Kiwa Nederland NV, stating that they comply with inspection requirement 214 on the suitability for admixture up to 100% hydrogen gas. gAvilar's own measurements showed oscillation of the regulator. In addition, an internal note was drawn up by RENDO in relation to the endurance test carried out on three hydrogen boilers at the site of Entrance [3].
The titles of the different reports, the notes and the declaration can be found under the heading Refere.
Test methods are described in standard NEN 7239:2018 [8] and contain requirements and test methods.

2.3. Specific working method

Together with the sparring group, which is represented both by distribution network operators and pressure regulator manufacturers, Kiwa identified the risks of using hydrogen in domestic pressure regulators. Based on the findings, Kiwa drafted a test programme for further research. The network companies then supplied a number of domestic pressure regulators from their gas distribution networks in order to test their regulating behaviour when hydrogen is used. Five network operators (Liander, Enexis, Stedin, RENDO and Westland Infra) each supplied 10 pressure regulators. Kiwa selected 40 of these 50 pressure regulators for the tests with hydrogen.
The 10 pressure regulators that were removed had to comply with the following characteristics:

- 5 regulators were removed because the shut-off pressure was too high.
- 5 regulators were removed from the grid without a complaint. As part of the selection process, preference was given to older models that the network operator wanted to see investigated. This was prompted by the increased uncertainty about the operational stability of older, less common regulator models.

Data relating to the production years of the home pressure regulators that the network operators provided can be found in Table 1:

Table 1 Data on production years of domestic pressure regulators tested with hydrogen

Number of regulators tested:	40
Quantity production year unknown	16
Quantity production year known	24
Production year of oldest regulator	1970
Production year of newest regulator	2019
Average of the known production years	2003

3. Test programme

Evolution of test programme

The test programme was prepared and carried out in consultation with the guidance/sparring group as follows:

- The risks were discussed with the guidance group/sparring group on 27/01/2021.
- Based on the results, Kiwa prepared a draft test programme.
- This draft test programme was discussed with the guidance group/sparring group on 24/03/21.
- Using this draft test programme, four domestic pressure regulators were tested as a pilot.
- On 14/04/21, the results of the first four pressure regulators were discussed and minor adjustments were made to the test programme. It can be noted that the pilot test results of the first four regulators are comparable with the other regulators tested.
- The remaining pressure regulators were tested in accordance with the slightly adjusted test programme.
- The results of the hydrogen measurements in the 40 pressure regulators were discussed on 28/05/2021, after which 10 were selected for verification measurements with natural gas.

Contents of test programme

In the final test programme, the following functions were tested with hydrogen on 40 of the supplied pressure regulators (*explanatory text is printed in italics*):

- Ambient pressure and ambient temperature are recorded.

- Shut-off pressure: requirements in compliance with 6.4.2.1 of NEN 7239:2018 (execution of test according to 8.4.2 and 8.4.3).
  In deviation from the standard, the capacity of the test installation is 12.7 dm^3 instead of 10 dm^3. [2]
  The standard states that the shut-off pressure is monitored for 60 seconds. In reality, the pressure can still increase afterwards due to internal leakage in the domestic pressure regulator. That is why the shut-off pressure is monitored for 15 minutes. As part of the shut-off pressure test, the pipe volume is reduced after 2 minutes (by closing a tap directly behind the gas meter).

- Leak tightness: Leak-tightness measurements are carried out only to a limited extent.
  No problems are expected to occur in terms of internal and external leak tightness when using hydrogen.[3]

  - The external leak tightness is determined using a gas detector fitted with a spacer.

[2] After the tests, it turned out that the volume of the gas meters was different from what had been assumed beforehand.

[3] Initially, it was proposed to perform leak tightness measurements on 10 pressure regulators (5 with complaints and 5 without complaints) and only with hydrogen. In case of a deviation from KE 214, follow verification measurements with natural gas. In consultation with the guidance/sparring group, this has been changed to checking the external gas tightness of all pressure regulators to be tested with a gas detector that is equipped with a spacer; gAvilar indicates that it does not expect any problem from external leakage of hydrogen.

  - Requirements for the internal leak tightness of hydrogen regulators are stated in KE 214. [4]In deviation from the determination method in that article, the calculations for internal leak tightness are based on the measurement results of the extended shut-off pressure test.

- Regulating behaviour and capacity: sampling according to 8.4.2 and 8.4.3 of NEN 7239:2018. In deviation from this standard, only the regulating characteristics at inlet pressures of 37.5 and 100 mbar.
  Where Qnom is mentioned, a flow rate of 15 m^3/hour is applied when testing with 100% hydrogen and a flow rate of 5m^3/hour is applied when testing with natural gas. These are realistic consumption levels for domestic environments.
  NEN 7239 prescribes 200 mbar as the maximum inlet pressure. However, most of the existing pressure regulators have a maximum pressure of 100 mbar.

- Noise and vibration: Assessment by ear.
  Since the noise of the gas meter was dominant in the tests, thus nullifying the purpose of the noise measurement, only audible noise production by the domestic pressure regulator was determined.

- Behaviour of UPSO valve: test according to 8.5.1 and 8.5.2 of NEN 7239: 2018. The pressure is also measured after repairing or resetting the under-pressure shut-off valve.
  This is done at a content level of 12.7 dm^3 at the outlet of the pressure regulator (N.B. the standard prescribes: 10 dm^3).
  As part of the study, attention is paid to the volume of the gas flow over the bypass of the UPSO valve (the opening is based on use with natural gas; more gas will flow through this small hole when hydrogen is used).[5]

The measurements in question were also performed with natural gas in 10 of the 40 pressure regulators that were tested. These 10 pressure regulators with natural gas were selected in consultation with the guidance group/sparring group.

The details of the parameters that were measured, as well as the diagram and photos of the measurement set-up, have been included in the appendices.

[4] KE 214, art. 4.2.2: The internal gas tightness of a domestic pressure regulator and combination regulator shall be measured at a pressure of 300 mbar on the inlet and 37,5 mbar on the outlet. The internal tightness is carried out in accordance with NEN 7239:2018. The leakage between the inlet and outlet side may not exceed 6,6 cm^3 /h.

[5] Whether the outflow of hydrogen via the bypass of the UPSO valve is safe will be part of answering question 101 (also part of WP1C HyDelta).

4. Results

Section 4.1 summarises the results of the hydrogen measurements. The measurement values where deviations were found are shaded orange.

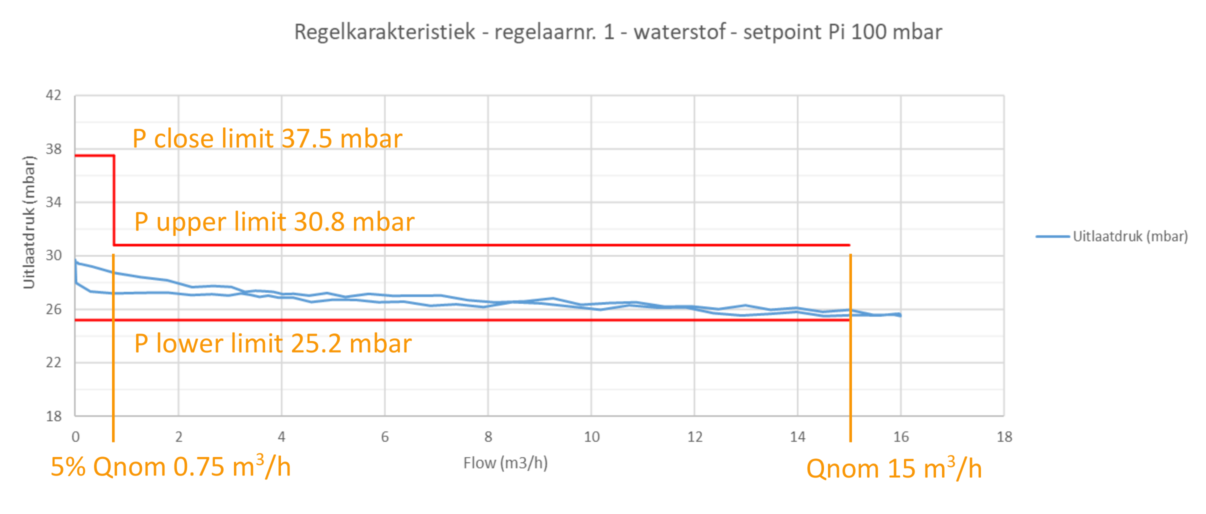
In consultation with the guidance group/sparring group, 10 of the pressure regulators were selected for testing with natural gas as well as with hydrogen; see the last column of Table 2. The goal of testing both substances is to enable a comparison between the regulating behaviour and shut-off pressure with hydrogen on the one hand, and with natural gas on the other.

4.1. Measurement results with hydrogen

Regulating behaviour, capacity, shut-off pressure and under-pressure protection

The regulating characteristics of pressure regulators must stay within the limits specified in NEN 7239: 2018[6] and are illustrated below in an example figure. Measuring the regulating characteristics with hydrogen was performed at a maximum capacity of 15 m^3/h.

All detailed regulating characteristics have been included in appendix IX



Parameter	Limit value according to NEN 7239:2018
P close limit (mbar)	37.5
P upper limit (mbar)	30.8
P lower limit (mbar)	25.2

Figure 1 Sample characteristic with limit values according to NEN7239:2018

The measurement results with hydrogen are summarised in table 2.
N.B. the measured regulating characteristics will decline slightly and will generally be somewhat lower. This is because the pressure was recorded behind the gas meter, which causes extra resistance. If the regulating characteristic doesn't meet requirements by only a small margin, the deviation of the measurement value from the limit values is shown in mbar in a green box. The

[6] Most of the regulators tested have a year of construction before 2018. These regulators do not formally need to meet these requirements.

minimum measured pressure is given at the maximum capacity of 15 m^3/h (N.B. For Qnom > 0.75 m^3/h the lower limit value = 25.2 mbar; upper limit value = 30.8 mbar).

Table 2 Summary of measuring results of 40 pressure regulators with hydrogen

Sample #	complaint yes/no	Regulating behaviour at 37.5 mbar OK?	Regulating behaviour at 100 mbar OK?	shut-off pressure P_f OK?	UPSO valve OK?	Verification with natural gas
1	none	min 24.7	yes	yes	yes	
2	none	min 25.0	yes	yes	n/a	
6	yes	no	no	no	no	x
7	yes	yes	yes	no	yes	
8	yes	yes	yes	yes	no	
9	yes	max 30.9	no	no	no	
10	yes	no	no	yes	n/a	
11	yes	yes	yes	yes	no	
12	yes	yes	yes	yes	no	
13	yes	yes	yes	yes	no	
14	yes	yes	max 30.6	yes	no	
16	none	no	yes	yes	no	
18	none	min 25.1	yes	no	no	x
19	yes	yes	yes	yes	no	
21	yes	yes	no	yes	n/a	
22	yes	yes	max 31.7	no	n/a	
23	yes	yes	max 30.9	yes	n/a	x
24	yes	yes	yes	no	n/a	
25	yes	no	no	no	n/a	
26	yes	max 31.3	yes	no	n/a	
28	yes	yes	no	no	no	
31	unknown	yes	yes	yes	n/a	x
33	unknown	yes	yes	yes	no	x
35	yes	yes	no	no	n/a	
36	yes	no	min 24.7	yes	no	
37	yes	yes	yes	no	n/a	
38	yes	yes	no	no	n/a	
40	none	yes	yes	no	n/a	
41	none	yes	yes	yes	n/a	
42	none	yes	yes	yes	n/a	x
43	none	yes	yes	yes	n/a	
44	yes	yes	max 31.2	no	no	
45	yes	yes	yes	yes	no	
47	yes	yes	yes	yes	yes	x
48	none	min 24.7	yes	no	n/a	x
49	none	yes	yes	yes	n/a	
50	none	no	yes	no	n/a	x
51	none	yes	yes	yes	n/a	

Sample #	complaint yes/no	Regulating behaviour at 37.5 mbar OK?	Regulating behaviour at 100 mbar OK?	shut-off pressure P_f OK?	UPSO valve OK?	Verification with natural gas
52	none	min 24.7	yes	yes	n/a	x
53	none	yes	yes	yes	n/a	

N.B. the network operators delivered more pressure regulators than was necessary. The table shows 40 tested pressure regulators, while the sample numbers continue to 53. Some of the supplied pressure regulators were or became unusable for different reasons. Some due to damage to the connection, for example, others due to exposure to an excessive inlet pressure because the pressure supplied by the test installation exceeded the allowable limit.

Tests were performed on 18 pressure regulators with a UPSO valve. It is worth noting that most of these regulators (14 of the 18 tested) with hydrogen do not meet the inspection requirements. This can possibly be attributed to:

1. the flow characteristics of hydrogen, (and)/or
2. the test set-up. It is conceivable that the UPSO valve can drop too soon because of vibrations in the gas meter installed in the test set-up. On a side note, this might also occur in practical settings.

The UPSO valve generally shuts prematurely if the pressure drops to 17.5 mbar. There are also regulators (numbers 13, 28 and 45) where the pre-closed UPSO valve unintentionally opens when the pressure rises to 200 mbar. Gas network pressures ≤17.5 mbar are extremely rare and the inconvenience will remain limited in the event of a brief drop in pressure. Furthermore, it will not cause a safety risk because all hydrogen devices will be equipped with an under-pressure shut-off valve.

Noise/vibration

No disturbing noise or vibrations were observed in any of the regulators. The sound of the gas meter is dominant. Vibrations or noise can occur in any regulator, i.e. with hydrogen as well as with natural gas, but can always be resolved. Relatively inexpensive retrofit solutions are available if complaints are received from the field, but it remains to be seen whether it will worsen with hydrogen. There are no indications that using hydrogen will cause more problems than when natural gas is used.

External leak tightness

One regulator (no. 23) was found to have an external leakage from the connection gasket, which was replaced for testing purposes. No external leaks were found in the other regulators.

Internal leak tightness and shut-off pressure

The following two tables show the findings of the shut-off pressure measurements. Calculations based on the volume and the measured pressures also gives an indication of the internal leakage flow rates.

The following applies to the tables:

- In accordance with NEN 7239:
  - pu = $P_{upstream}$ = inlet pressure
  - pf = shut-off pressure
  - pd = $P_{downstream}$ = outlet pressure

- * Calculation of internal leakage based on the pressure increase in the given volume for a period of 13 minutes, whereby it is assumed that the atmospheric pressure and gas temperature are constant.
- ** KE 214 prescribes an inlet pressure of 300 mbar and an outlet pressure of 37.5 mbar. At these pressure levels, the leak between the inlet and outlet for hydrogen may not exceed 6.6 cm^3/h. In the present study, leak tightness was measured with an inlet pressure of approximately 100 mbar and an outlet pressure with a deviating value. The outlet pressure determines the force with which the valve is closed. N.B. KE 214 applies only to new pressure regulators and not to existing regulators as tested in this study.

Table 3 Shut-off pressure and leak tightness of regulators tested with hydrogen (1)

Determining the shut-off pressure and leak tightness										
Sample #	Regulator with or without complaint	Medium	8.4.3: Is Pd OK at sudden shut-off at Q50% + 15 min extra and smaller V (close blue valve) after 2 min H_2: = Q50% = 7.5 m³/h CH_4: = Q50% = 2.5 m³/h					Volume [dm³] after reduction		6.25 dm³
			pf at pu = 40 mbar after 60 s	pf at pu = 40 mbar after 120 s	pf at pu = 100 mbar after 60 s	pf at pu = 100 mbar after 120 s	pf at pu = 100 mbar after 15 min	intake [dm³] in 13 min	indicative leak (cm³/h)*	complies with KE 214 (< 6.6 cm³/h)**
1	none	H2	-	-	30.9	30.9	33.4	0.015	69	no**
2	none	H2	34.2	33.9	32.2	31.9	33.1	0.007	33	no**
6	yes	H2	38.5	38.6	59.0	59.0	63.1	0.024	110	no
7	yes	H2	33.1	33.4	35.5	36.0	39.6	0.021	98	no
8	yes	H2	33.2	33.2	32.1	32.0	32.9	0.005	25	no**
9	yes	H2	37.1	37.7	41.7	42.5	46.7	0.025	114	no
10	yes	H2	35.6	35.5	32.8	32.7	33.1	0.002	11	no**
11	yes	H2	33.1	33.0	31.9	32.3	34.1	0.011	49	no**
12	yes	H2	32.9	32.9	31.9	32.1	34.6	0.015	68	no**
13	yes	H2	33.2	33.2	32.6	32.7	34.8	0.012	57	no**
14	yes	H2	34.6	34.9	36.9	37.5	41.1	0.021	97	no
16	none	H2	31.9	31.8	30.6	30.8	32.6	0.011	49	no**
18	none	H2	34.7	35.4	38.9	40.1	46.6	0.038	177	no
19	yes	H2	32.2	32.1	32.0	32.2	34.8	0.015	71	no**
21	yes	H2	33.1	33.1	32.3	32.6	35.8	0.019	87	no**
22	yes	H2	38.1	38.0	39.2	42.0	50.4	0.050	229	no
23	yes	H2	36.6	36.4	34.3	34.3	36.0	0.010	47	no**
24	yes	H2	37.0	36.9	34.8	35.0	39.2	0.025	115	no
25	yes	H2	37.8	37.7	44.8	46.2	49.6	0.020	92	no
26	yes	H2	34.8	34.8	35.7	37.4	53.2	0.092	427	no

Table 4 Shut-off pressure and leak tightness of regulators tested with hydrogen (2)

Determining the shut-off pressure and leak tightness										
Sample #	Regulator with or without complaint	Medium	8.4.3: If Pd meets requirements at sudden shut-off at Q50% + 15 min extra and smaller V (close blue valve) after 2 min H_2: = Q50% = 7.5 m³/h CH_4: = Q50% = 2.5 m³/h					Volume [dm³] after reduction		6.25 dm³
			pf at pu = 40 mbar after 60 s	pf at pu = 40 mbar after 120 s	pf at pu = 100 mbar after 60 s	pf at pu = 100 mbar after 120 s	pf at pu = 100 mbar after 15 min	intake [dm³] in 13 min	indicative leak (cm³/h)*	complies with KE 214 (< 6.6 cm³/h)**
28	yes	H2	35.6	36.5	46.7	50.3	63.5	0.078	361	no
31	not known	H2	34.5	34.4	32.3	32.3	33.0	0.004	20	no**
33	not know	H2	33.4	33.3	32.0	32.3	34.2	0.011	53	no**
35	yes	H2	33.8	33.8	33.6	34.2	38.0	0.023	104	no
36	yes	H2	31.4	31.4	30.1	30.3	32.8	0.015	70	no**
37	yes	H2	32.7	32.9	33.6	34.9	43.8	0.053	247	no
38	yes	H2	36.8	37.6	45.7	48.6	58.9	0.061	283	no
40	none	H2	33.6	33.8	33.3	34.0	40.3	0.037	172	no
41	none	H2	35.3	35.2	34.0	33.9	34.5	0.004	17	no**
42	none	H2	33.4	33.3	32.7	32.8	34.5	0.010	47	no**
43	none	H2	33.3	33.2	32.8	32.9	35.1	0.013	61	no**
44	yes	H2	34.2	34.3	35.7	37.0	44.3	0.044	203	no
45	yes	H2	33.3	33.1	32.6	32.5	34.1	0.010	45	no**
47	yes	H2	32.6	32.5	31.2	31.3	33.4	0.013	58	no**
48	none	H2	38.0	38.0	35.8	35.7	36.0	0.002	8	no
49	none	H2	31.1	31.3	30.5	31.1	36.7	0.033	125	no**
50	none	H2	30.3	31.3	36.6	39.5	67.8	0.167	557	no
51	none	H2	34.3	34.1	33.3	33.2	34.2	0.006	27	no**
52	none	H2	33.6	33.5	30.8	30.8	32.5	0.010	42	no**
53	none	H2	36.7	36.7	34.6	34.7	36.7	0.012	54	no**

Explanation: A shut-off pressure that is too high is not a safety risk.

Summary of results: During the tests with hydrogen, at least 17 of the 40 regulators that were tested do not meet the internal leakage requirements set for new regulators. That being said, the observed deviations also do not pose a safety risk.

4.2. Results of verification measurements with natural gas

Of the 40 pressure regulators tested using hydrogen, the researchers chose to repeat the tests on 10 pressure regulators using natural gas, as presented in table 2. Appendix IV shows the key characteristics of the pressure regulators supplied by each network operator and the method used for selecting the 10 pressure regulators to be verified with natural gas. The main question that the distribution network operators want answered is whether and to what extent they can expect more shut-off pressure complaints if they use the current pressure regulators to distribute hydrogen. The characteristics of the selected regulators are listed in table 5.

Table 5 Characteristics of pressure regulators to be verified with natural gas

Sample no.	Characteristics and test results with hydrogen
6	complaint registered, regulating behaviour 37.5 mbar and 100 mbar NOK, closing pressure NOK, UPSO valve NOK
18	no complaint, regulating behaviour 37.5 mbar close to OK, 100 mbar OK, shut-off pressure and UPSO valve NOK
23	complaint registered, regulating behaviour 37,5 mbar OK, 100 mbar close to OK, no UPSO valve
31	unknown if there are complaints, no deviations, no UPSO valve
33	unknown if there are complaints, UPSO valve NOK
42	no complaint, test results OK, no UPSO valve
47[7]	complaint registered, no deviations, UPSO valve OK
48	no complaint, regulating behaviour 37.5 mbar close to OK and shut-off pressure NOK; no UPSO valve
50	no complaint, regulating behaviour 37.5 mbar NOK and shut-off pressure NOK; no UPSO valve
52	no complaint, regulating behaviour 37.5 mbar close to OK, no UPSO valve

Regulating behaviour, capacity, shut-off pressure and under-pressure protection

If the regulating characteristic does not meet requirements by only a small margin, the deviation of the measurement value from the limit values is shown in mbar in a green box. This concerns pressures that are just above or below the limit values of 25.2 and 30.8 mbar in the capacity range between 0.25 and 5 m^3/h.

The regulating characteristics with natural gas are also included in appendix IX

[7] Originally, no. 13 was selected, but it failed due to an overshoot in inlet pressure. Instead, no. 47 has been chosen.

Table 6 Summary of measuring results of 10 pressure regulators with natural gas

Sample #	complaint yes/no	Regulating behaviour at 37.5 mbar OK?	Regulating behaviour at 100 mbar OK?	shut-off pressure P_f OK?	UPSO valve OK?	Difference with hydrogen?+ what aspect
6	yes	no	no	no	no	no
18	none	yes	yes	no	no	yes (37.5 mbar)
23	yes	max 31.3	max 31.4	yes	n/a	yes (37.5 mbar)
31	unknown	yes	yes	yes	n/a	no
33	unknown	yes	yes	yes	no	no
42	none	yes	yes	yes	n/a	no
47	yes	yes	yes	yes	yes	no
48	none	min 25.0	yes	yes	n/a	yes (shut-off pressure)
50	none	no	yes	no	n/a	no
52	none	yes	yes	yes	n/a	yes (37.5 mbar)

Noise/vibrations

No disturbing noise or vibrations were observed in any of the regulators. The sound of the gas meter is dominant.

External leak tightness

No external leakage was observed in any of the regulators tested.

Internal leak tightness

The table below shows the findings of the shut-off pressure measurements. Calculations based on the volume and the measured pressures also gives an indication of the internal leakage flow rates.

Table 7 Shut-off pressure and leak tightness of regulators tested with natural gas

Determining the shut-off pressure and leak tightness										
			8.4.3: If Pd meets requirements at sudden shut-off at Q50% + 15 min extra and smaller V (close blue valve) after 2 min H_2: = Q50% = 7.5 m^3/h CH_4: = Q50% = 2.5 m^3/h					Volume [dm^3] after reduction		6.25 dm^3
Sample #	Regulator with or without complaint	Medium	pf at pu = 40 mbar after 60 s	pf at pu = 40 mbar after 120 s	pf at pu = 100 mbar after 60 s	pf at pu = 100 mbar after 120 s	pf at pu = 100 mbar after 15 min	intake [dm^3] in 13 min	indicative leak (cm^3/h)*	complies with NEN 7239 (< 10 cm^3/h) **indicative****
6	yes	natural gas	39.0	39.1	55.9	55.8	55.4	-0.002	-11*	yes**
18	none	natural gas	32.4	32.7	33.6	34.4	40.8	0.038	177	no**
23	yes	natural gas	35.1	35.0	34.6	34.6	34.0	-0.004	-17*	yes**
31	ND	natural gas	33.1	32.7	31.6	31.3	29.9	-0.008	-39*	yes**
33	ND	natural gas	31.7	31.2	31.2	30.9	32.2	0.008	36*	yes**

42	none	natural gas	32.6	32.5	32.4	32.3	32.4	0.001	3*	yes **
47	yes	natural gas	32.7	32.7	32.5	32.7	33.9	0.007	33*	yes **
48	none	natural gas	35.3	35.1	33.4	33.3	31.5	-0.011	-50*	yes**
50	none	natural gas	30.3	30.8	35.5	38.1	60.3	0.133	612	no**
52	none	natural gas	32.3	32.2	31.4	31.3	30.6	-0.004	-19*	yes **

The following applies to the tables:

- * Negative and positive values (< approx. 50 cm^3/h) for the leakage flow rate must be attributed to temperature decreases and increases respectively during the measuring time of 13 minutes.
- ** NEN 7239 prescribes an inlet pressure of 300 mbar and an outlet pressure of 37.5 mbar. The outlet pressure determines the extent to which the valve is drawn closed. The leak tightness was measured with an inlet pressure of approximately 100 mbar and an outlet pressure with a deviating value. At that pressure difference, the leak between the inlet and outlet side for natural as may not exceed 10 cm^3/h of air. Only with the prescribed pressures can it actually be determined whether or not those pressures comply with NEN 7239.

Summary of results:
During the tests with natural gas, 7 of the 10 regulators that were tested meet the internal leakage requirements set for new regulators. These all concern used pressure regulators. The shut-off pressure may increase due to ageing.

Comparison of shut-off pressures
The table below shows the shut-off pressures after 15 minutes of the regulators tested with both hydrogen and natural gas.

Table 8 Shut-off pressures with hydrogen and with natural gas

Sample no.	Shut-off pressure with hydrogen after 15 min [mbar]	Does the shut-off pressure comply with NEN 7239?	Shut-off pressure with natural gas after 15 min [mbar]	Does the shut-off pressure comply with NEN 7239?	Difference [mbar]
6	63.1	no	55.4	no	7.5
18	46.6	no	40.8	no	5.8
23	36.0	yes	34.0	yes	2.0
31	33.0	yes	29.9	yes	3.1
33	34.2	yes	32.2	yes	2.0
42	34.5	yes	32.4	yes	2.1
47	33.9	yes	33.4	yes	0.4
48	36.0	yes	31.5	yes	4.5
50	67.8	no	60.3	no	7.5
52	32.5	yes	30.6	yes	1.9

The table shows that the shut-off pressure for hydrogen is higher than for natural gas in all cases. The differences are greatest in those regulators where the shut-off pressure does not meet the set requirements (shaded yellow in the table).

4.3. UPSO valve failure using hydrogen versus natural gas

The under-pressure protection can fail in a number of ways. This is explained further in Table 9 for regulators where the protection did not meet requirements, and thus ascertain whether a distinction can be made in the characteristics of the failure. The results of the following tests were considered.

1. Column 37.5→17.5 mbar (test 1):
   At Qnom: pu = 37.5 -> 17.5 mbar and vice versa after 60 s. Valve must not close
2. Column 37.5→12.5 mbar (test 2):
   At Qnom: Pd = 12.5 mbar Pu = 37.5 -> 12.5 mbar and vice versa after 60 s. Valve must not open
3. Column UPSO valve not activated with pilot flame (test 3):
   UPSO valve dropped. Afterwards at Pu = 200 mbar: Not activated at pilot flame consumption (Pu = normal regulating pressure approx. 30 mbar) ≈
   a. H_2: 0.05 m^3/h
   b. CH_4: 0.016 m^3/h
4. Column Breakdown pressure (test 4):
   Pu = 200 mbar, reduce to 12.5 mbar to close UPSO valve. At pressure increase to 150 mbar: No activation after UPSO valve intervenes at nominal consumption and Qnom ≈
   a. H_2: 15 m^3/h
   b. CH_4: 5 m^3/h
5. Pressure after UPSO valve reset at 100 mbar pre-pressure.

Table 9   Failure of under-pressure protection in hydrogen versus natural gas

Sample no.; gas	37.5→17.5 mbar test 1)	37.5→12.5 mbar test 2)	No activation with pilot flame test 3)	Breakdown pressure test 4)	Pressure after UPSO valve reset [mbar] test 5)
6, H_2	NOK	OK	OK	OK	81.7
6, CH_4	NOK	OK	OK	OK	96.5
18, H_2	NOK	OK	OK	OK	73.0
18, CH_4	NOK	OK	OK	OK	95.9
33, H_2	NOK	OK	OK	OK	85.9
33, CH_4	NOK	OK	NOK[1)]	OK	85.0
47, H_2	OK	OK	OK	OK	72.2
47, CH_4	OK	OK	OK	OK	95.6

[1)] outlet pressure increases to 12.1 mbar, after which the UPSO valve opens

Result: The failure behaviour of the UPSO valve during tests 1) and 2) are the same for natural gas and hydrogen.
In test 3), the UPSO valve opens regulator no. 33 at a pre-pressure of 200 mbar natural gas while there is pilot flame consumption. This did not occur with hydrogen.
In three of the four regulators tested, the pressure after resetting the UPSO valve is higher with hydrogen than with natural gas. This may cause problems slightly sooner when an appliance's gas valve is opened.

4.4. Consideration of measurement results

The table below provides an overview of the results per category of tested regulators.

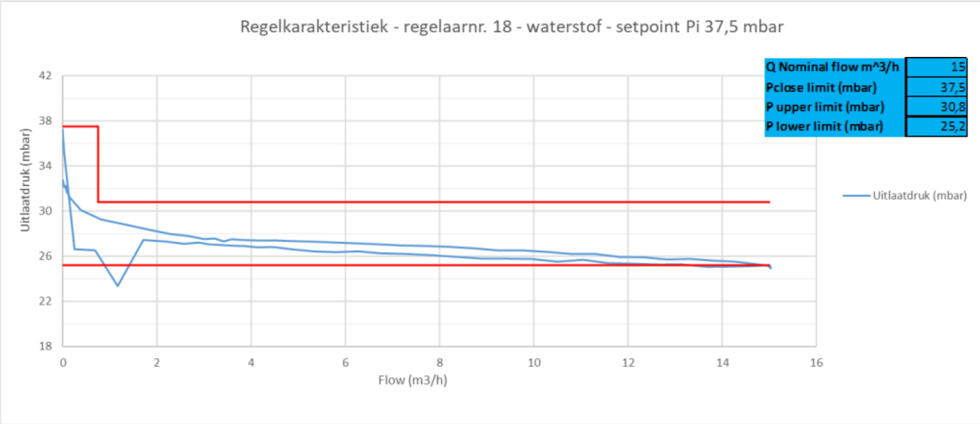
Table 10 Overview of test results in categories. The relevant sample numbers are listed per category

Category	Result category (and the associated sample numbers)	quantity
Domestic pressure regulators tested	**Total**	**40**
	With complaints (6, 7, 8, 9, 10, 11, 12, 13, 14, 19, 21, 22, 23, 24, 25, 26, 28, 35, 36, 37, 38, 44, 45, 47)	24
	Without complaints (1, 2, 16, 18, 40, 41, 42, 43, 48, 49, 50, 51, 52, 53)	14
	Unknown (31, 33)	2
Measurement results of domestic pressure regulators with complaints	**Total**	**24**
	Tested only with hydrogen; meet requirements	0
	Tested only with hydrogen; do not meet requirements (7, 8, 9, 10, 11, 12, 13, 14, 19, 21, 22, 24, 25, 26, 28, 35, 36, 37, 38, 44, 45)	21
	Tested with hydrogen and natural gas; meet requirements (23, 47)	2
	Tested with hydrogen and natural gas; do not meet requirements (6)	1
Measurement results of domestic pressure regulators without complaints	**Total**	**14**
	Tested only with hydrogen; meet requirements	0
	Tested only with hydrogen; do not meet requirements (1, 2, 16, 41, 43, 48, 49, 51, 53)	9
	Tested with hydrogen and natural gas; meet requirements (42, 52)	2
	Tested with hydrogen and natural gas; do not meet requirements (18, 48, 50)	3
Measurement results of domestic pressure regulators unknown	**Total**	**2**
	Tested only with hydrogen; meet requirements	0
	Tested only with hydrogen; do not meet requirements	0
	Tested with hydrogen and natural gas; meet requirements (31)	1
	Tested with hydrogen and natural gas; do not meet requirements (33)	1

Differences in regulating characteristics

After a closer look at the regulating characteristics of the four regulators (numbers 18, 23, 48 and 52) where differences in the regulating behaviour between hydrogen and natural gas were observed, it can be concluded that these differences are marginal. These marginal differences are limited to the test results at an inlet pressure of 37.5 mbar. The following figures show the differences in the regulating characteristics between the four pressure regulators mentioned above.

It should be noted that the regulating characteristics may be slightly lower than in an official test according to the NEN 7239 standard. This is because Pd was measured downstream from a bellows gas meter that is installed downstream from the regulator being tested, thus creating extra resistance.



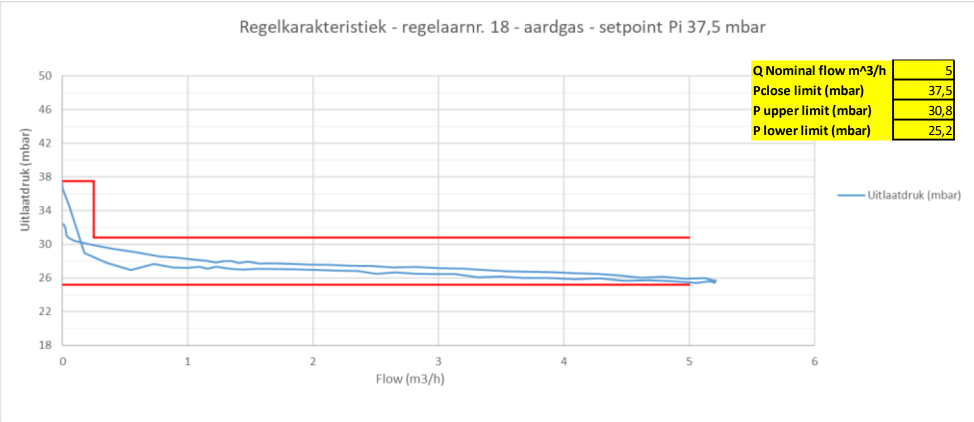
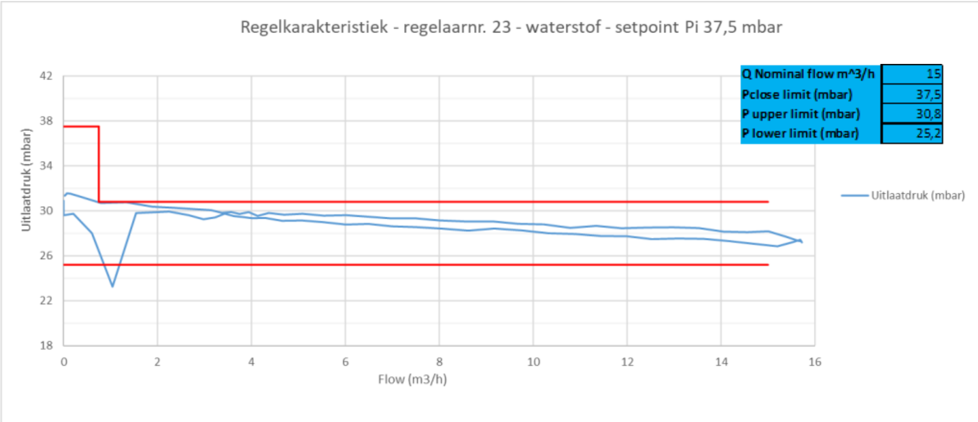


Figure 2 Regulator 18: Min. outlet pressure with increasing flow: hydrogen 24.9 mbar, natural gas 25.4 mbar. N.B. the dip in hydrogen at approx. 1 m³/h is caused by an activation phenomenon in the supply pressure



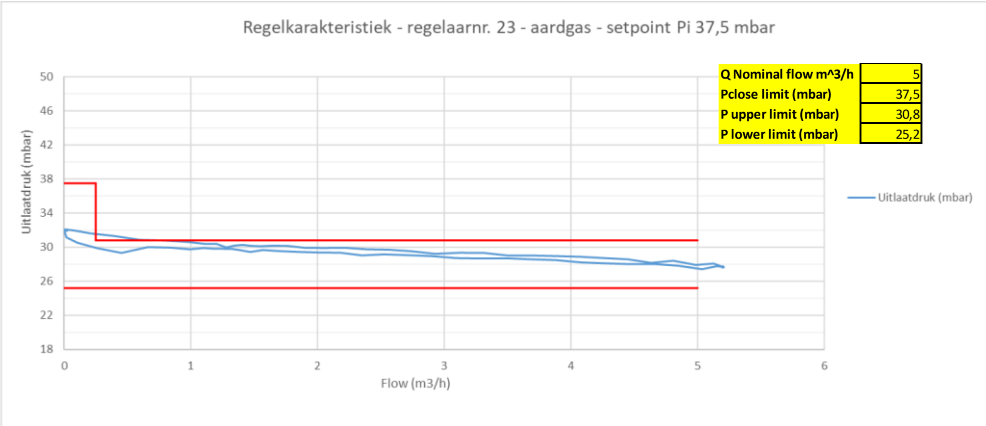
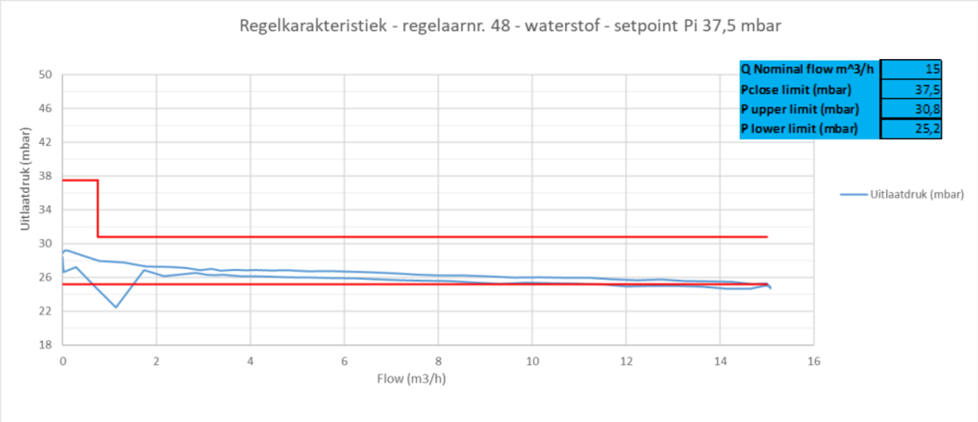


Figure 3 Regulator 23. Outlet pressure with decreasing flow at transition from P upper limit to P close limit: Hydrogen: 30.7 mbar; natural gas 31.6 mbar.
N.B. the dip in hydrogen at approx. 1 m^3/h is caused by an activation phenomenon in the supply pressure



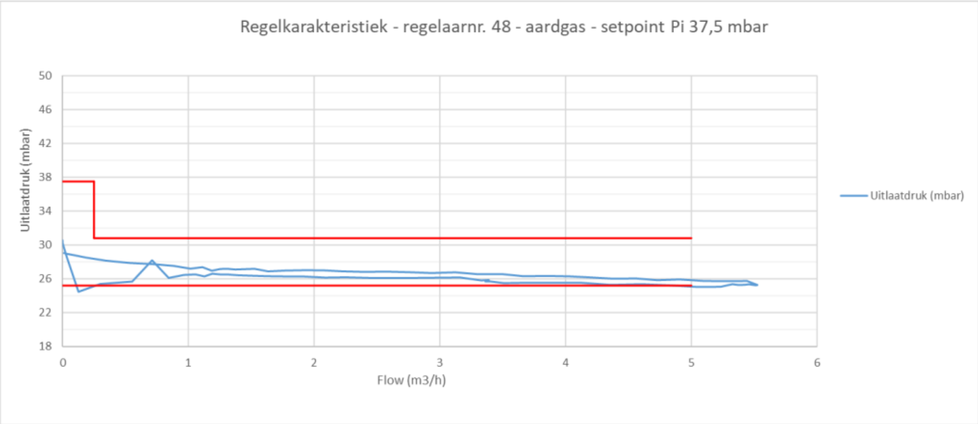
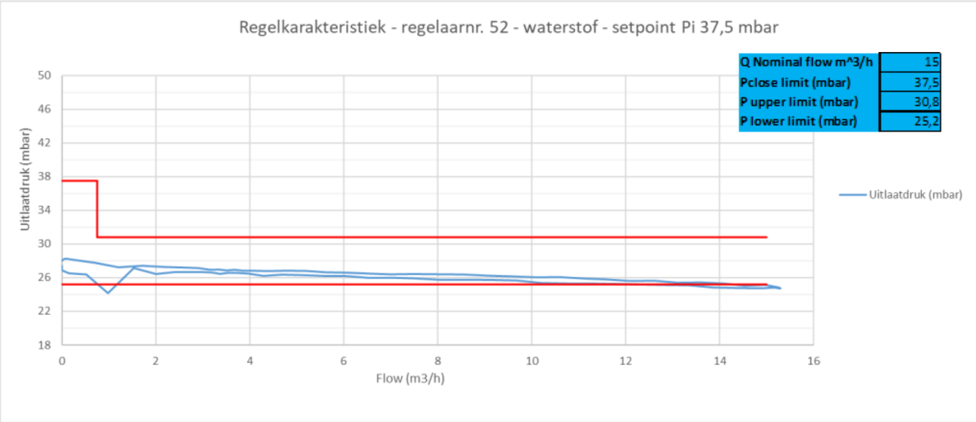


Figure 4 Regulator 48. Min. outlet pressure with increasing flow: hydrogen 24.7 mbar, natural gas 25.0 mbar. N.B. dips at low flow are caused by an activation phenomenon of the supply pressure



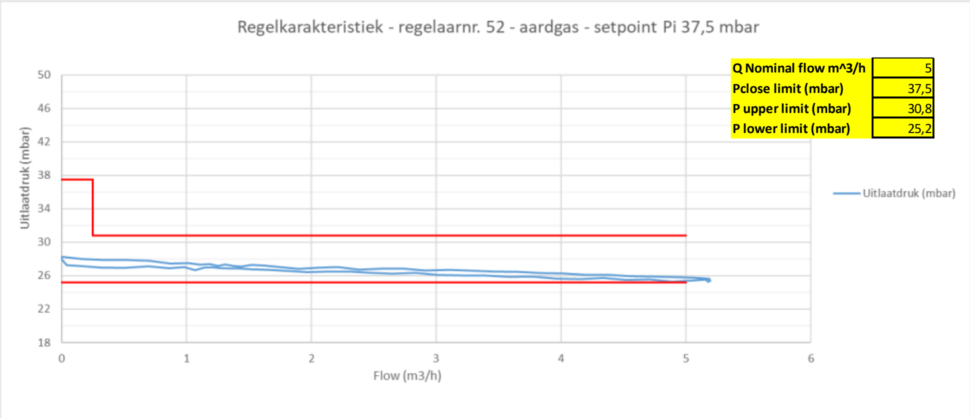


Figure 5 Regulator 52. Min. outlet pressure with increasing flow: hydrogen 24.7 mbar, natural gas 25.3 mbar.
N.B. the dip in hydrogen at approx. 1 m^3/h is caused by an activation phenomenon in the supply pressure

In all 10 regulators that were tested twice, the regulating characteristics of hydrogen are a fraction lower (tenths of mbar) than those of natural gas. For regulators showing regulating characteristics with natural gas that are in the lowest region of permissible pressures, this can result in the regulator with hydrogen falling slightly below the permissible pressure limits. This effect can be attributed to the aforementioned bellows gas meter in the test set-up.

Shut-off pressure

The shut-off pressure when using hydrogen after 15 minutes of measuring is several mbars above the shut-off pressure when using natural gas. A longer measuring time means the pressures may increase even more. The difference is greater in regulators where the shut-off pressure for natural gas does not meet requirements.

Internal leak

The internal leakage of domestic pressure regulators is greater with hydrogen than with natural gas. This will translate into a higher shut-off pressure in practice.

Deviations from the under-pressure protection

The UPSO valve generally closes prematurely when the inlet pressure drops to 17.5 mbar. The deviations in the functioning in relation to the criteria in the inspection requirement of the UPSO valve in these tests are the same for natural gas and hydrogen. There is also a chance that the gas meter has caused the activation of the UPSO valve: the gas meter creates a pulsating pressure. The minimum required supply pressure is 23.4 mbar. Therefore, failure due to an inlet pressure that is too low is not very likely in practice. Even if this were the case, closing the valve too soon does not

lead to a dangerous situation.
The following applies to regulator 33 with natural gas, where the pre-closed UPSO valve unintentionally opens when the pressure rises to 200 mbar at pilot flame consumption. This failure behaviour occurred with natural gas, but not with hydrogen[8]. It does not constitute a safety issue with hydrogen. Moreover, the systems for hydrogen will never be installed without flame monitoring devices[9].

4.5. Decision tree for replacing pressure regulators

When converting to hydrogen, network operators can make a decision based on one's own considerations as to whether or not to replace the existing pressure regulators, with or without a UPSO valve that is or is not fitted with a bypass. This choice can be made using the decision tree in figure 6, based on the arguments for and against the various options given in table 11.

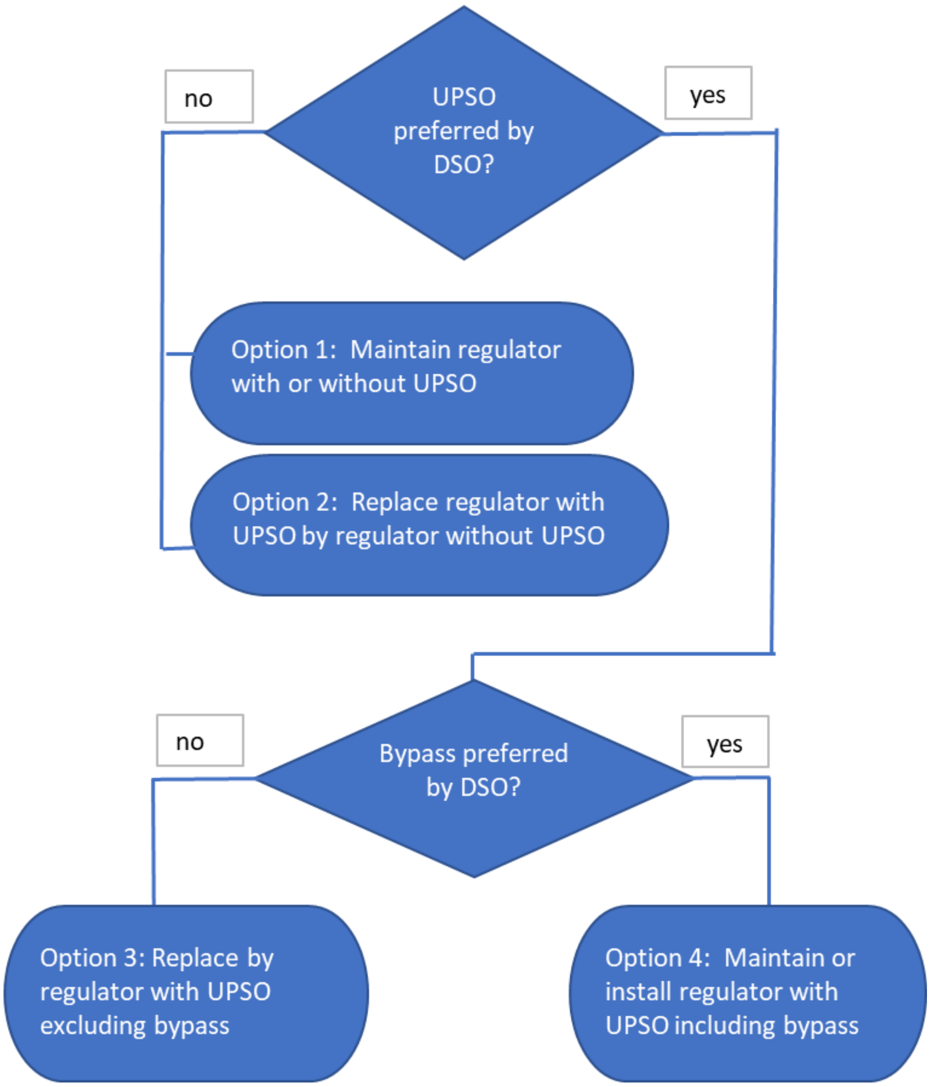


Figure 6 Decision tree for replacing pressure regulators

The arguments for and against are given in table 11. The following principles apply:

[8] Whether this is an important safety issue for existing situations with 200 mbar natural gas supply should be investigated. This is beyond the scope of this report.
[9] According to CE regulations, since 2010, new cooking appliances must feature a flame monitoring device.

- It is currently still the policy to also flush internal pipelines with nitrogen before they can be used or reused with hydrogen
- The network operators each have other strategies on whether or not to apply under-pressure shut-off protection
- If a network operator chooses the option of replacing pressure regulators that have a UPSO valve, it is consistent to also install a UPSO valve in a 30 mbar network.

Table 11 The options with the arguments for and against

Option	**Arguments for**	**Arguments against**
Option 1: Do not replace, but maintain pressure regulator	Activating the UPSO valve earlier will not quickly lead to complaints. The pressure needs to drop significantly. If there is a dip in the grid pressure, the supply will restore itself. The existing pressure regulators work well with hydrogen. Opening the UPSO valve earlier is not a safety issue, as hydrogen appliances have flame protection.	Tests have shown that a closed UPSO valve at pilot flame consumption opens unintentionally when the pressure increases to 200 mbar
Option 2: Replace with a pressure regulator without UPSO protection	The UPSO valve is possibly slightly more prone to malfunction: - Premature closing of the UPSO valve - Unintentionally opening a closed UPSO valve during pilot flame consumption when the pressure rises to 200 mbar - The pressure after resetting the UPSO valve is higher with hydrogen than with natural gas. This might cause problems slightly sooner in opening an appliance's gas valve unit.	This may also have be caused by the measurement set-up. Particularly since the UPSO valve also drops prematurely with natural gas measurements. Experience from sampling conducted by gAvilar is that the UPSO valve generally drops at around 14 mbar (when measuring with air). Moreover, new regulators can be set to a different set point for UPSO valve activation. Consideration should not only be made regarding the sensitivity to failures, but also the management function of the UPSO valve.

Option	Arguments for	Arguments against
	When changing over to hydrogen distribution, a larger gas meter needs to be installed in most cases. The indoor installation is then tested for tightness. Consequently, the UPSO valve loses the additional function of detecting a major leak in the indoor installation.	The function of the UPSO valve is not only intended for the conversion to hydrogen when the indoor pipe is tested for leak tightness. It is also important to consider the possible consequences of incorrect or unprofessional work on indoor installations. These consequences are less likely to be noticed if no UPSO valve is installed. In terms of capacity, installing a larger gas meter may not be needed in all cases. There is a real possibility that, after regulation, the sector is forced to install a different meter that meets the MID (measuring instruments directive) for hydrogen (although this is not yet in place).
Option 3: replace by pressure regulator with UPSO valve without bypass	When the gas pressure drops, it forces the UPSO valve to be flushed with nitrogen again. That pressure then reopens the UPSO valve.	This causes problems with commissioning. If it appears that gas appliances cannot cause a flash back, the question is whether the necessity to flush with nitrogen still exists in the future.
Option 4: replace by pressure regulator with UPSO valve with bypass	The control function for detecting leaks is retained after a drop in the gas network pressure.	After maintenance work on the indoor installation *and* intervention/repair of the UPSO valve takes place, there is a chance that an explosive mixture can fill the indoor installation.

5. Conclusions

The general conclusion based on the studies is that no safety risks are expected in the domestic pressure regulators following the conversion from natural gas to hydrogen. There is a slightly greater chance of more failures due to the more sensitive intervention of the UPSO valve. However, this does not give an urgent reason to replace all pressure regulators, seeing as all hydrogen appliances will be equipped with a flame protection device that mitigates the safety risk.
If a network operator chooses to replace the pressure regulators in homes as part of the conversion to hydrogen, there is no need to do this immediately. New pressure regulators can be installed at a later stage and are not necessarily needed at the time of conversion.

- In a relatively large number of the regulators tested with hydrogen, the UPSO valve closes prematurely. This occurs especially when lowering the pressure to 17.5 mbar. It is worth noting that the failure behaviour of the UPSO valve during these tests were the same for natural gas and hydrogen. The minimum supply pressure is 23.4 mbar, which in practice means that it is highly unlikely that the device will be prematurely triggered. Even if this were the case, closing the valve too soon does not lead to a dangerous situation. However, supply disruptions may occur earlier due to the more sensitive UPSO valve operation with hydrogen.
- The pre-closed UPSO valve in some regulators can also open unintentionally when the inlet pressure increases to 200 mbar. This could possibly be a safety issue in 200 mbar grids, were it not for the fact that the hydrogen systems will not have unprotected devices installed because all new stoves must be equipped with flame protection since 2010.
- In all regulators that were also tested with natural gas, the regulating characteristics of hydrogen at inlet pressures of 37.5 mbar and 100 mbar were only a fraction (in the order of a few tenths of mbar) below the regulating characteristics of natural gas. No consequences are expected in practice from this marginal effect.
- No irritating noises or vibrations were discerned in any of the tested regulators. There are no indications that using hydrogen will cause problems on this point.
- No external leakage was observed in any of the regulators tested. If a regulator does not show external leakage with natural gas, it is also not likely that this will happen with hydrogen.
- The shut-off pressure is several millibars higher with hydrogen than with natural gas. Only in highly exceptional cases could this lead to a higher chance that a gas valve unit of a hydrogen boiler will not open at start-up. (N.B. For most gas valve units, the manufacturer of the gas valve unit prescribes a maximum inlet pressure of 60 mbar).
- The chance of internal leaks from pressure regulators is greater with hydrogen than with natural gas. This effect translates into higher shut-off pressures.

6. Recommendation

When converting to hydrogen, network operators can make a decision based on one's own considerations as to whether or not to replace the existing pressure regulators, with or without a GGB that is or is not fitted with a bypass. This choice can be made using the decision tree in figure 6, based on the arguments for and against the various options given in table 11.

References

[1] Onderzoek naar kwaliteit van huisdrukregelaars in het veld GT-130058 - [Arend Herwijn en Michiel van der Laan, Kiwa 2013]

[2] Kiwa Rapport GT 150028 - DNWB Huisdrukregelaars 05062015. - [Michiel van der Laan, Kiwa 2015].

[3] notitie tbv test waterstof in container te Groningen INTERN versie 21 okt 2020 - [interne notitie Johan Jonkman, RENDO 2020].

[4] Kiwa-Permeatie gAvilar drukregelaars Liander Def 2018.12.10 - [Arie Kooiman, Kiwa 2018].

[5] 2021-02-RN Openingspiek WMRG regelaar vergeleken bij lucht en waterstof [Rinie Neelen, gAvilar].

[6] W 20201221_gAvilar B.V._AR 214_106761-01 certificaat regelaar [Uitgave Kiwa NV].

[7] Bevindingen Helium testen WMRG 14-11-2018 - 02-2021 [power point presentatie gAvilar 2021].

[8] NEN 7239: 2018 Huisdrukregelaars, gasgebrekbeveiligingen en combinatieregelaars voor aansluitingen met een capaciteit van maximaal 10 m3 en een inlaatdruk (MOPu) tot en met 200 mbar

[9] Keuringseis 214: 2019 Geschiktheid voor bijmenging tot en met 100% waterstofgas

Appendices

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?
- 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 question 185

Table 1. Composition of guidance group and sparring group

Name	**Employer**	Guidance group	**Sparring group**
D. Nieuwenhuizen	Stedin	V	V
H. Smit	Enexis	V	V
W. Koppenol	Enexis		V
W.R. Nispeling	Alliander	V	V
R. den Hartog	Westland Infra		V
J. Jonkman	RENDO	V	V
R. Scholten	RENDO	V	V
A. Kooiman	Kiwa Technology	V	V
S. Lueb	Kiwa Technology	V	V
P. Klijs	gAvilar		V
L. Mostert	gAvilar		V
K. Havelaar	Honeywell		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 assesment

Kiwa has drawn up an overview of possible events when converting the natural gas network to a hydrogen network without adjustments to the house pressure regulator. During a meeting on 27-1-2021 with the guidance and sparring group, an inventory was made of the possible consequences and which investigations are necessary to further determine the risks. The table below describes the possible consequences. For each event, it was checked what has already been investigated by the manufacturers gAvilar and Honeywell or by the network operators, which reports are already available and which other comments have been made. For the sake of overview, those columns are not included, but that information is available in the spreadsheet of which this table is an excerpt.

No	Description event	Type of event	Possible consequence	Additional testing makes sense?	What to investigate?
1	Excessive noise	General functioning	nuisance	Possible combination with intended measurements closing pressure, control behavior and leakage	The noise aspect can be included in the measurements to be performed
2	Higher speed	General functioning	effect on general functioning	Yes. Gavilar; Expect no problems with speed and capacity for pressure regulators from 10 to 25 years old, perhaps investigation into other types.	
3	Vibrations in the pressure regulator	General functioning	limitation of the lifespan of the domestic pressure regulator	See line 1.	See line 1 (vibrations will manifest as sound)
4	Limitations in capacity	General functioning	Device failures	yes	Check which capacity is achievable with existing pressure regulators (test for example 10, 20 and 30 m^3/hour) [10][11]

[11] Debiet aardgas tbv cv en tapwater in een normale woning zal in de regel kleiner zijn dan 4 m3/uur (40 kW cv-combi-toestel, dat is al hoog). Bij overgang naar H2 waarschijnlijk elektrisch koken. Op basis hiervan is het maximum debiet waterstof 12m3/uur. Besloten is om max debiet van 15 m3/h aan te houden bij de tests.

No	Description event	Type of event	Possible consequence	Additional testing makes sense?	What to investigate?
5	Corrosion	General functioning	Limitation of the lifespan of the domestic pressure regulator	No	n/a
6	Contamination of the regulator	General functioning	effect on general functioning	Yes	Rob Nispeling, much to do with polluted pressure regulator: proposal to investigate whether closing pressure of polluted and non-polluted pressure regulator is higher with H2 compared to natural gas.
7	Damage to the regulator with a combination of hydrogen and hydrochloric acid gas	General functioning	effect on general functioning	Possibly, but not in the context of this sub-question.	To be determined[12]
8	Deviating behavior in case of pressure surge after gas shortage protection has been restored	General functioning	Pressure too high	Yes	The height of the pressure after gas shortage protection has been restored. N.B. with natural gas, pressure can also rise to 80 mbar.
9	Formation of explosive mixture during intervention/ repair gas shortage protection	General functioning	explosive ignition	Not in the context of this sub-question.	n/a
10	Unstable pressure control	Regulating behavior	Device failures	Yes	Regulating behavior in accordance with NEN 7239
11	Pendulum behavior at normal inlet pressure	Regulating behavior	Device failures	Yes	Regulating behavior in accordance with NEN 7239
12	Pendulum behavior at too high inlet pressure	Regulating behavior	Device failures	Yes	Regulating behavior in accordance with NEN 7239

[12] Mogelijk in vervolgtraject nader onderzoeken.

No	Description event	Type of event	Possible consequence	Additional testing makes sense?	What to investigate?
13	Pendulum behavior at too low inlet pressure	Regulating behavior	Device failures	Yes	Regulating behavior in accordance with NEN 7239
14	Controller behavior with increasing ambient temperature (fire in meter cupboard)	Regulating behavior	Device failures	Yes	Regulating behavior in accordance with NEN 7239
15	regulated pressure too high	Regulating behavior	Device failures	Yes	Regulating behavior in accordance with NEN 7239
16	regulated pressure too low	Regulating behavior	Device failures	Yes	Regulating behavior in accordance with NEN 7239
17	Closing pressure too high	Regulating behavior	Device failures	Yes	Closing pressure in accordance with NEN 7239
18	Internal leakage	Leakage	Device failures	Yes	Leakage in accordance with NEN 7239
19	External leakage	Leakage	explosion, fire	Yes	Leakage in accordance with NEN 7239
20	External leakage through breathing hole	Leakage	explosion, fire	Yes	Leakage in accordance with NEN 7239
21	Ruptured membrane	Leakage	Explosion, fire	No additional research in this context. Based on report GT-200237 by Kiwa Technology on behalf of Netbeheer Nederland, no problems are expected with the soft materials in pressure regulators in contact with H_2.	N.v.t.
22	Leakage membrane	Leakage	explosion, fire	Yes	Leakage in accordance with NEN 7239

No	Description event	Type of event	Possible consequence	Additional testing makes sense?	What to investigate?
23	Permeation membrane	Leakage	explosion, fire	See note at no. 21	n/a
24	Adhesion of the membrane	General functioning	Device failures	see note at no. 21	n/a
25	Resistance gas blocks of 60 mbar appliances	General functioning	Device failures, incorrect gas/air ratios at the appliances	yes	See line 14
26	Influence of the presence of hydrogen on plastic parts	General functioning	Regulator failure	no	n/a

IV. Details Test Programme

The following data were recorded for the hydrogen measurements of the 40 pressure regulators tested: The numbering in the list below corresponds to the columns in the spreadsheet with measurement results.

Before each measurement, it is first determined whether the measuring circuit is not leaking. Explanation of the values noted in the spreadsheet, indicated by the letters of the columns:

A. Samplo no.
B. Medium (hydrogen or natural gas)
C. Atmospheric pressure [mbar]
D. Temperature testroom [^{o}C]
E. Tightness circuit: Pinlet [mbar]
F. Pinlet after 1 min [mbar]
G. Tightness circuit: Poutlet [mbar]
H. Poutlet after 1 min [mbar]

Subsequently, the regulating characteristic and the capacity are determined. With a flow rate for:
H_2: 0 - 15 m3/h and v.v.
CH_4: 0 - 5 m3/h and v.v.
NB. Conform NEN 7239 used abbreviations:
$P_u = P_{upstream} = P_{inlaat}$ = inlet regulator
P_f = clossing pressure
$P_d = P_{downstream} = P_{uitlaat}$ = outlet regulator

I. at P_u =37,5 mbar
J. at P_u =100 mbar
K. Is the regulating characteristic P_d within the limits of figure 3 of NEN 7239 over the entire range?

After that the determination of the closing pressure and leak tightness. Compare with NEN7239, par 8.4.3: Is P_d sufficient at Q50% in the event of a sudden shutdown?
+ Measuring 15 min longer at a smaller volume (tap immediately after gas meter is closed) after 2 min. Flow rates:
H_2: = Q50% = 7,5 m3/h
CH_4: = Q50% = 2,5 m3/h

L. P_f at P_u =40 mbar after 60 s
M. P_f at P_u =40 mbar after 120 s
N. Temp before measurement [^{o}C]
O. Atm pressure before measurement [mbara]
P. P_f at P_u =100 mbar after 60 s
Q. P_f at P_u =100 mbar after 120 s
R. P_f at P_u = 100 mbar after 15 min
S. Temp after measurement [^{o}C]
T. atm. Pressure after measurement [mbara]

Subsequently, the function of the UPSO is tested in accordance with NEN7239, par. 8.5.1 at Qnom :
H_2: 15 m3/h
CH_4: 5 m3/h"

U. P_u = 37,5 -> 17,5 mbar and v.v. after 60 s. Valve should not close.
V. P_d = 12,5 mbar P_u = 37,5 -> 12,5 mbar and v.v. after 60 s. Valve should not open.
W. Activate UPSO. Then at P_u = 200 mbar: UPSO not opening at pilot flame consumption (P_u = normal regulating pressure ca 30 mbar) ≈ H_2: 0,05 m3/h CH_4: 0,016 m3/h.
X. Breakdown pressure: 8.5.2 P_u = 200 mbar, lowering to 12,5 mbar as a result of which UPSO closes. With pressure increase to 150 mbar: not opening after closing UPSO at nominal consumption with Qnom ≈ H_2: 15 m3/h and CH_4: 5 m3/h
Y. Pressure after recovery at 100 mbar pre-pressure [mbar]

Then it is noted whether there is audible noise nuisance at 100 mbar pre-pressure and Qnom H2: 15 m3/h and external leakage is checked with a gas detector with spacer.

Z. Sound OK?
AA. External leak with spacer? [ppm]
BB. Remarks

Main features of the pressure regulators supplied by network operators

Netwerk operator	Number with complaints	Number without complaints	Number unknown if complaint	Total
Westland	5	5	0	**10**
Stedin	8	3	0	**11**
Enexis	9	0	3	**12**
Rendo	5	5	0	**10**
Alliander	4	6	0	**10**
Total	**31**	**19**	**3**	**53**

Findings of the regulators tested with hydrogen and choice of regulators to be tested with natural gas as well.

Characteristic	Behavior with H2	Number tested	Regul Char 37,5 mbar Not OK	Regul Char 100 mbar Not OK	Closing pressure Not OK	Regul Char + closing pressure Not OK	UPSO Not OK	Number to be tested with natural gas	Choice of numbers Kiwa
With complaint	OK	9	0	0	0	0	0	2	42 and 52
	Not OK	5	2	0	4	2	nvt	3	18, 48 and 50
Without complaint	OK	2						2	23 and 13
	Not OK	22	4	8	12	6	12	1	6
Unknown	OK	1						1	31
	Not OK	1	1	1	1	0	1	1	33
Total		**40**						**10**	

NB. Where "almost OK" is given in the qualification, "OK" is used in this table.

V. Tested regulators

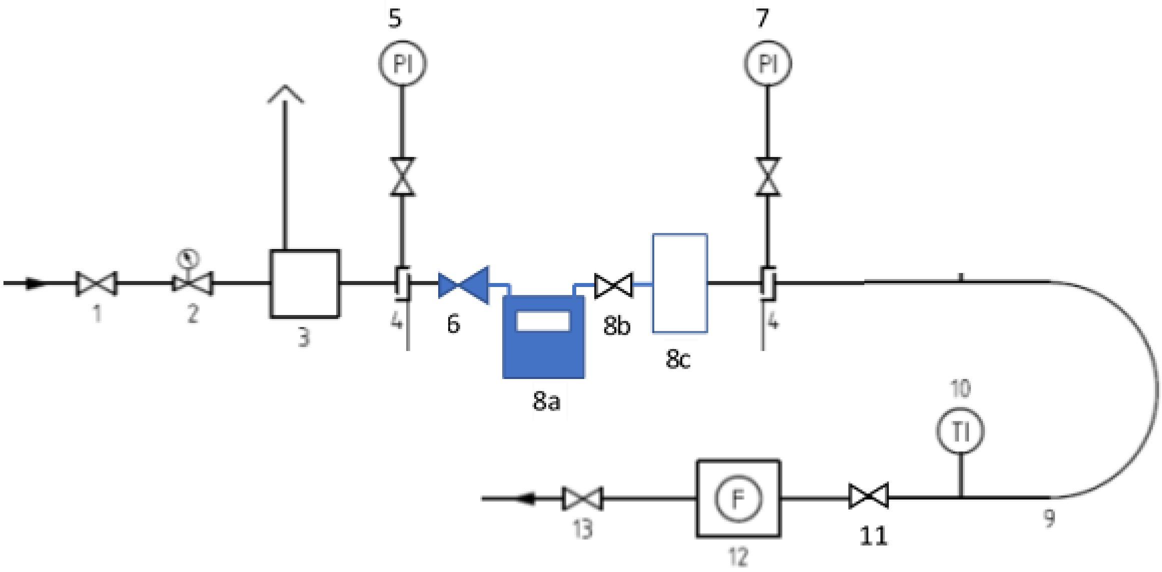
Kiwa no.	Network operator	Manufacturer	Quality-mark	Year	Type	UPSO	Serial no	Adress withdrawal	With/ without complaint	Connection inlet
1	Westland Infra	Itron	Gastec QA	2010?	WMRG-10	Yes	2/1/002567	Unknown	With	Anaconda
2	Westland Infra	Schlumberger	Giveg	?	WMR8	No	?	Unknown	Without	Anaconda
6	Westland Infra	Elster - Jeavons	QA	?	UPCO NOM 15mb	?	batch no. 1026601423	Unknown	With	via meterbracket
7	Westland Infra	Gavilar	Gastec QA	2014	WMRG-10	Yes	14000573	Unknown	With	Anaconda
8	Westland Infra	Consusa	Giveg	?	NL 20 E/B	Yes	?	Unknown	With	Anaconda
9	Westland Infra	Acataris	Gastec QA	2009?	WMRG-10	Yes	2/1/024959	Unknown	With	Anaconda
10	Westland Infra	Schlumberger	Giveg	?	WMR8	?	?	Unknown	With	Anaconda
11	Stedin	Gavilar	Gastec QA	24/07/ 2018	WMRG-10-F	Yes	18232970	Stoofplein 2, Oude-Tonge, Goeree Overflakkee	With	via meterbracket
12	Stedin	Gavilar	Gastec QA	20/09/ 2018	WMRG-10	Yes	18911300	Parelgrijs 15, 2718 NW	With	Anaconda
13	Stedin	Gavilar	Gastec QA	16/08/ 2016	WMRG-10-F	Yes	16285094	Jaarsveldstraat 226, 2546 CW Den Haag	With	via meterbracket
14	Stedin	Gavilar	Gastec QA	?	WMRG-10	Yes	2/1/031699	Vreeswijkstraat 264	With	Fit connection
16	Stedin	Schlumberger	Giveg	20-01-95?	WMRG-10	Yes	2/1/001751	Snoekenveen 876, Spijkenisse	Without	Fit connection
18	Stedin	Actaris	Gastec QA	?	WMRG-10-F	Yes	4/0/024285	Rhederoord 112, 3079 JM, Rotterdam	Without	via meterbracket
19	Stedin	Gavilar	Gastec QA	2016	WMRG-10-F	Yes	16918797	Wildenborghstraat 137	With	via meterbracket
21	Stedin	Consusa	Giveg	?	NL 20 E (Syst. Rombach)	No	?	Valkenboslaan 269, Den Haag	With	Anaconda
22	Enexis	Elster Jeavons	Gastec QA	?	J42	Yes	122260251	Musselweg 87, Mussel	With	via meterbracket

Kiwa no.	Network operator	Manufacturer	Quality-mark	Year	Type	UPSO	Serial no	Adress withdrawal	With/ without complaint	Connection inlet
23	Enexis	Elster Jeavons	Gastec QA	2020	J42	Yes	1014601309	Semstraat 5, Stadskanaal	With	via meterbracket
24	Enexis	Elster Jeavons	Gastec QA	?	J42	Yes	1222602519	Borgercompagnie 132, 9331TL, Veendam	With	via meterbracket
25	Enexis	Schlumberger	Giveg	1993?	WM	Yes	?	Zuidwending 281, Veendam	With	via meterbracket
26	Enexis	Schlumberger	Giveg	02/05/ 1995	NL-22 E	Yes	?	Sportlaan 149, Nieuw-Amsterdam	With	Fit connection
28	Enexis	Joh. Bierman Groenlo Rombach-regelaar	Giveg	1970	ZR 20 B - .. "	yes	244620	Rolderstraat 41, De Kiel	With	Fit connection
31	Enexis	Schlumberger	Gastec QA	04/01/ 1997	NL-22 E	No	?	Musselkanaal	?	Fit connection
33	Enexis	Schlumberger/ Rombach	DIN-DVGW-Nr. 87.22e 056 t	?	ZR 20 - 3/4" voor aardgas	Yes	?	Noorderdiep, Valthermond	?	Fit connection
35	Rendo	Gavilar	Gastec QA	2019	WMR-10	No	19397176	Kanaalweg 97A, Hoogeveen	With	Anaconda
36	Rendo	Schlumberger	Giveg	1990	WMRG-10	Yes	02/1/04622	Het Anker 55, Hoogeveen	With	Nut
37	Rendo	Gavilar	Gastec QA	2013	WMR-10	No	1/1/0113228	Schumerstraat 25, Wilhelminaoord	With	Nut
38	Rendo	Wilson	Giveg	1979	WMR8	No	?	Beukencamp 11, Hoogeveen	With	Thread on regulator
40	Rendo	Gavilar	Gastec QA	2015	WMR-10	No	15253848	Schoolstraat 14, Uffelte	Without	Anaconda
41	Rendo	Schlumberger	Gastec QA	1997	WMR-10	No	1/1/013337	De Zende 30, Steenwijk	Without	Thread on regulator
42	Rendo	Gavilar	Gastec QA	2013	WMR-10	No	1/1/004003	Achterstraat 8A, Diever	Without	Thread on regulator
43	Rendo	Actaris	Gastec QA	2004	WMR-10F	no	5/0/009968	Troelstraplein 88, Meppel	Without	via meterbracket
44	Alliander	Gavilar	Gastec QA	2018	WMRG-10	Ja	18032438	surrounding Nijmegen	With	Thread on regulator

Kiwa no.	Network operator	Manufacturer	Quality-mark	Year	Type	UPSO	Serial no	Adress withdrawal	With/ without complaint	Connection inlet
45	Alliander	Gavilar	Gastec QA	2019	WMRG-10	Yes	19214381	surrounding Nijmegen	With	Thread on regulator
47	Alliander	Actaris	Gastec QA	?	WMRG-10-F	Yes	4/0/051848	surrounding Nijmegen	With	via meterbracket
48	Alliander	Itron	Gastec QA	?	WMRG-10-F	Yes	4/0/093538	Hoofderburg 76, 1191 NJ Ouderkerk aan de Amstel	Without	via meterbracket
49	Alliander	Wilson	Giveg	?	?	No	?	Trompenburgstraat Amsterdam	Without	Anaconda
50	Alliander	Conval	Giveg	1971	A-25	No	?	Trompenburgstraat Amsterdam	Without	Anaconda
51	Alliander	Schlumberger	Gastec QA	2000	WMR-10-F	No	5/0/012609	7103 DS	Without	via meterbracket
52	Alliander	Schlumberger	Giveg	1986	WMR-8-F	No	02/0/16799	7051 ZV	Without	via meterbracket
53	Alliander	Schlumberger	Giveg	1989	WMR-8-F	no	05/0/32680	7103 AD	Without	via meterbracket

VI. Schematic view test set-up

In deviation from the scheme in 8.1.1. of NEN 7239 a gas meter is included downstream of the house pressure/combination regulator to be tested. This gives an extra resistance and causes the control characteristic to be slightly lower.



Legenda:

1.	Valve inlet
2.	Regulator inlet pressure
3.	Extra volume for inlet pressure
4.	Connection measuring point
5.	Measuring point inlet pressure
6.	Tested pressure regulator
7	Pressure transmitter with registration equipment for outlet pressure (response t <100 ms)
8a.	Bellows gas meter G6
8b.	Valve
8c	Extra volume for outlet pressure
9.	Volume test rig between outlet regulator to test (no. 6) and valve 11 = 12,7 dm^3
10	Temperatuurmeter
11.	Valve
12	Flow meter
13	Control valve

VII. Photos of test set-up

Top left :	supply system of testrig with pressure regulator
Top right:	regulator, connected with anaconda, directly mounted on gasmeter
Middle left:	volume installation simulated with role copper
Middle right:	measuring tubes with mass flow controllers
Bottom left:	eqiupment for registration measured values
Bottom right:	For testing the UPSO a pilot light is connected. Gas flows out in the open air.

VIII. Measuring equipment used

Description	Manufacturer and type	Kiwa no.
Mass Flow Controller hydrogen	Bronkhorst, F-106BZ-RAD-01-V 60 m3/h	114573
Mass Flow Controller natural gas	Bronkhorst, F-106AZ-RAD-01-V 12 m3/h	114574
Manometer Pin	Bronkhorst EL-PRESS P-502-C	114570
Manometer Puit	Bronkhorst P-502C-350R-RAD-59-V	114571
Manometer Puit	Digitron B2021P	112064
Leak tester H2	Sewerin Ex-Tec PM4	110976
Leak tester CH4	Sewerin Ex-Tec PM4	113807
Manometer	BlueLine S4602 ST	113737
Temperature meter	Mera	102412
Gasmeter (part of the volume, not for measuring purposes).	Flonidan UNIFLO G6SRT	Metercode: G0065 P/N 19291868 Jaar: 2019

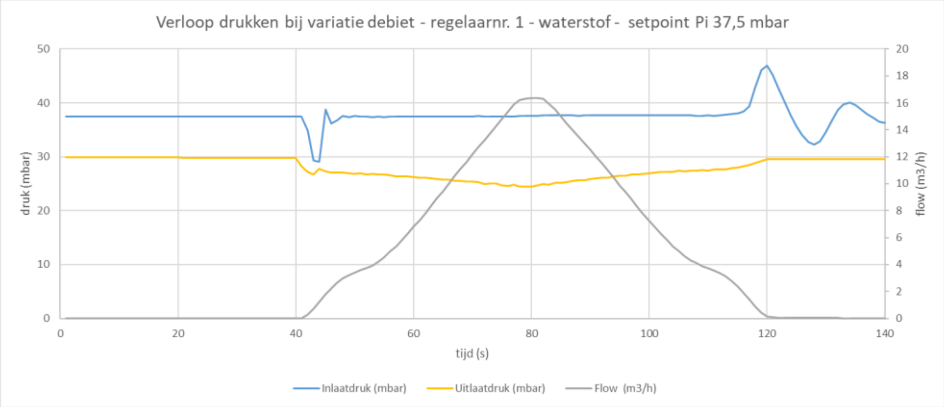
IX. Regulating characteristics hydrogen and natural gas

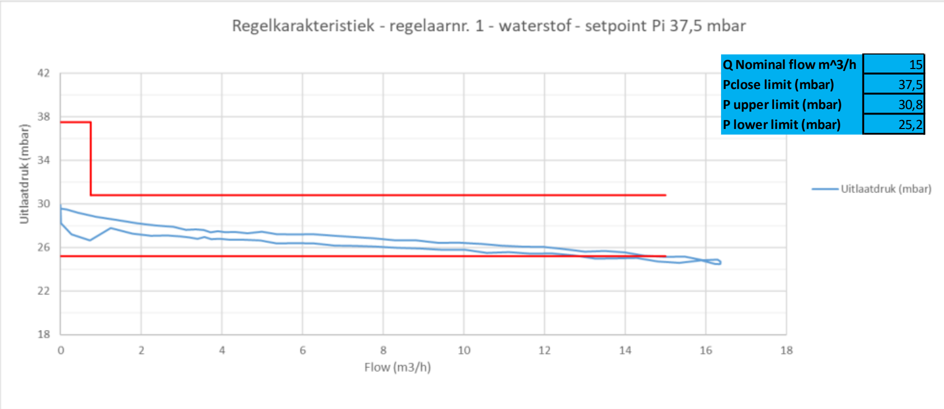
For each test, a gradient of the pressure as a function of the flow is shown. In the second graph, it has been converted to a control characteristic. In the control characteristic, the gradient can be seen for successively increasing flow (bottom blue line) or decreasing flow (top blue line).

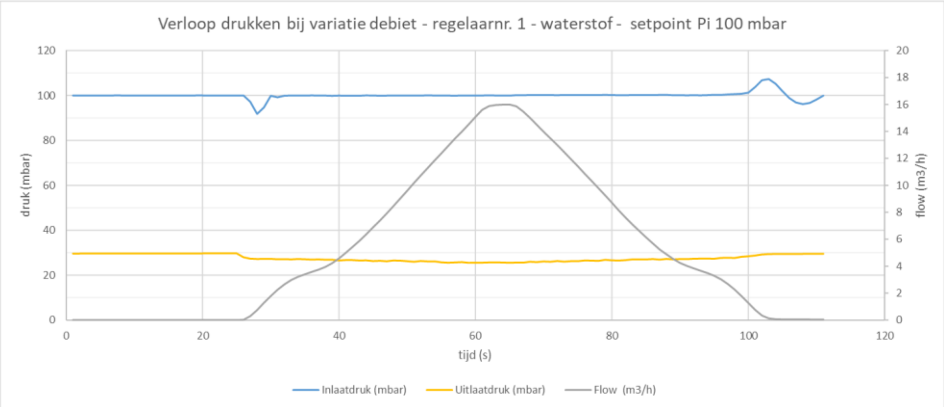
If controllers have been tested for both hydrogen and natural gas, a separate colour legend has been added for the limit values (blue for hydrogen; yellow for natural gas).

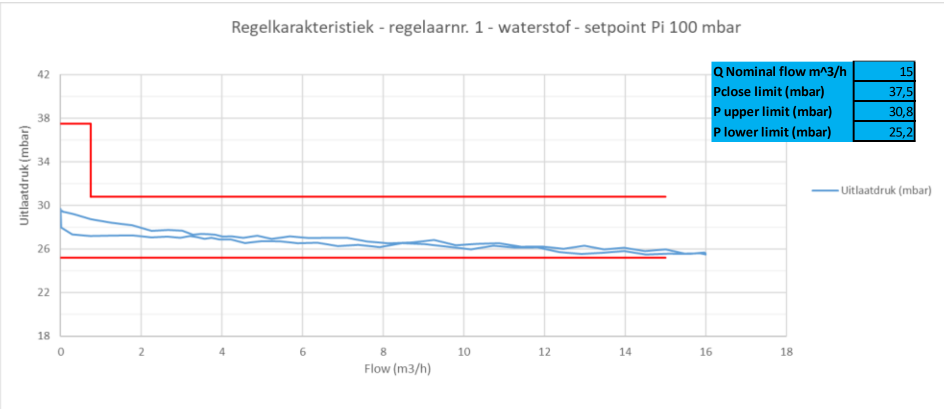
The graphs are in the Dutch language, as a guidance see the first table below.

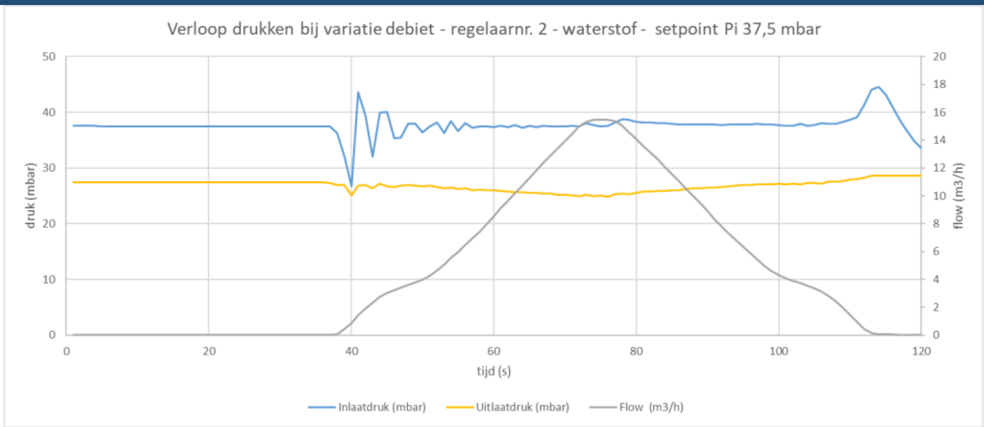
Dutch	**English**
Verloop	Gradient
Drukken	Pressures
Variatie	Variation
Debiet	Flow
Regelaar	Regulator
Waterstof	Hydrogen
Aardgas	Natural gas (G25)
Inlaatdruk	Inlet pressure
Uitlaatdruk	Outlet pressure

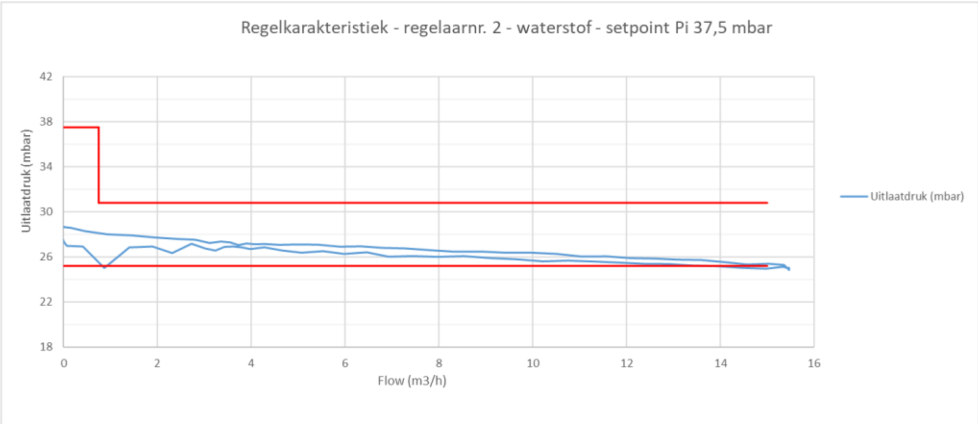

Verloop drukken bij variatie debiet - regelaarnr. 1 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

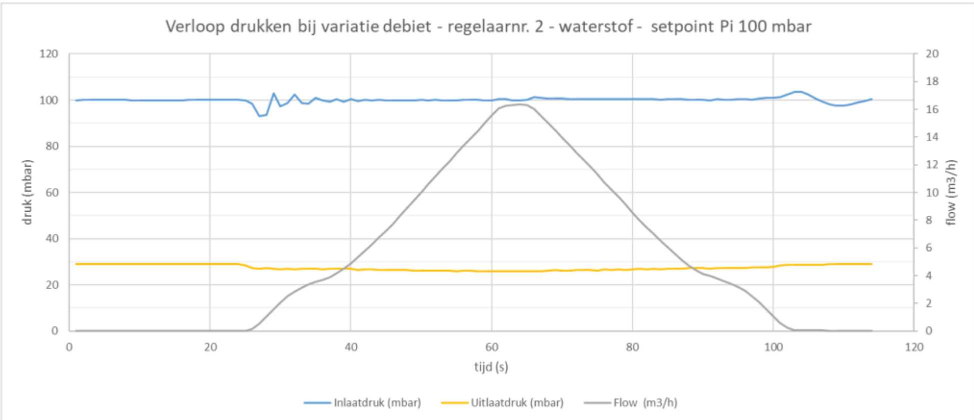

Regelkarakteristiek - regelaarnr. 1 - waterstof - setpoint Pi 37,5 mbar
Q Nominal flow m^3/h 15
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

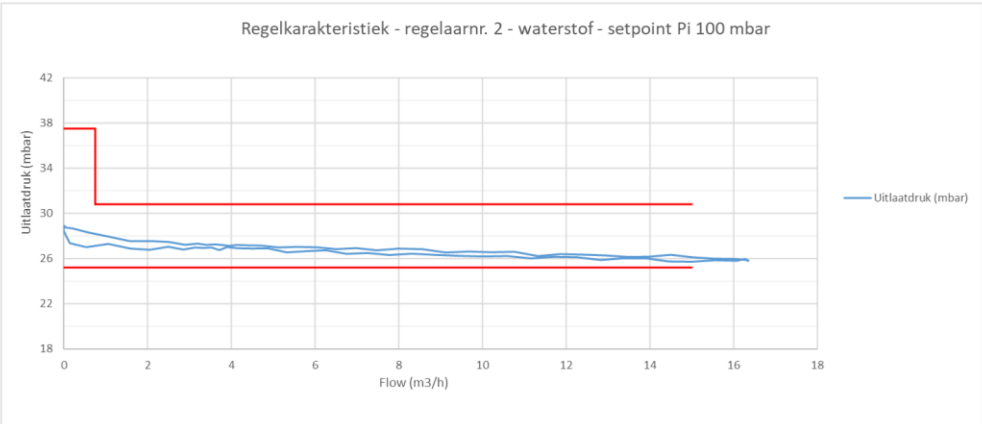

Verloop drukken bij variatie debiet - regelaarnr. 1 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

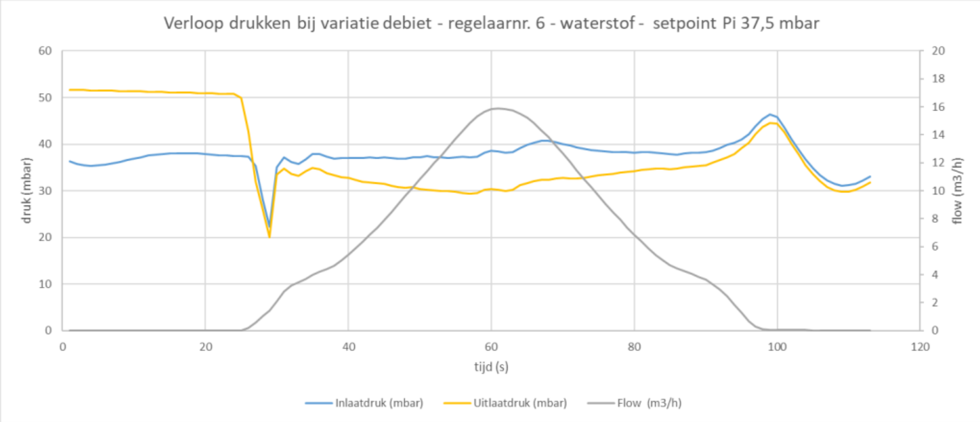

Regelkarakteristiek - regelaarnr. 1 - waterstof - setpoint Pi 100 mbar
Q Nominal flow m^3/h 15
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

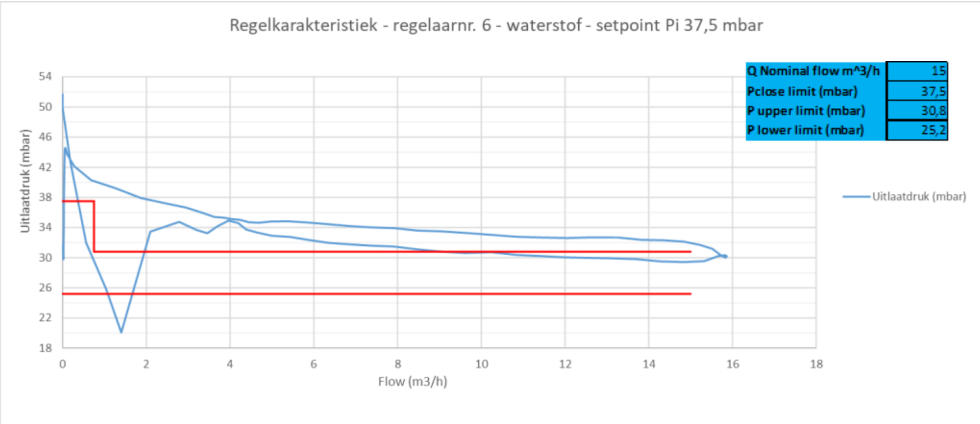

Verloop drukken bij variatie debiet - regelaarnr. 2 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

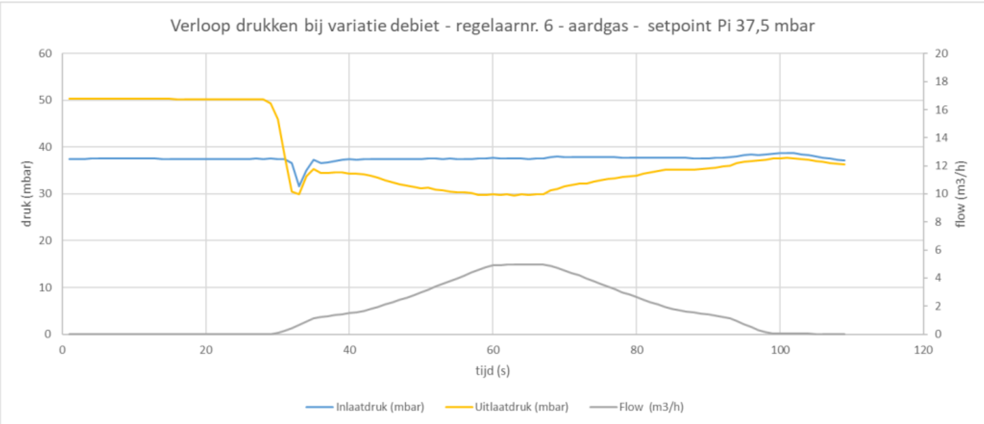

Regelkarakteristiek - regelaarnr. 2 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

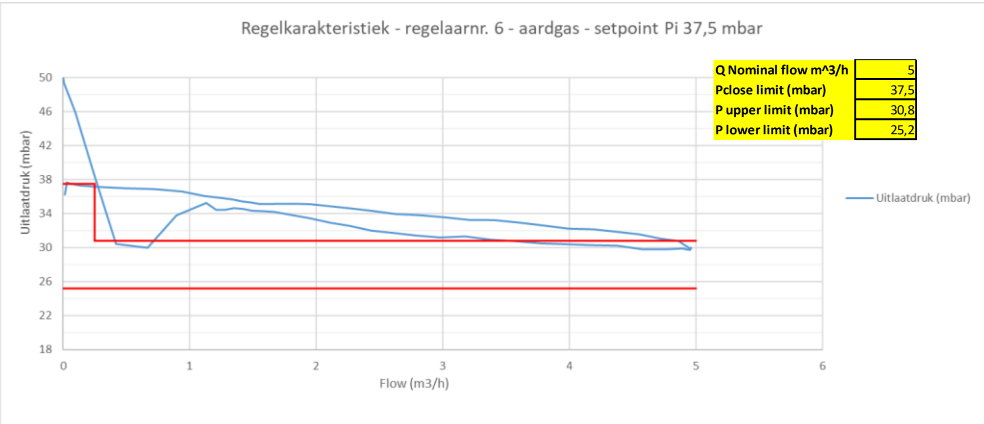

Verloop drukken bij variatie debiet - regelaarnr. 2 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

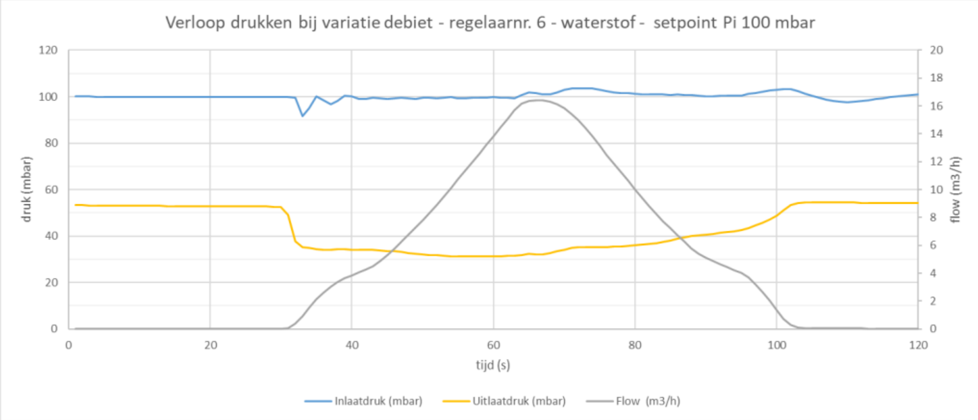

Regelkarakteristiek - regelaarnr. 2 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

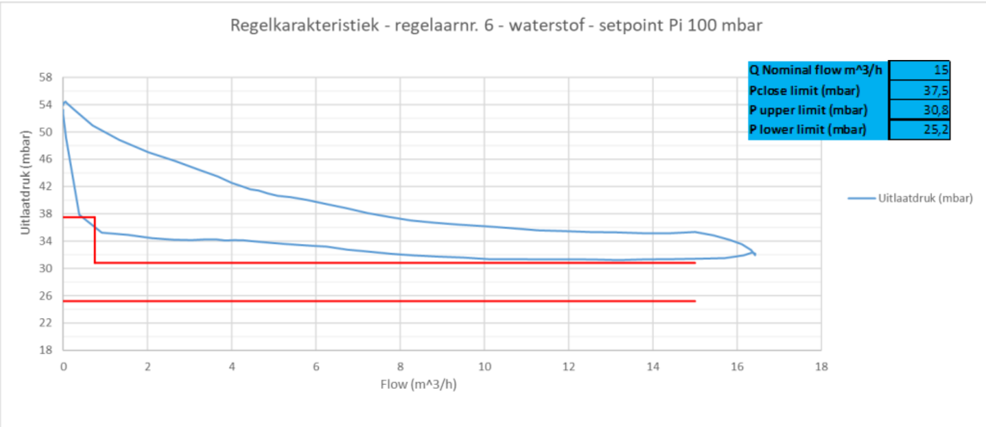

Verloop drukken bij variatie debiet - regelaarnr. 6 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

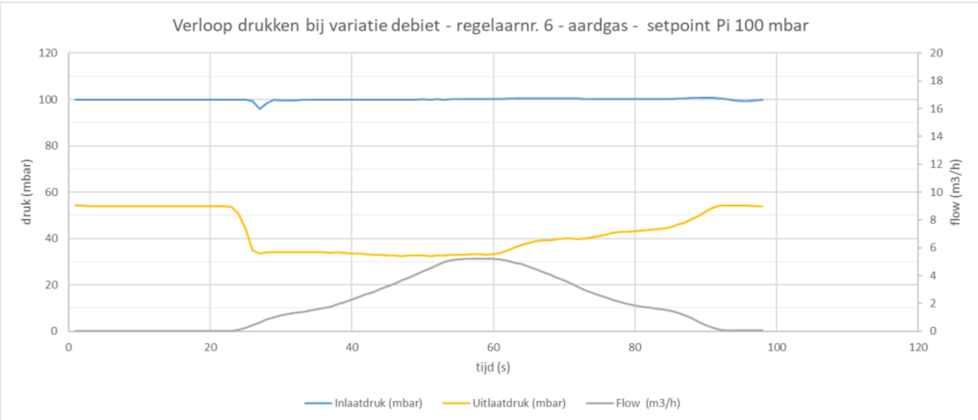

Regelkarakteristiek - regelaarnr. 6 - waterstof - setpoint Pi 37,5 mbar
Q Nominal flow m^3/h 15
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

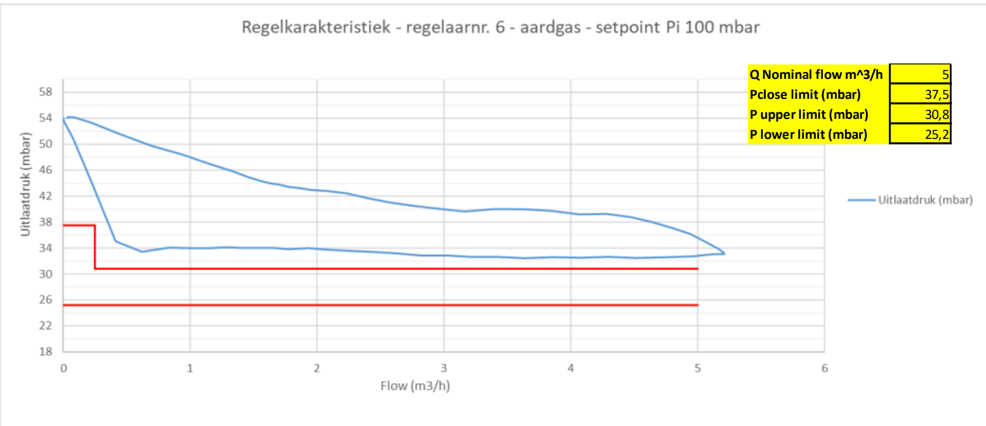

Verloop drukken bij variatie debiet - regelaarnr. 6 - aardgas - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

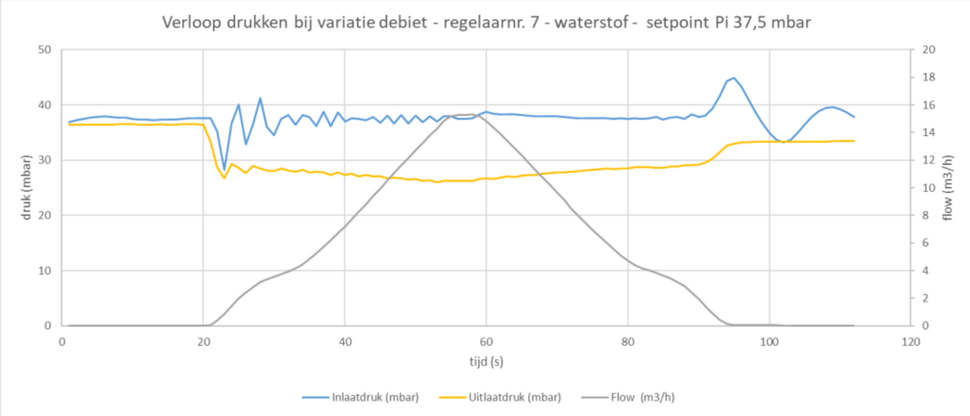

Regelkarakteristiek - regelaarnr. 6 - aardgas - setpoint Pi 37,5 mbar
Q Nominal flow m^3/h 5
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

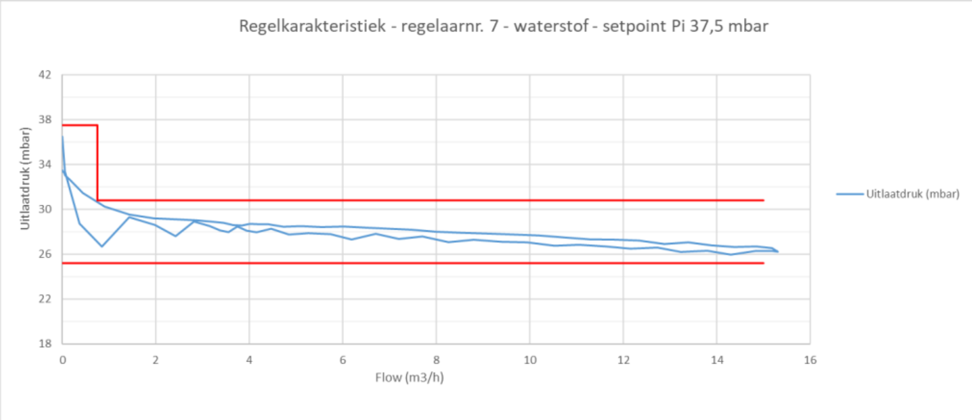

Verloop drukken bij variatie debiet - regelaarnr. 6 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

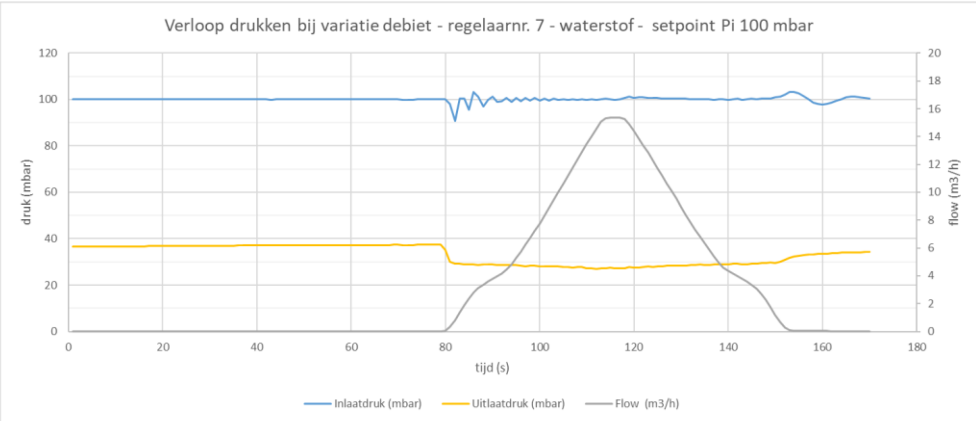

Regelkarakteristiek - regelaarnr. 6 - waterstof - setpoint Pi 100 mbar
Q Nominal flow m^3/h 15
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m^3/h)
Uitlaatdruk (mbar)

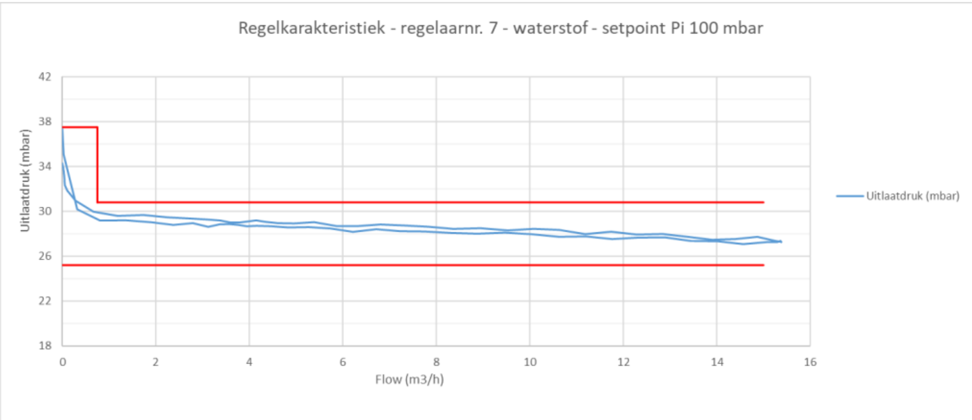

Verloop drukken bij variatie debiet - regelaarnr. 6 - aardgas - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

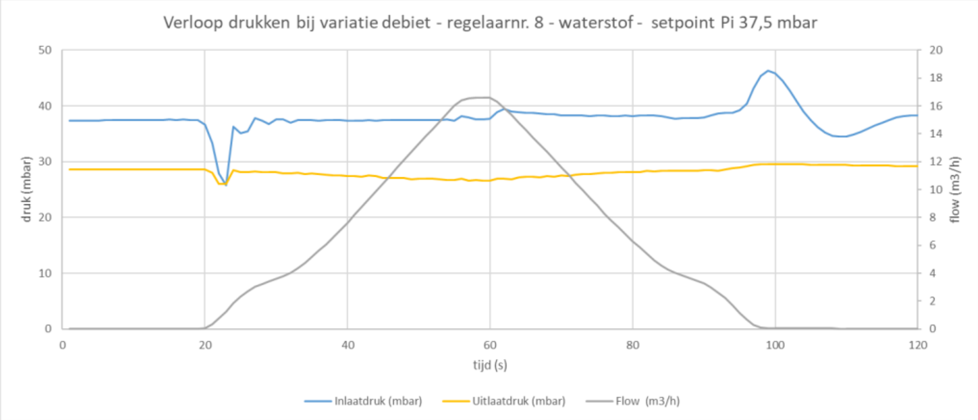

Regelkarakteristiek - regelaarnr. 6 - aardgas - setpoint Pi 100 mbar
Q Nominal flow m^3/h 5
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

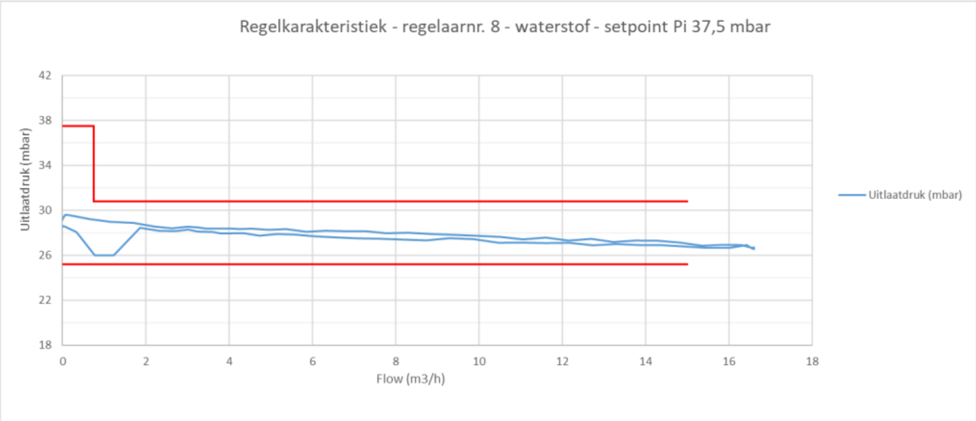

Verloop drukken bij variatie debiet - regelaarnr. 7 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

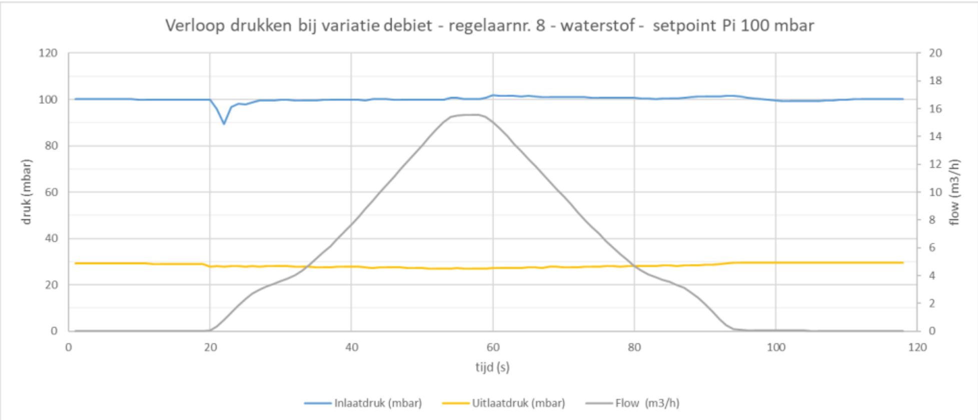

Regelkarakteristiek - regelaarnr. 7 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

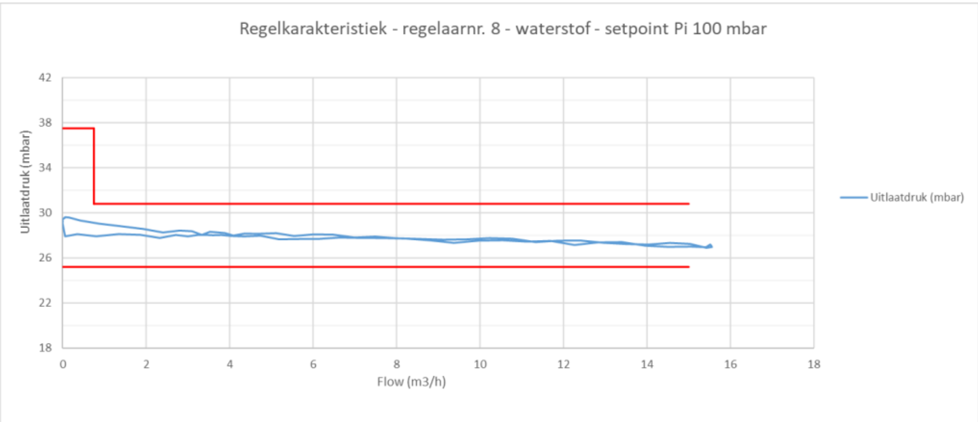

Verloop drukken bij variatie debiet - regelaarnr. 7 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

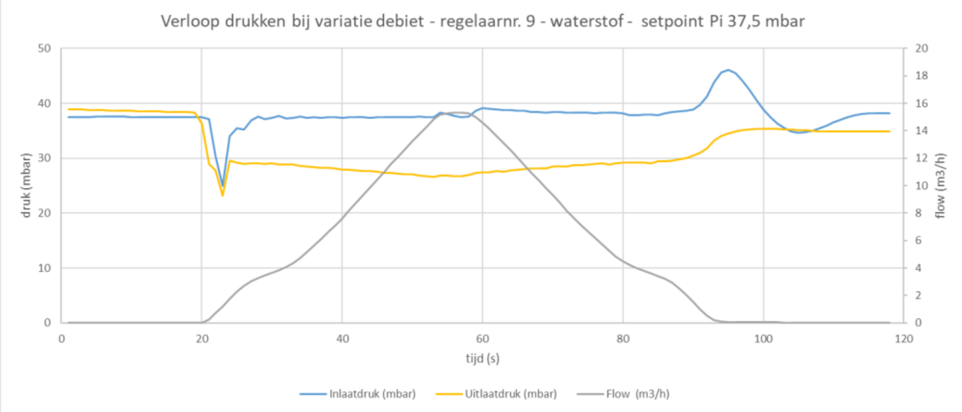

Regelkarakteristiek - regelaarnr. 7 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

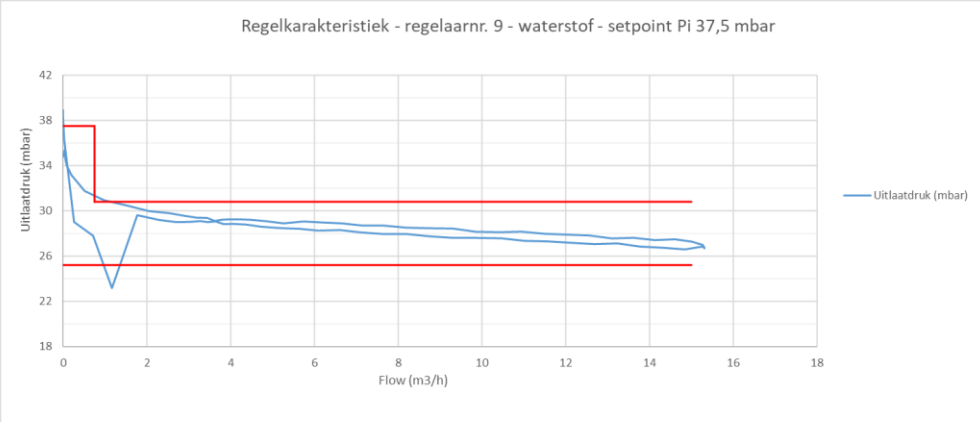

Verloop drukken bij variatie debiet - regelaarnr. 8 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

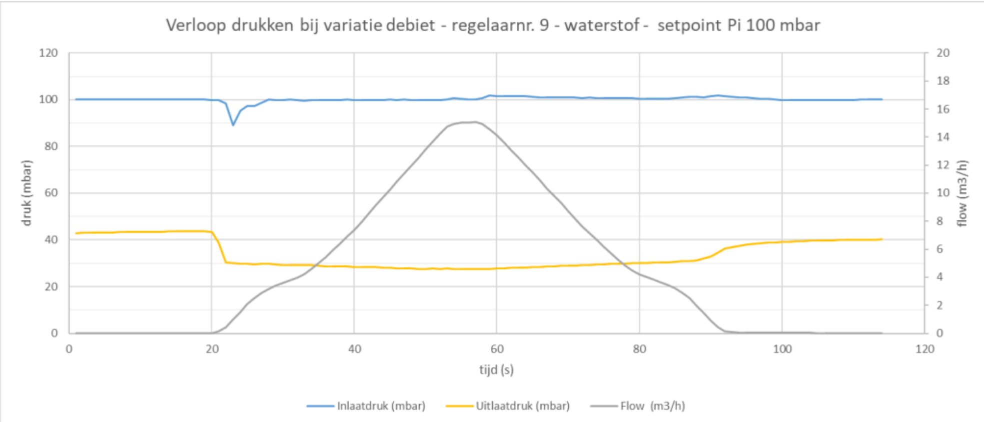

Regelkarakteristiek - regelaarnr. 8 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

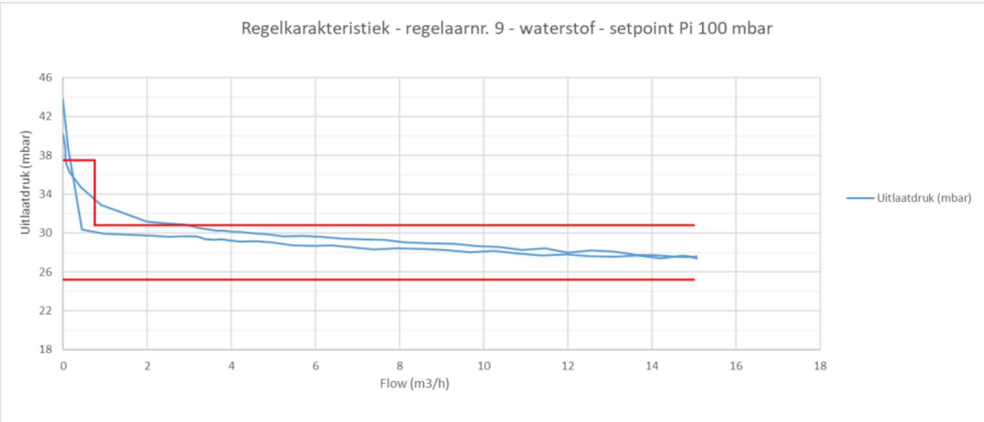

Verloop drukken bij variatie debiet - regelaarnr. 8 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

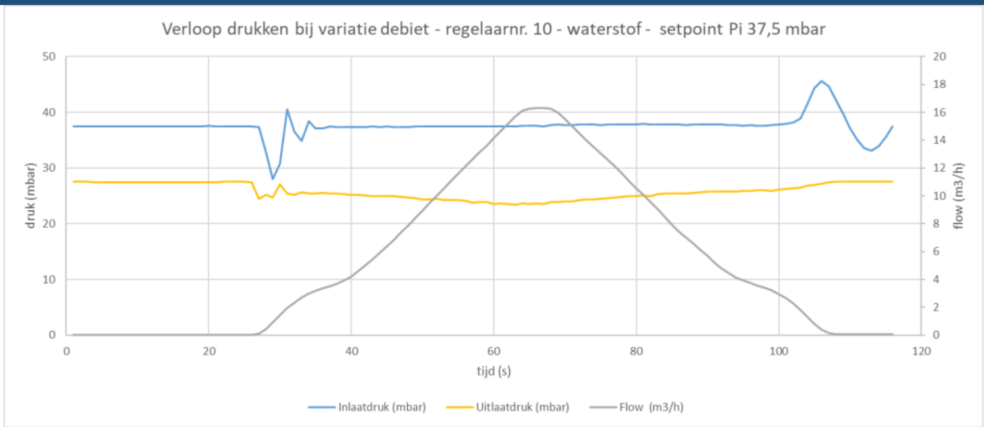

Regelkarakteristiek - regelaarnr. 8 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

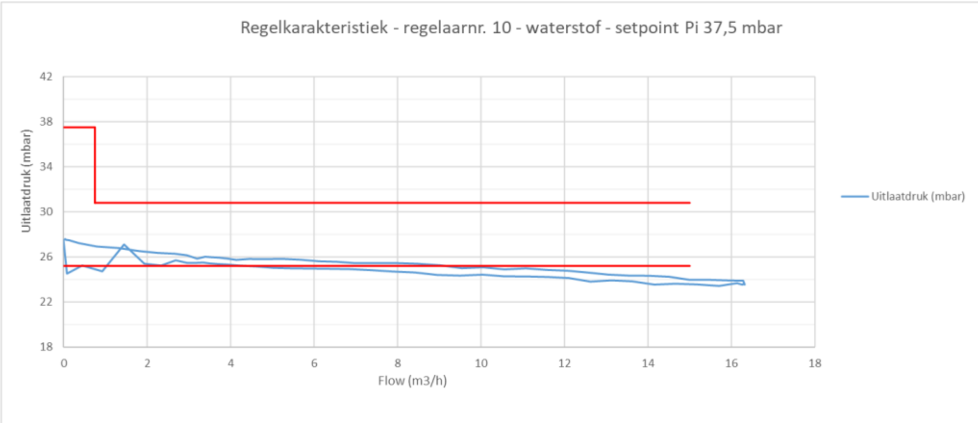

Verloop drukken bij variatie debiet - regelaarnr. 9 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

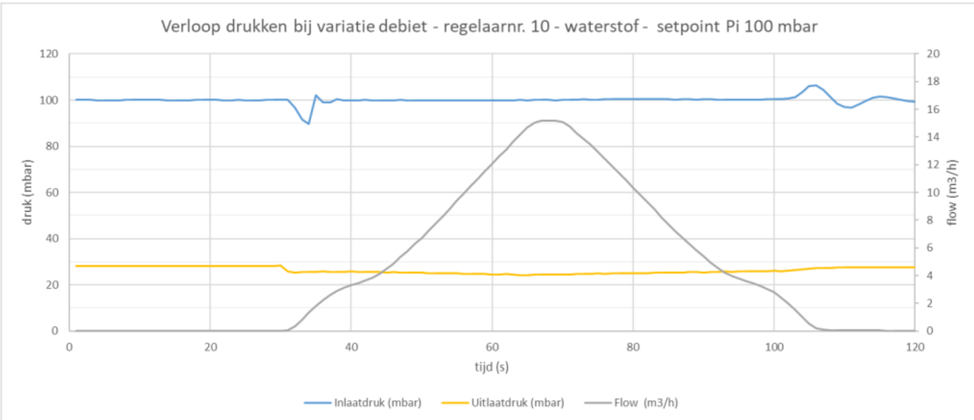

Regelkarakteristiek - regelaarnr. 9 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

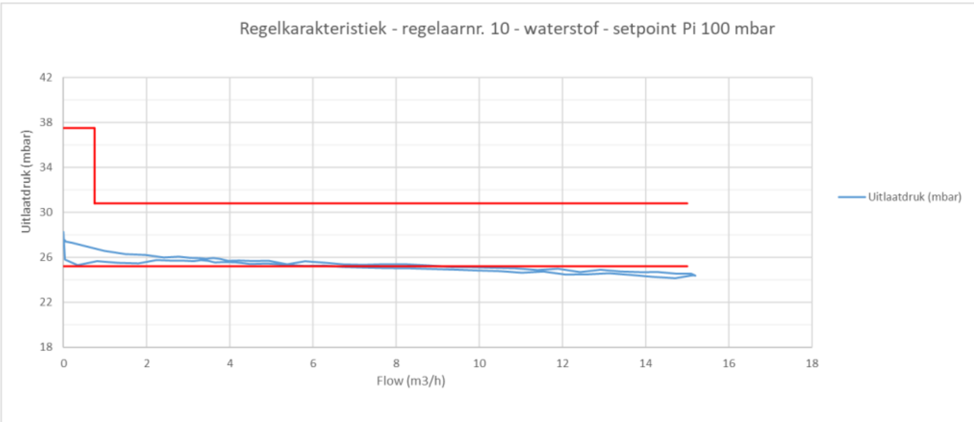

Verloop drukken bij variatie debiet - regelaarnr. 9 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

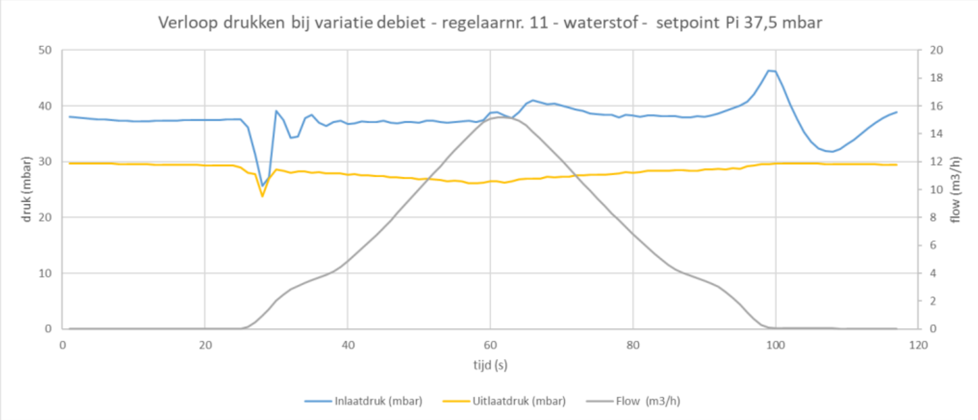

Regelkarakteristiek - regelaarnr. 9 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

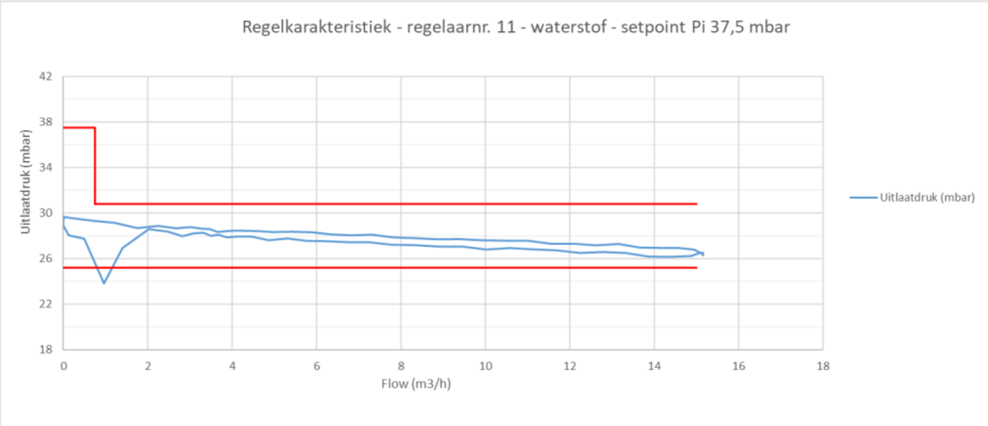

Verloop drukken bij variatie debiet - regelaarnr. 10 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

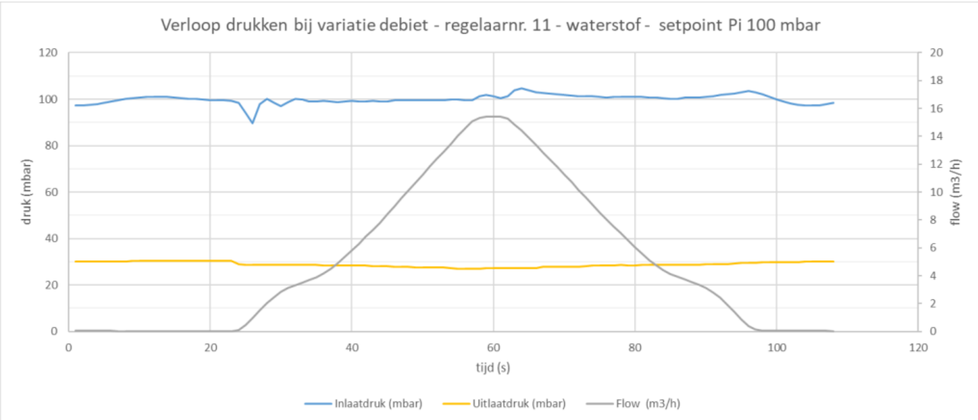

Regelkarakteristiek - regelaarnr. 10 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

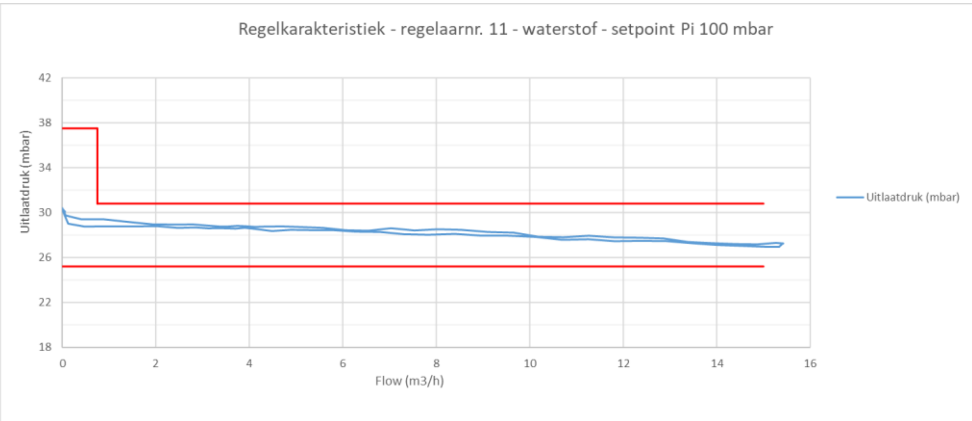

Verloop drukken bij variatie debiet - regelaarnr. 10 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

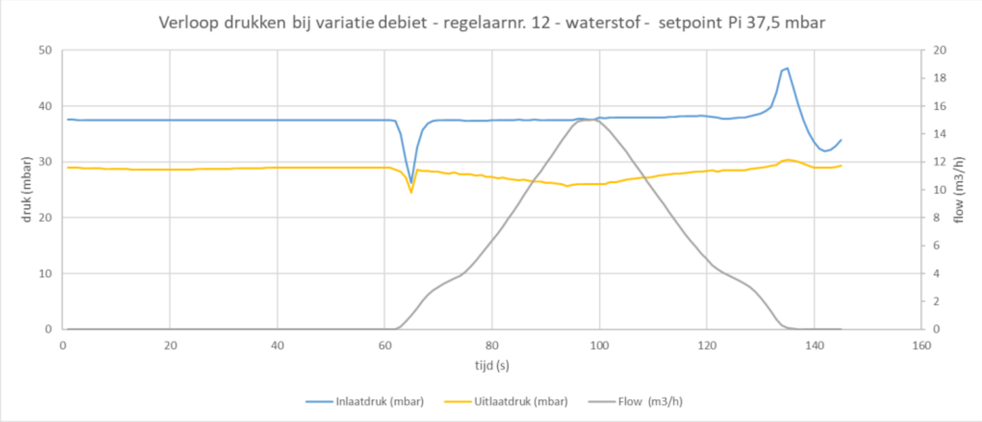

Regelkarakteristiek - regelaarnr. 10 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

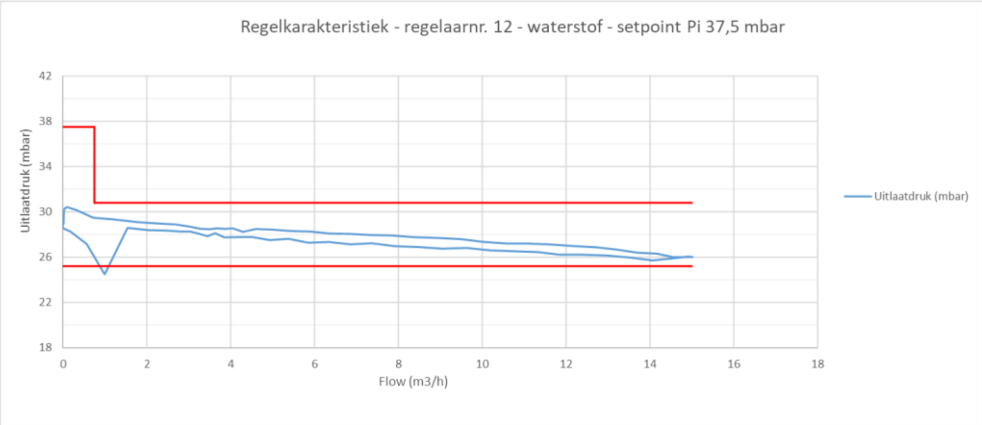

Verloop drukken bij variatie debiet - regelaarnr. 11 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

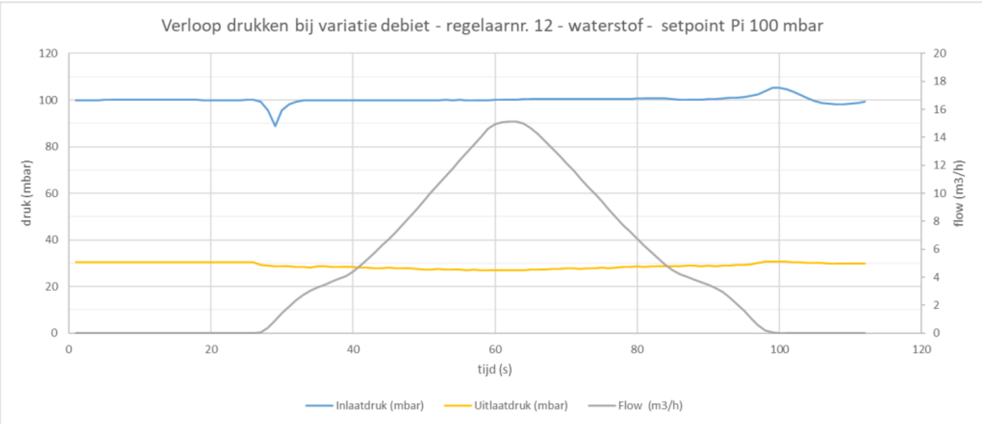

Regelkarakteristiek - regelaarnr. 11 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

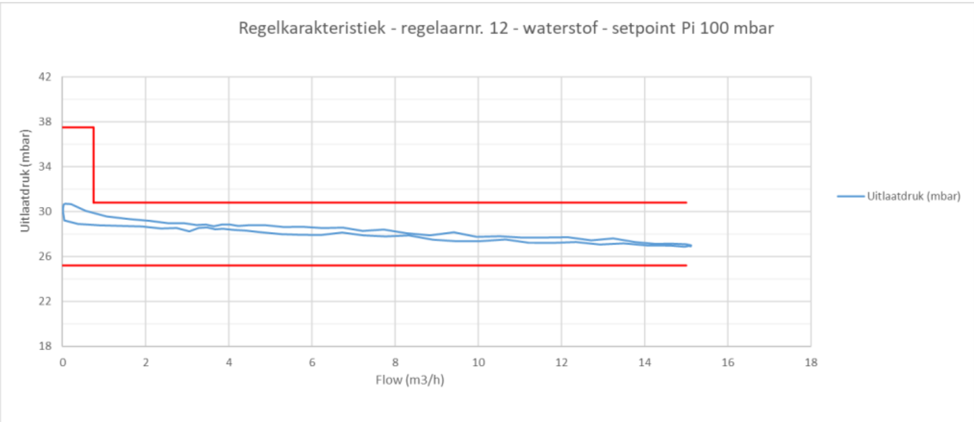

Verloop drukken bij variatie debiet - regelaarnr. 11 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

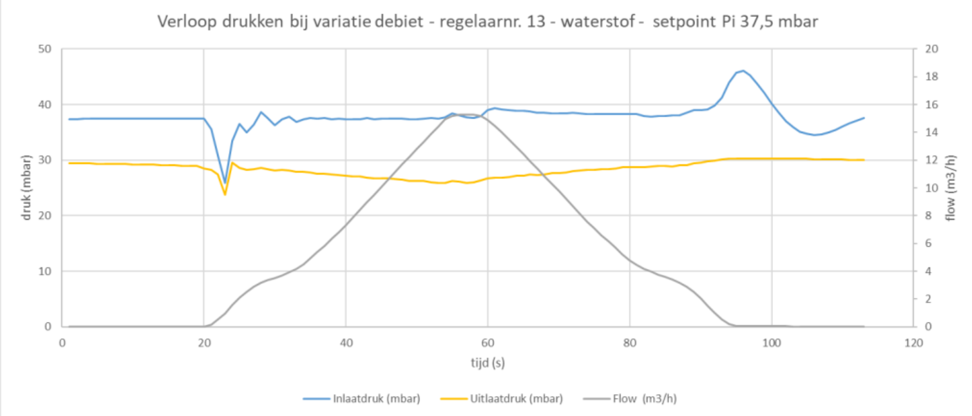

Regelkarakteristiek - regelaarnr. 11 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

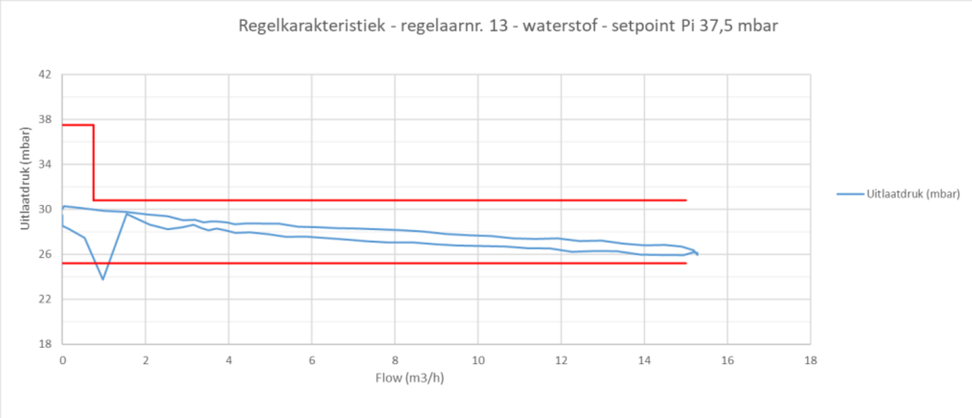

Verloop drukken bij variatie debiet - regelaarnr. 12 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

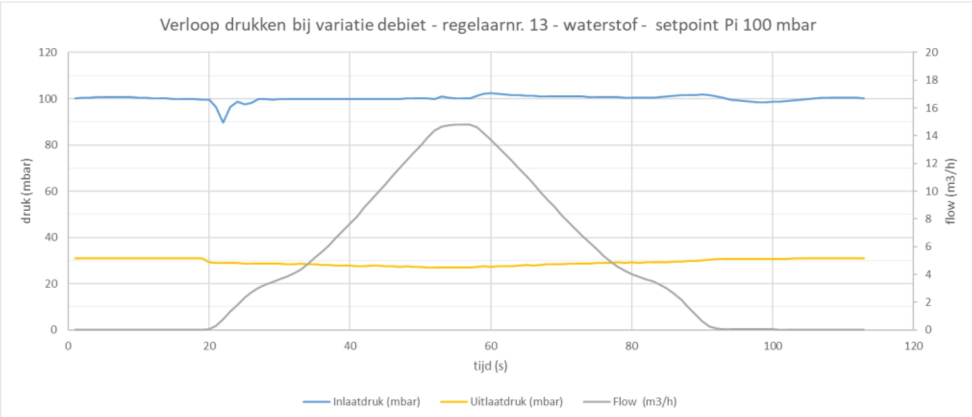

Regelkarakteristiek - regelaarnr. 12 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

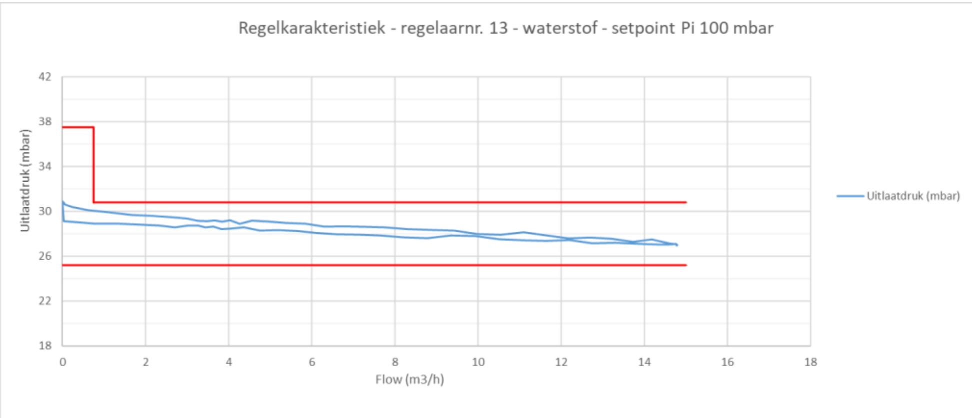

Verloop drukken bij variatie debiet - regelaarnr. 12 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

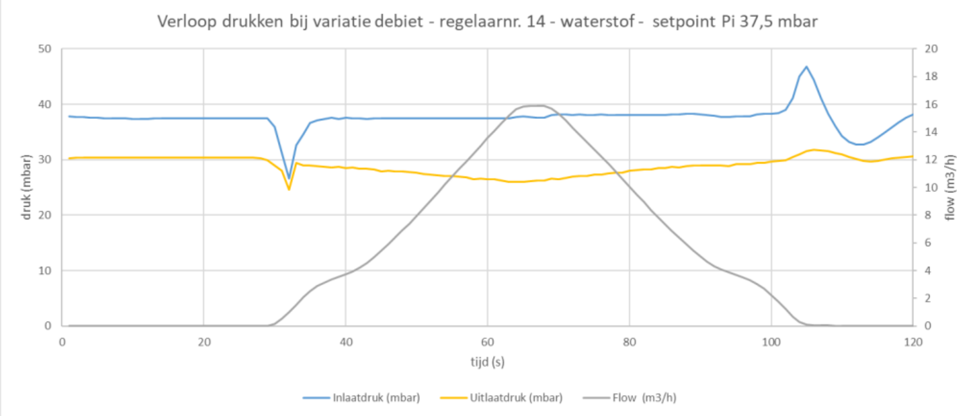

Regelkarakteristiek - regelaarnr. 12 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

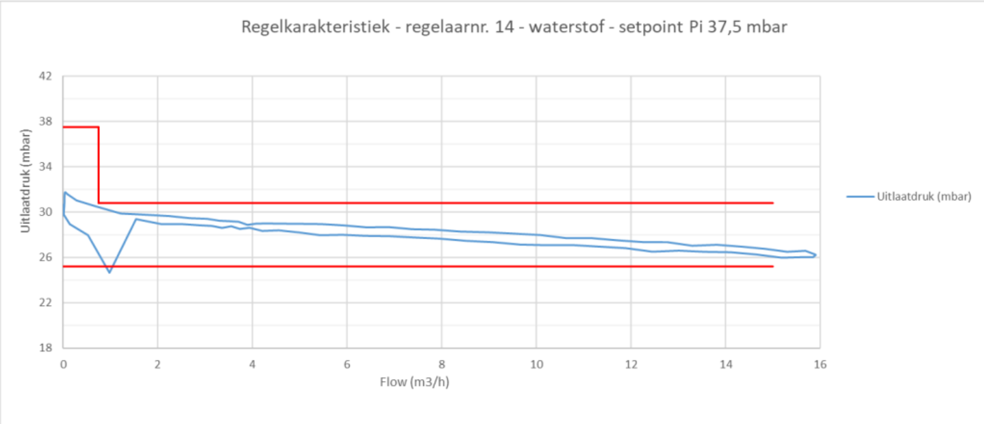

Verloop drukken bij variatie debiet - regelaarnr. 13 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

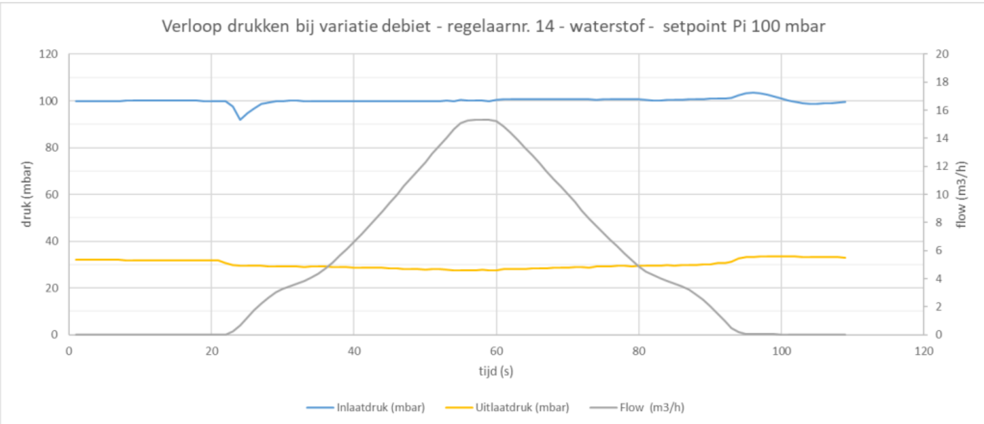

Regelkarakteristiek - regelaarnr. 13 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

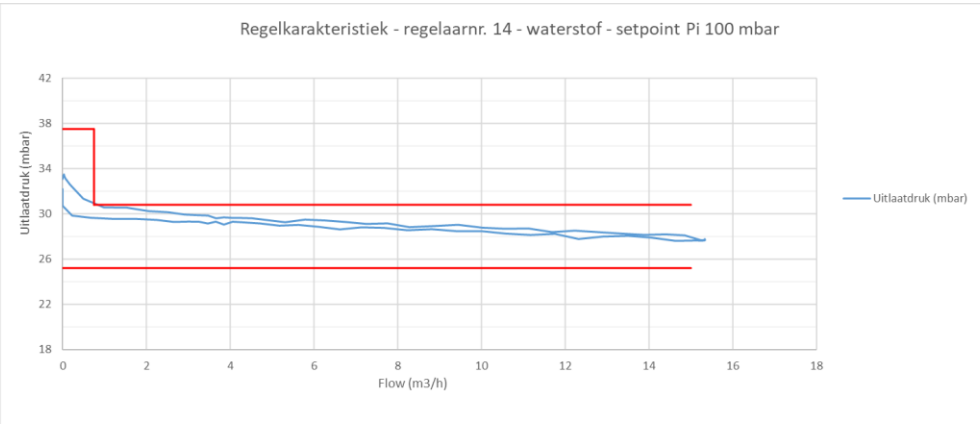

Verloop drukken bij variatie debiet - regelaarnr. 13 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

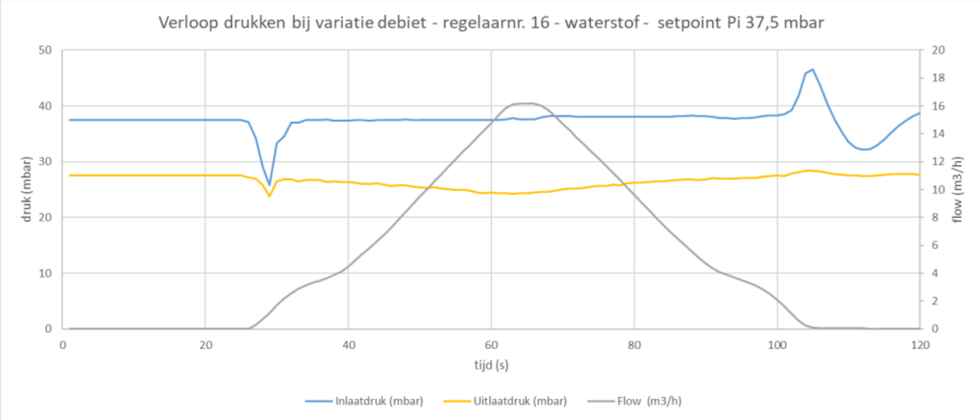

Regelkarakteristiek - regelaarnr. 13 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

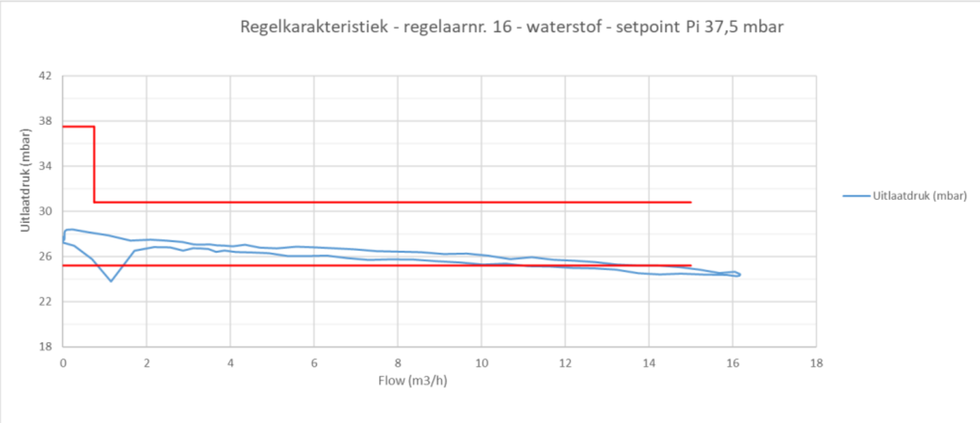

Verloop drukken bij variatie debiet - regelaarnr. 14 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

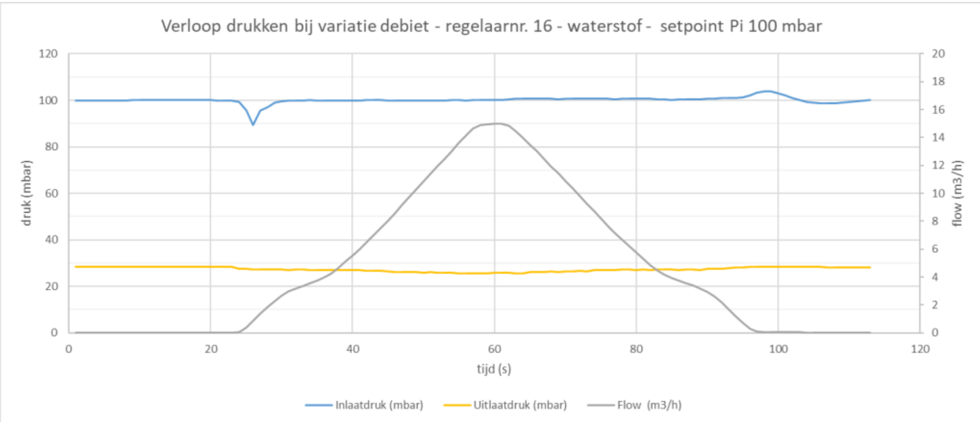

Regelkarakteristiek - regelaarnr. 14 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

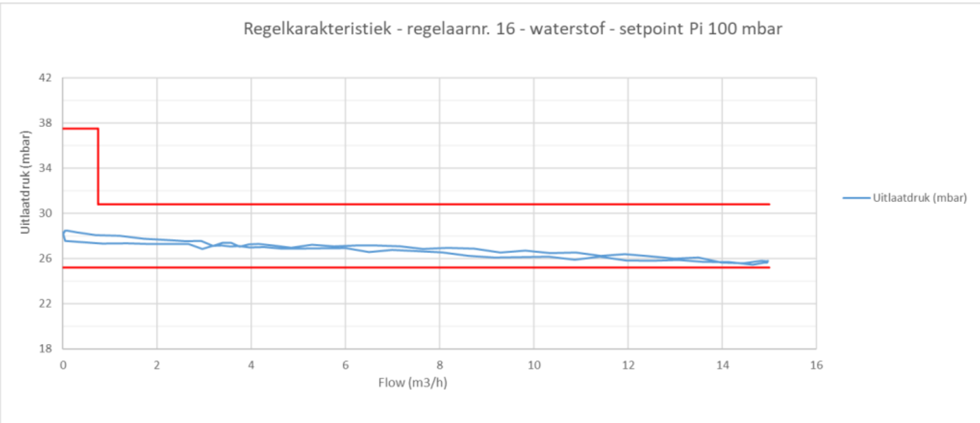

Verloop drukken bij variatie debiet - regelaarnr. 14 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

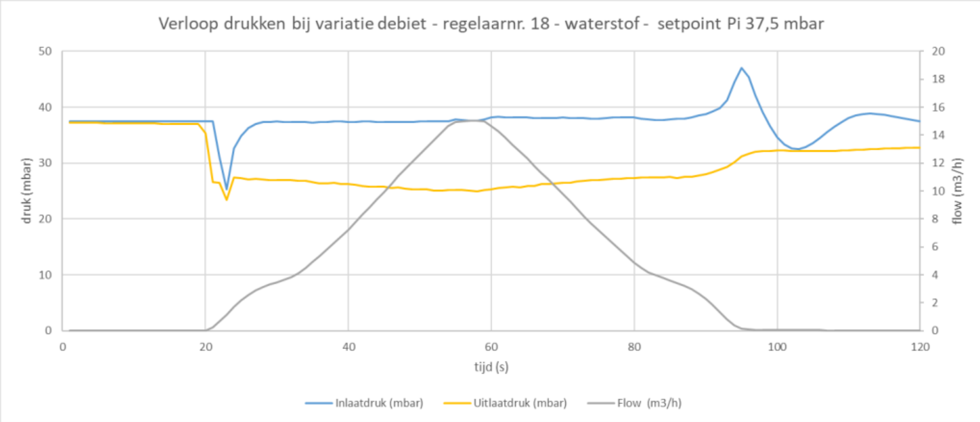

Regelkarakteristiek - regelaarnr. 14 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

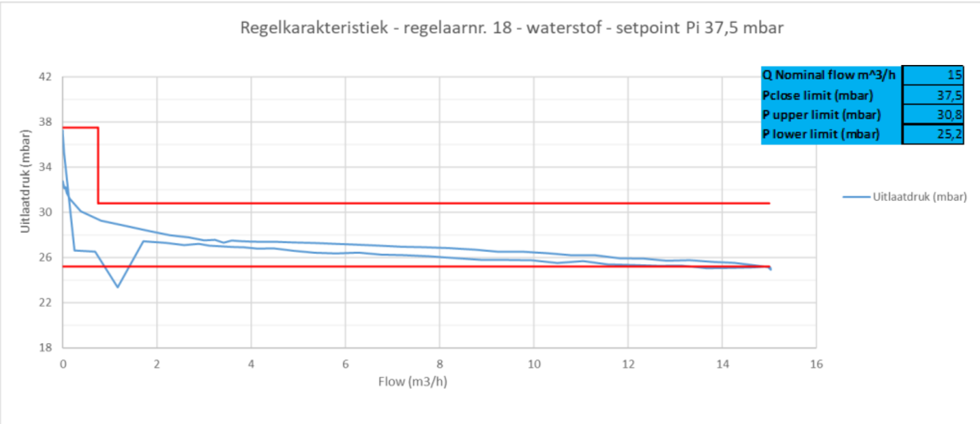

Verloop drukken bij variatie debiet - regelaarnr. 16 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

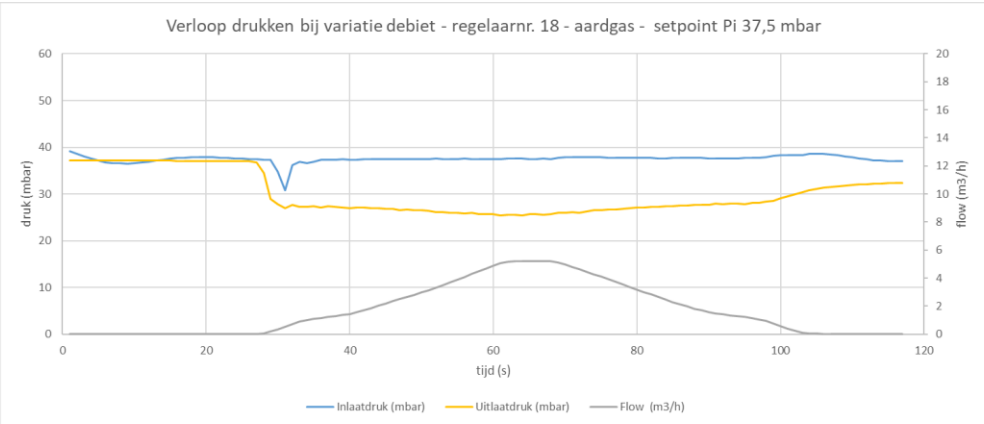

Regelkarakteristiek - regelaarnr. 16 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

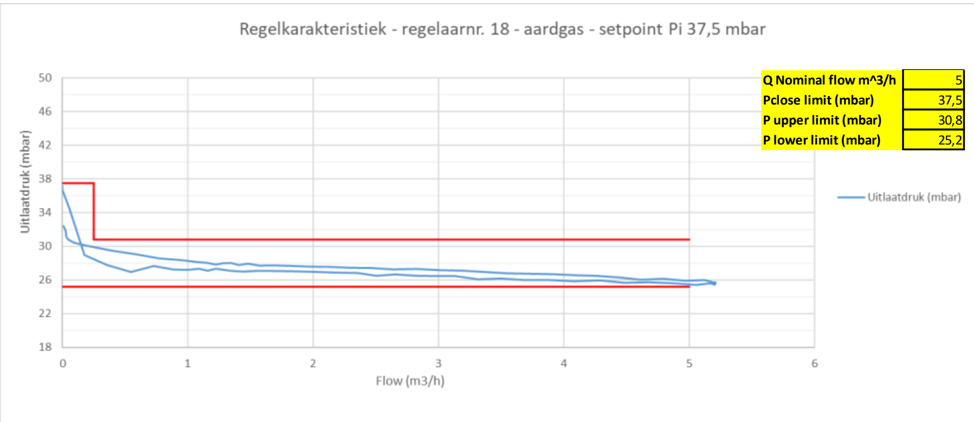

Verloop drukken bij variatie debiet - regelaarnr. 16 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

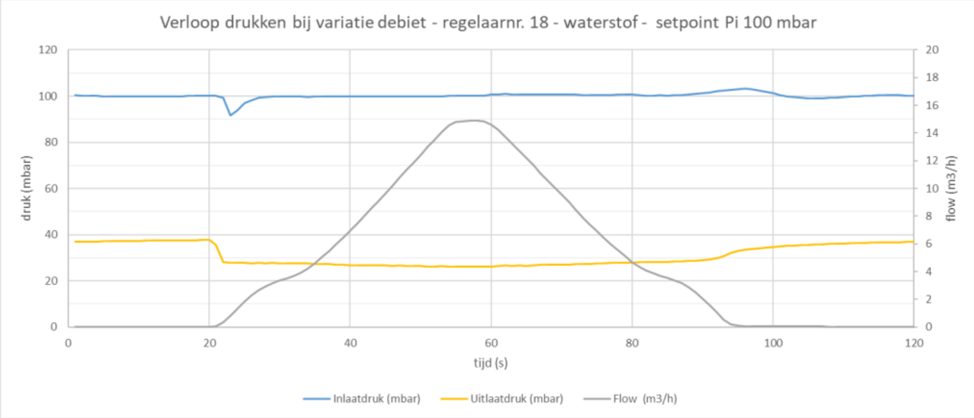

Regelkarakteristiek - regelaarnr. 16 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

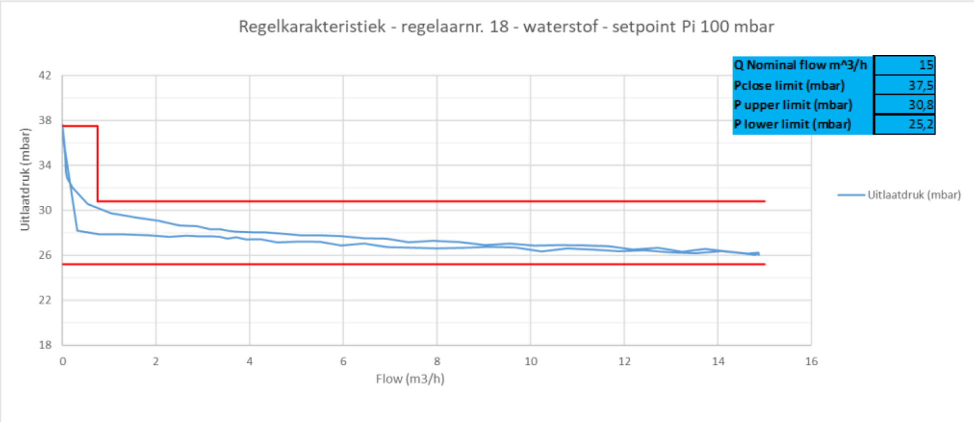

Verloop drukken bij variatie debiet - regelaarnr. 18 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

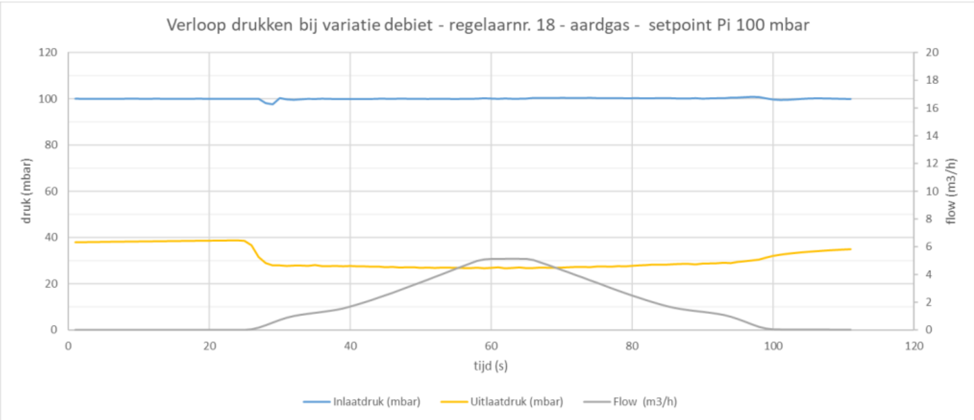

Regelkarakteristiek - regelaarnr. 18 - waterstof - setpoint Pi 37,5 mbar
Q Nominal flow m^3/h 15
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

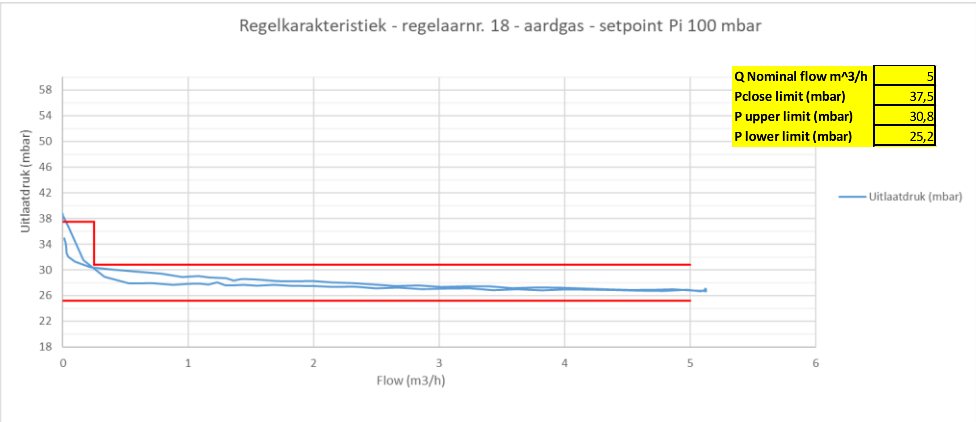

Verloop drukken bij variatie debiet - regelaarnr. 18 - aardgas - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

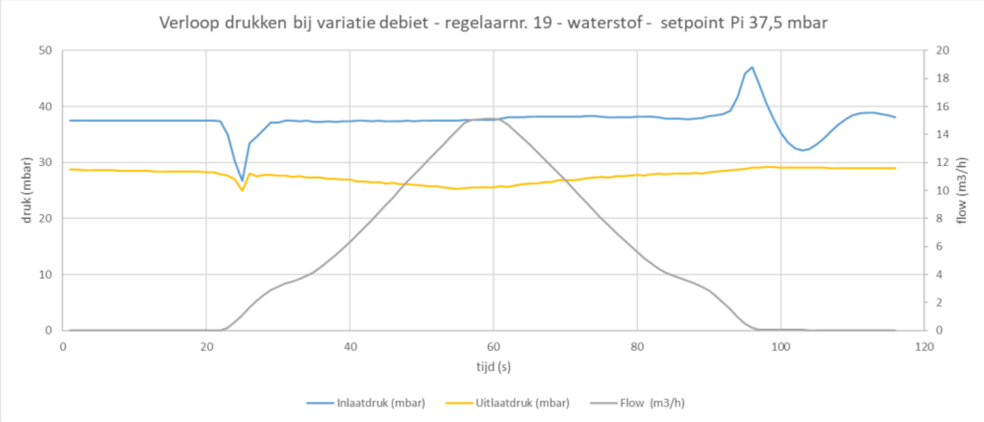

Regelkarakteristiek - regelaarnr. 18 - aardgas - setpoint Pi 37,5 mbar
Q Nominal flow m^3/h 5
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

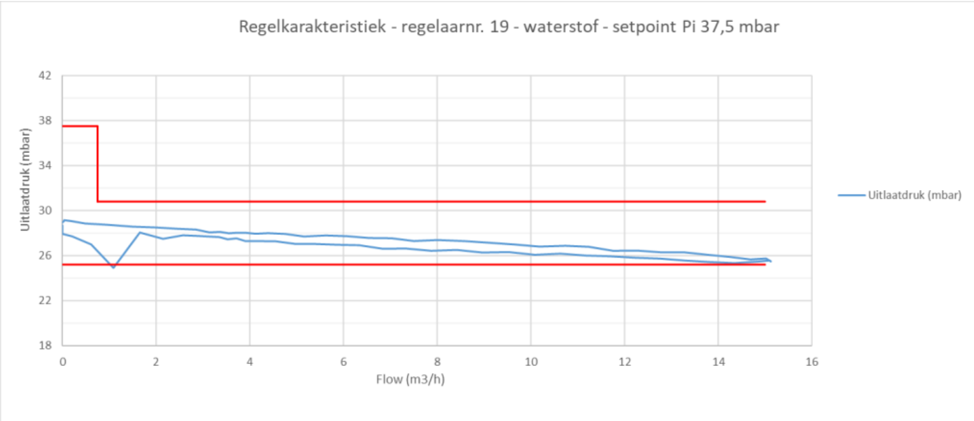

Verloop drukken bij variatie debiet - regelaarnr. 18 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

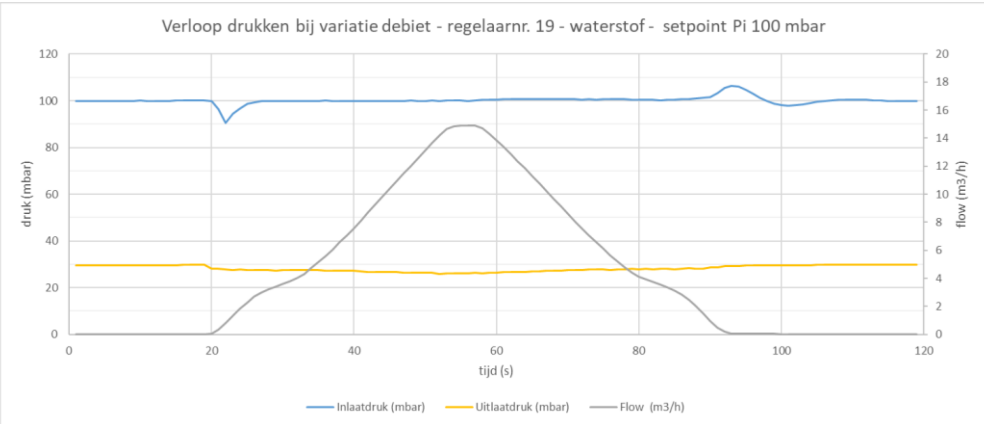

Regelkarakteristiek - regelaarnr. 18 - waterstof - setpoint Pi 100 mbar
Q Nominal flow m^3/h 15
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

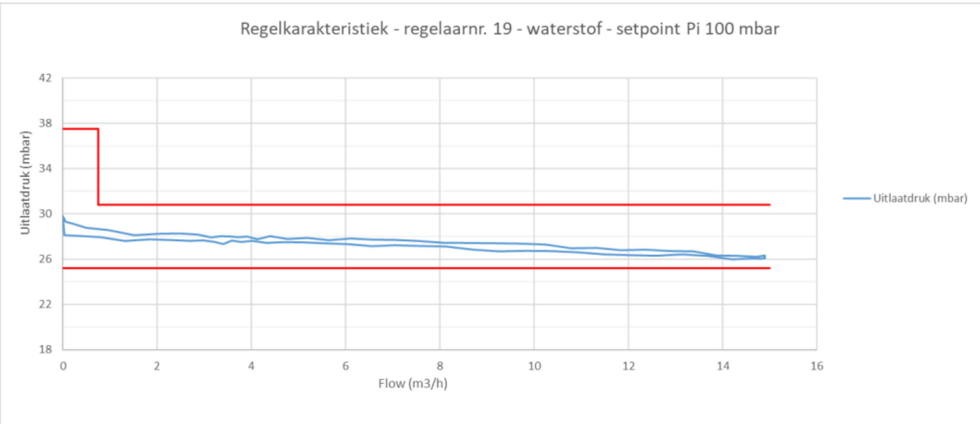

Verloop drukken bij variatie debiet - regelaarnr. 18 - aardgas - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

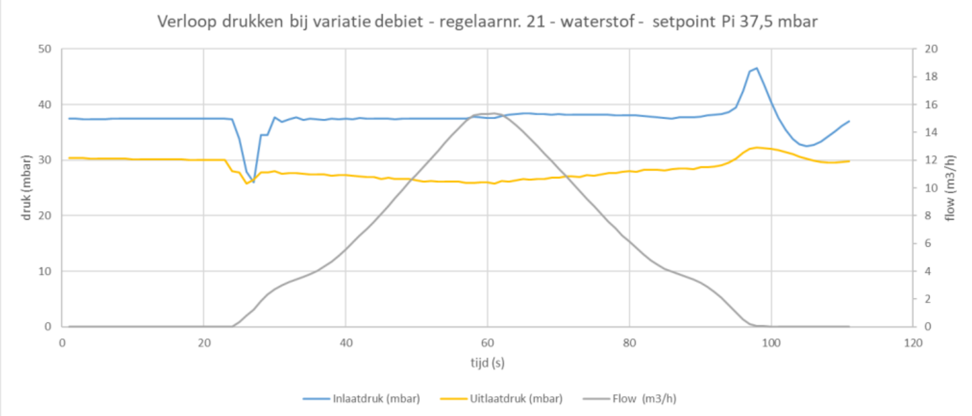

Regelkarakteristiek - regelaarnr. 18 - aardgas - setpoint Pi 100 mbar
Q Nominal flow m^3/h 5
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

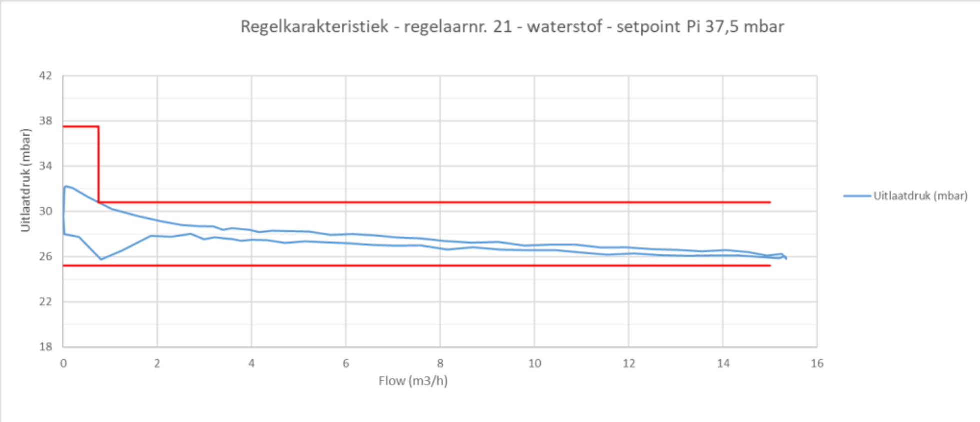

Verloop drukken bij variatie debiet - regelaarnr. 19 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

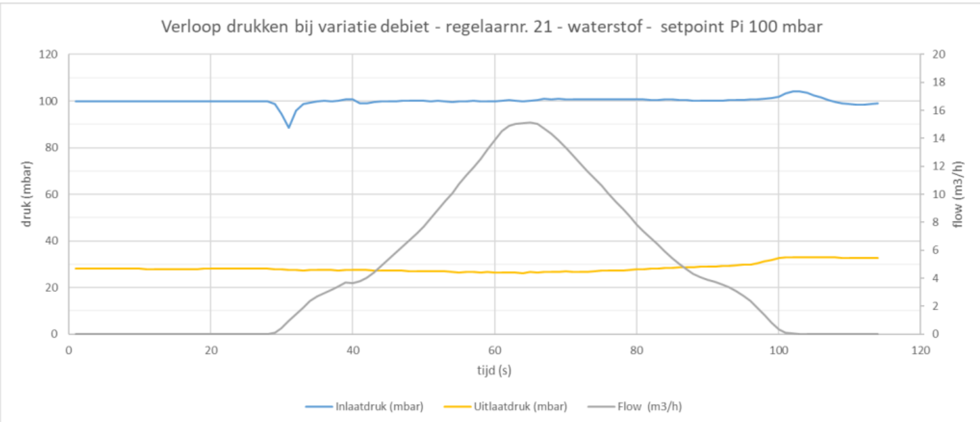

Regelkarakteristiek - regelaarnr. 19 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

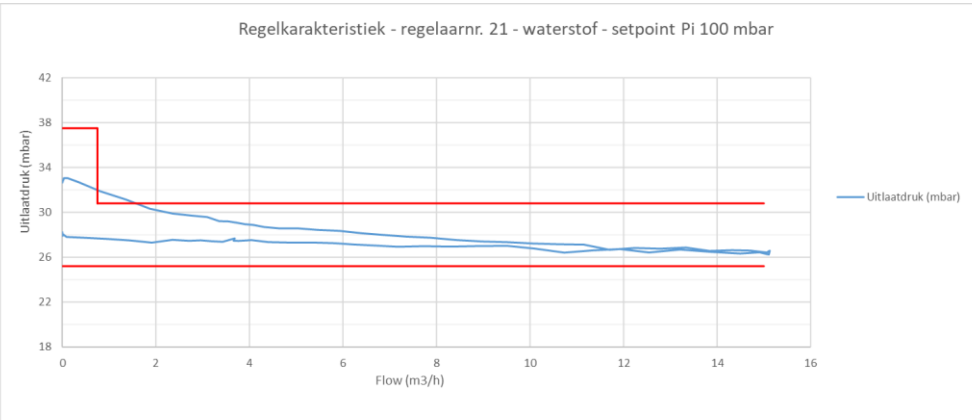

Verloop drukken bij variatie debiet - regelaarnr. 19 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

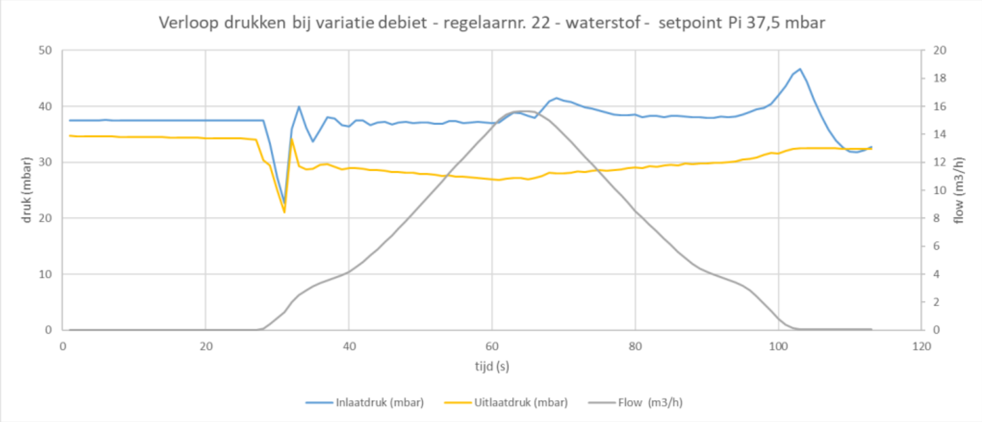

Regelkarakteristiek - regelaarnr. 19 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

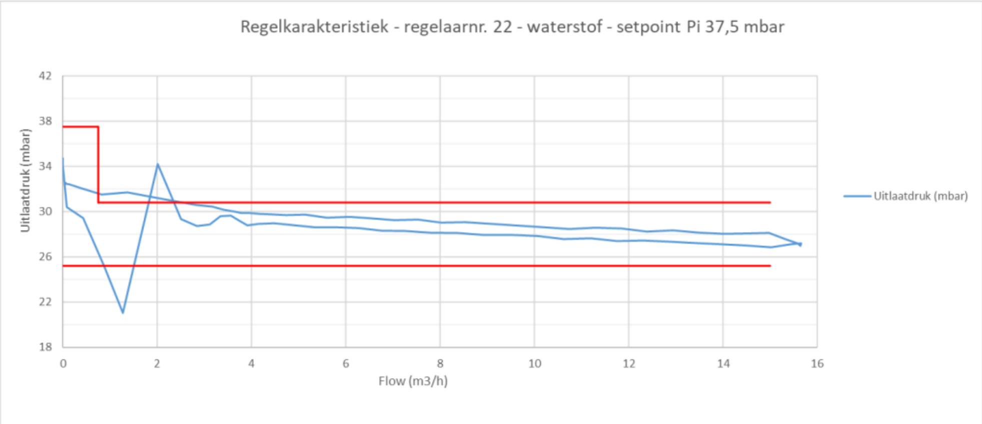

Verloop drukken bij variatie debiet - regelaarnr. 21 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

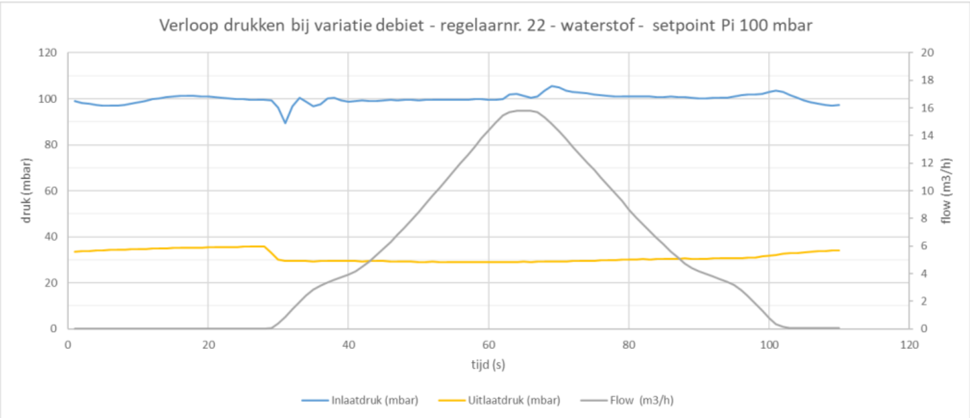

Regelkarakteristiek - regelaarnr. 21 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

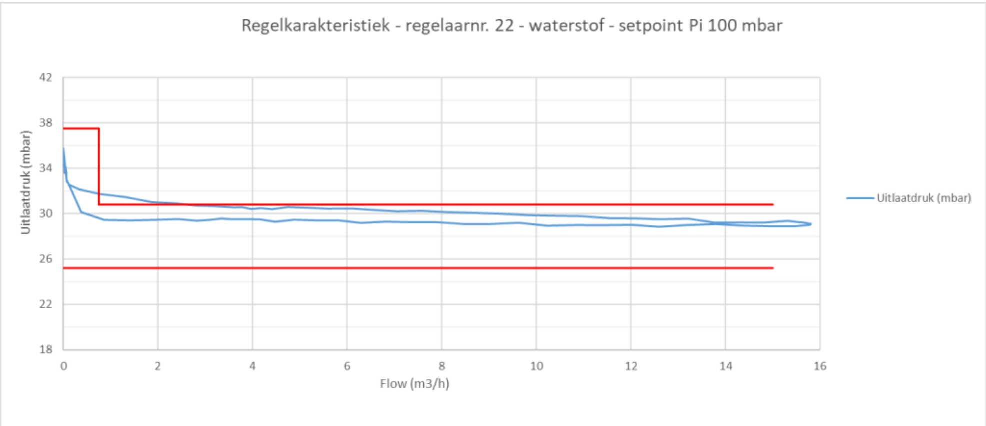

Verloop drukken bij variatie debiet - regelaarnr. 21 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

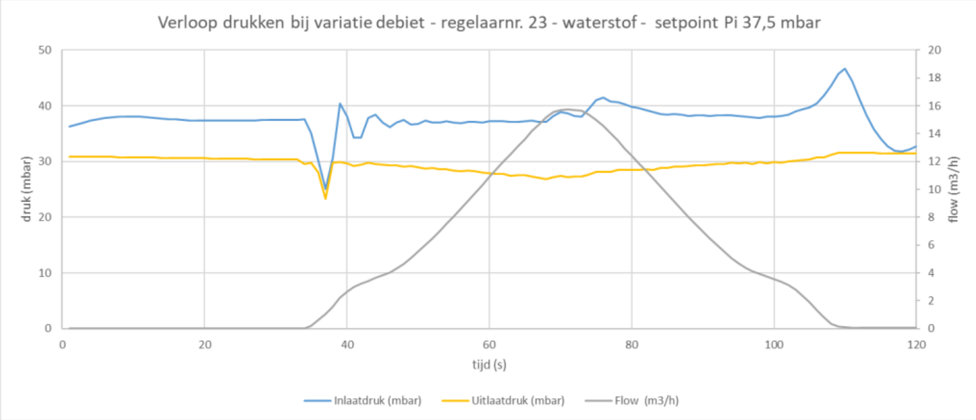

Regelkarakteristiek - regelaarnr. 21 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

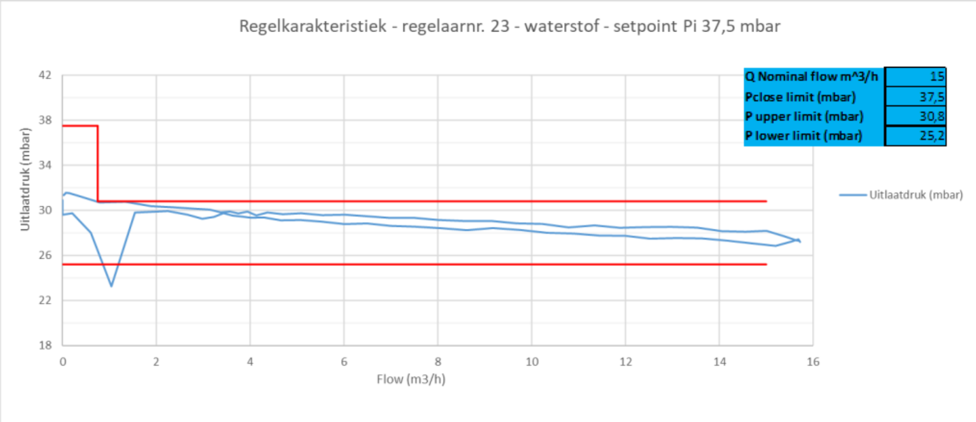

Verloop drukken bij variatie debiet - regelaarnr. 22 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

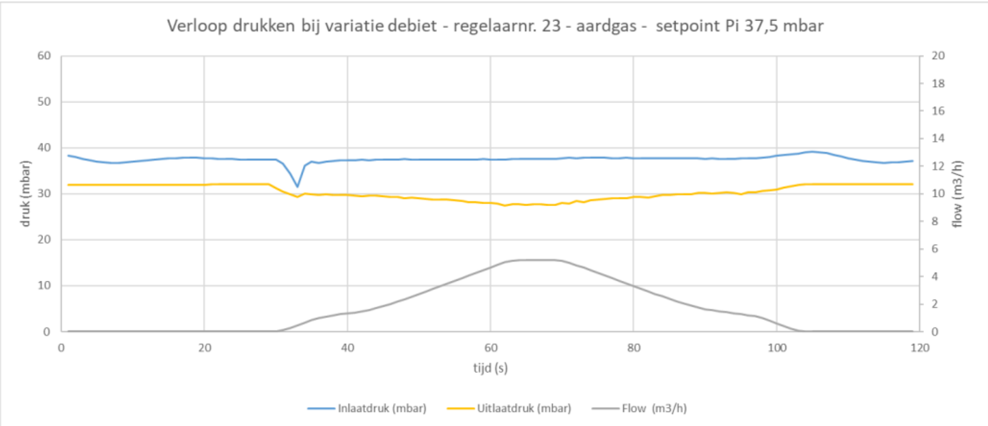

Regelkarakteristiek - regelaarnr. 22 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

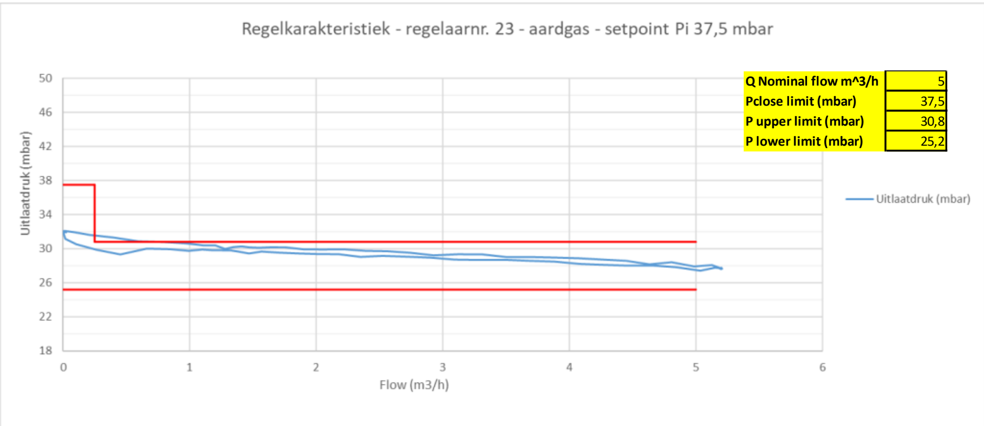

Verloop drukken bij variatie debiet - regelaarnr. 22 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

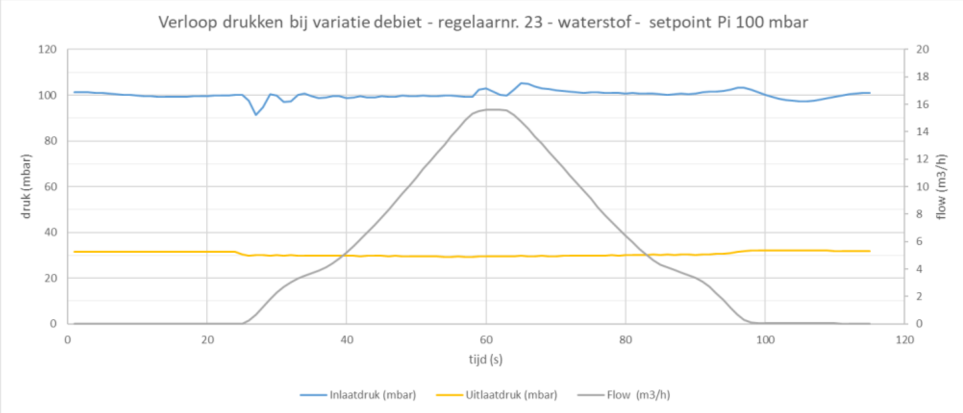

Regelkarakteristiek - regelaarnr. 22 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

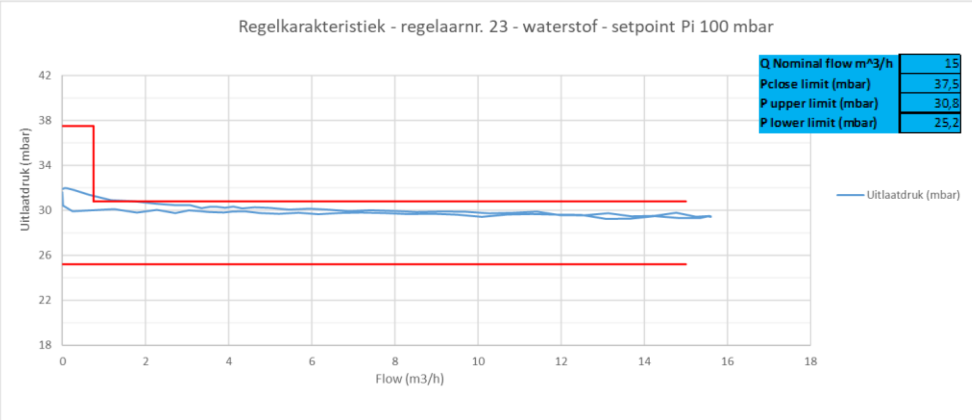

Verloop drukken bij variatie debiet - regelaarnr. 23 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

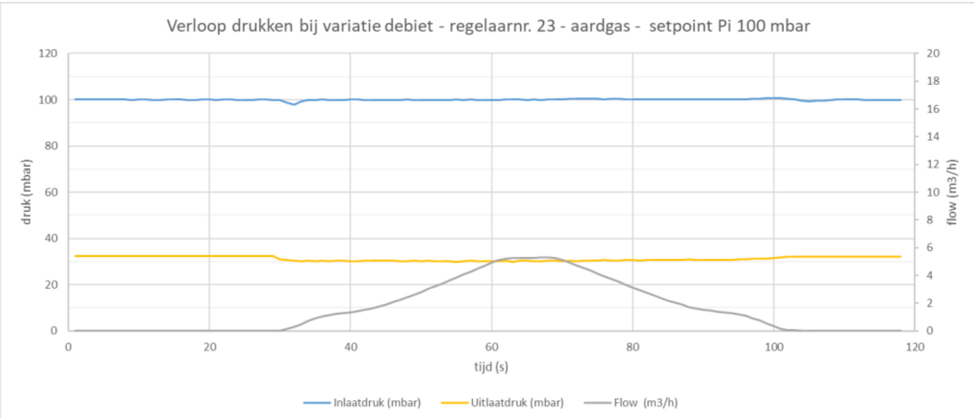

Regelkarakteristiek - regelaarnr. 23 - waterstof - setpoint Pi 37,5 mbar
Q Nominal flow m^3/h 15
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)

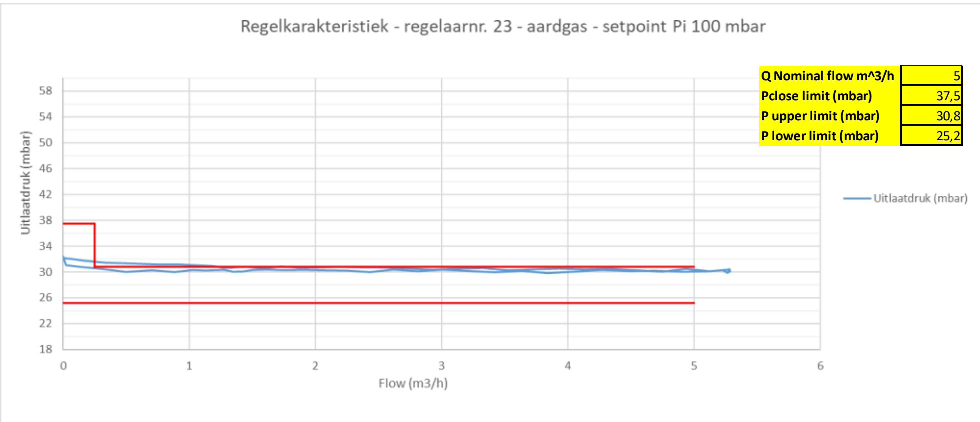

Verloop drukken bij variatie debiet - regelaarnr. 23 - aardgas - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

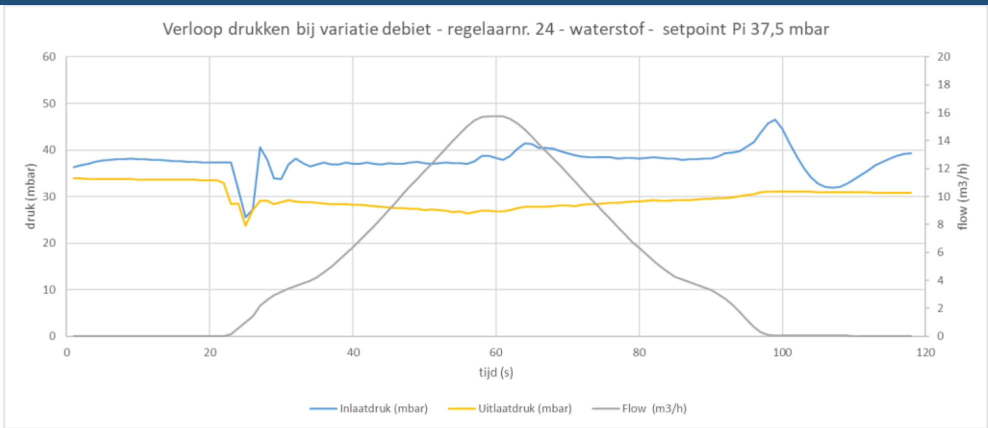

Regelkarakteristiek - regelaarnr. 23 - aardgas - setpoint Pi 37,5 mbar
Q Nominal flow m^3/h 5
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)

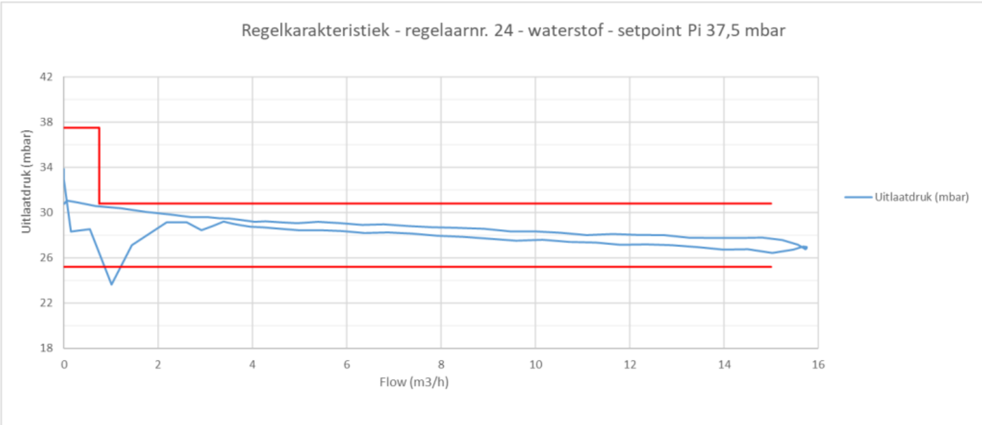

Verloop drukken bij variatie debiet - regelaarnr. 23 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

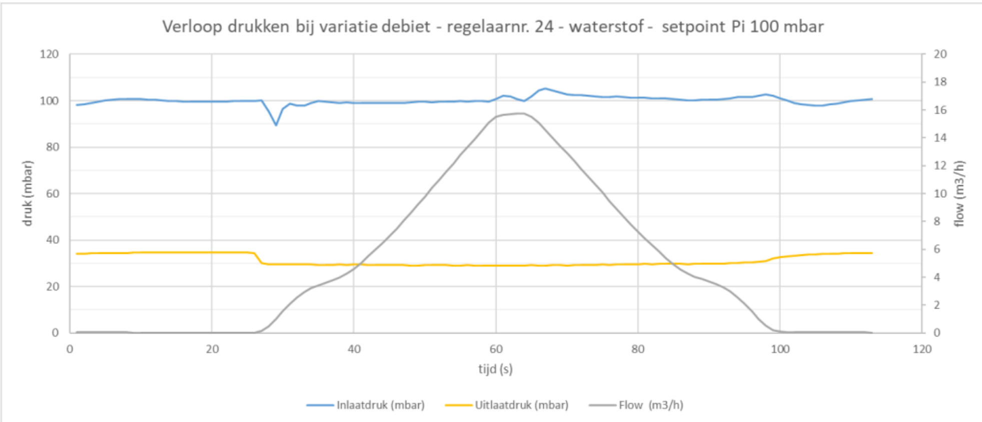

Regelkarakteristiek - regelaarnr. 23 - waterstof - setpoint Pi 100 mbar
Q Nominal flow m^3/h 15
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

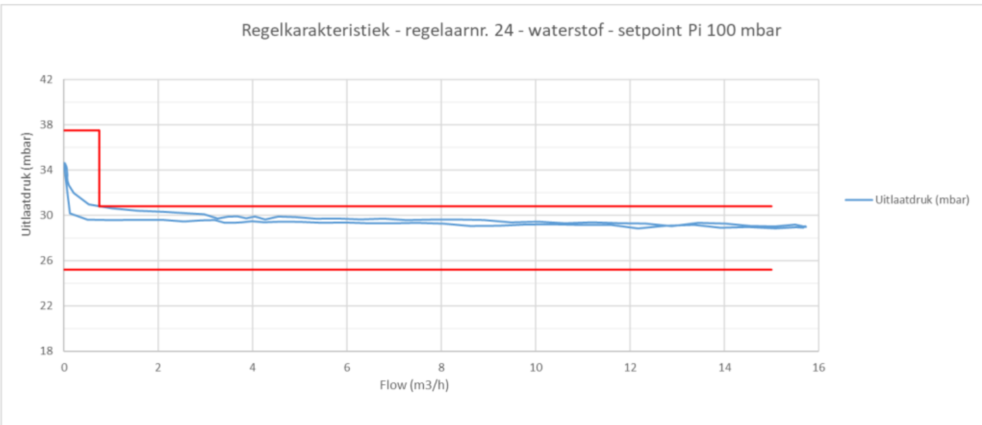

Verloop drukken bij variatie debiet - regelaarnr. 23 - aardgas - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

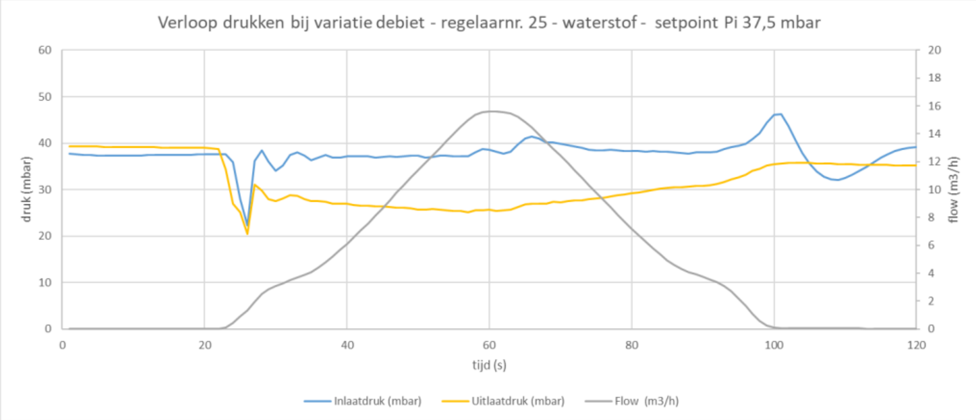

Regelkarakteristiek - regelaarnr. 23 - aardgas - setpoint Pi 100 mbar
Q Nominal flow m^3/h 5
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

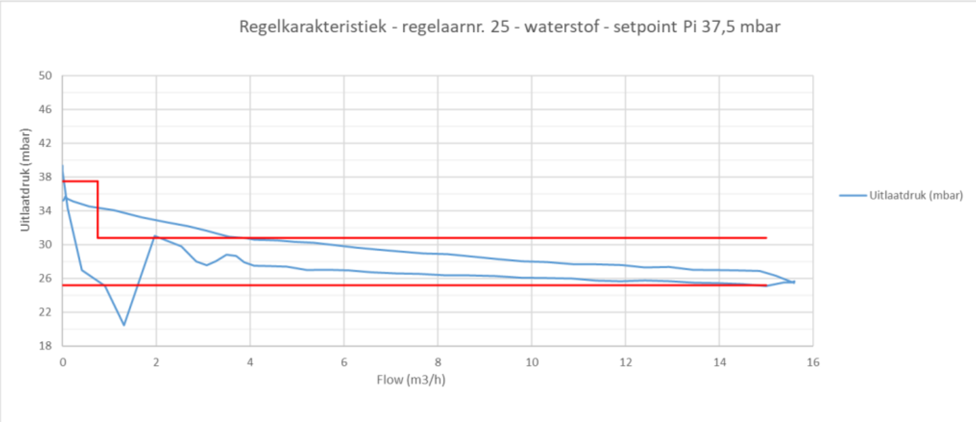

Verloop drukken bij variatie debiet - regelaarnr. 24 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

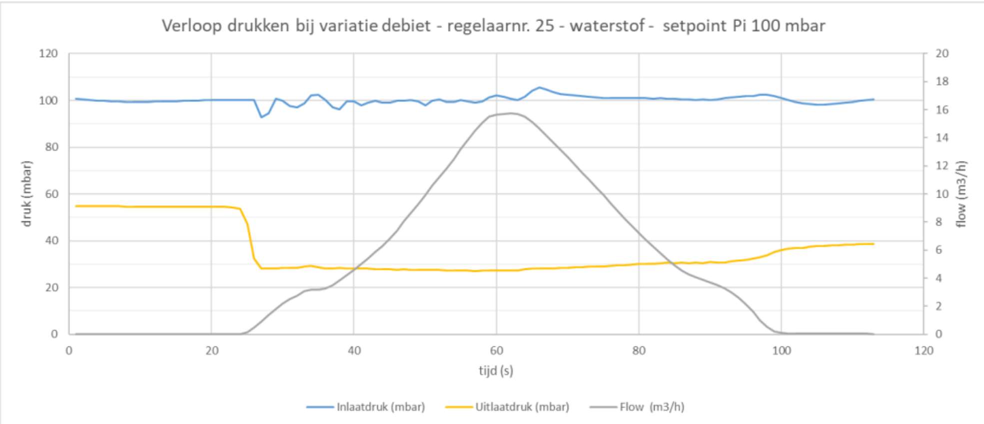

Regelkarakteristiek - regelaarnr. 24 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

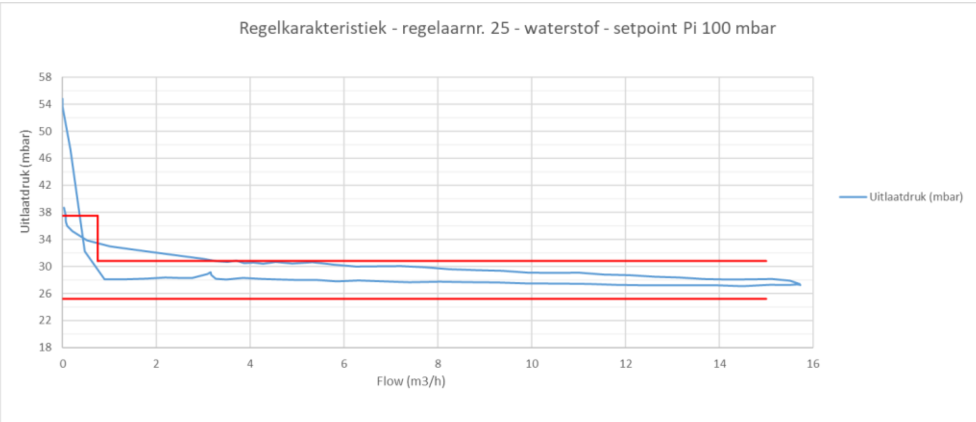

Verloop drukken bij variatie debiet - regelaarnr. 24 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

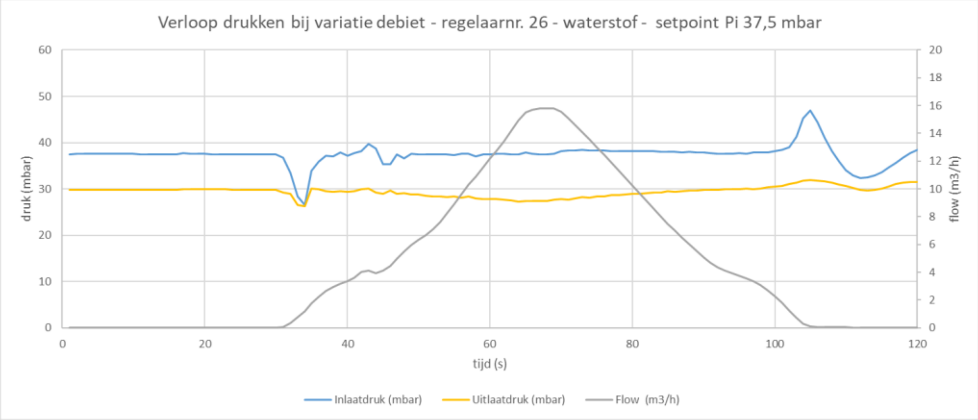

Regelkarakteristiek - regelaarnr. 24 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

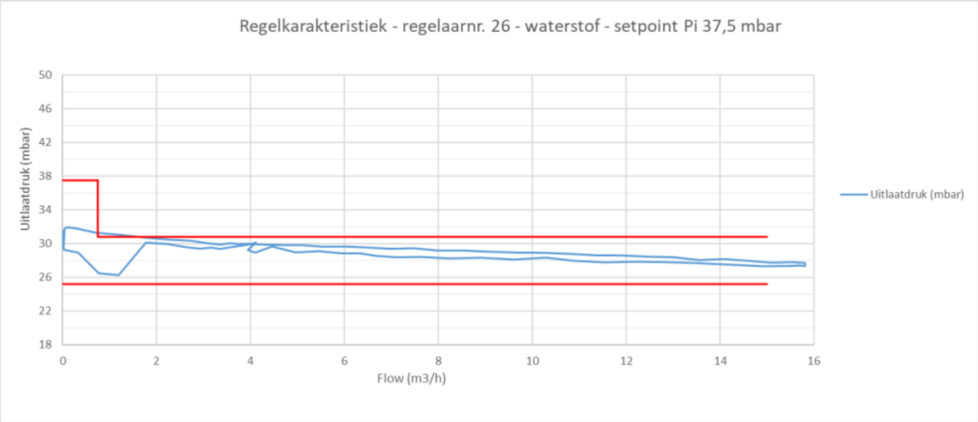

Verloop drukken bij variatie debiet - regelaarnr. 25 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

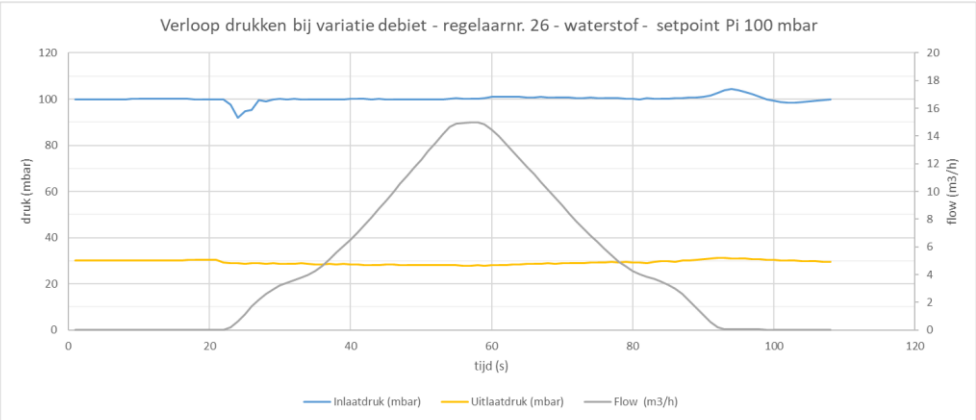

Regelkarakteristiek - regelaarnr. 25 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

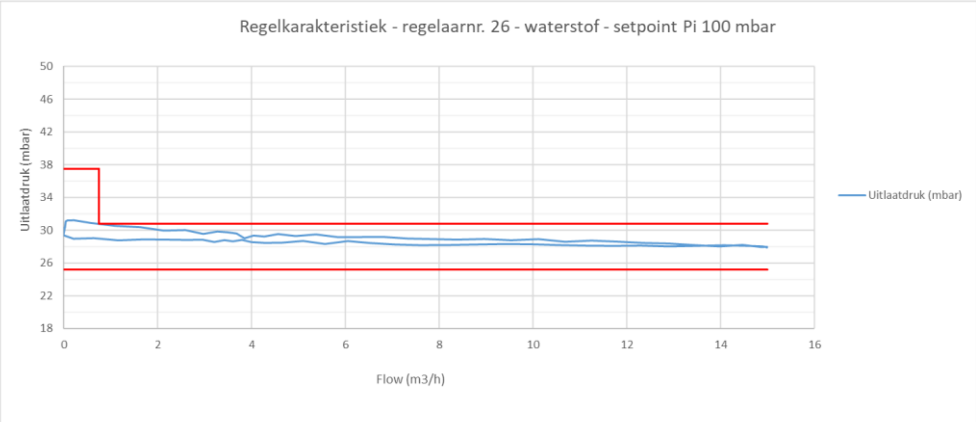

Verloop drukken bij variatie debiet - regelaarnr. 25 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

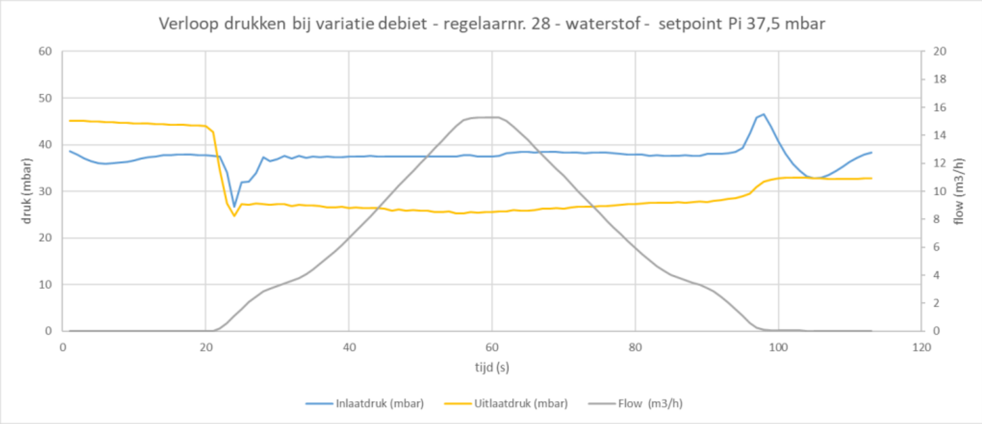

Regelkarakteristiek - regelaarnr. 25 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

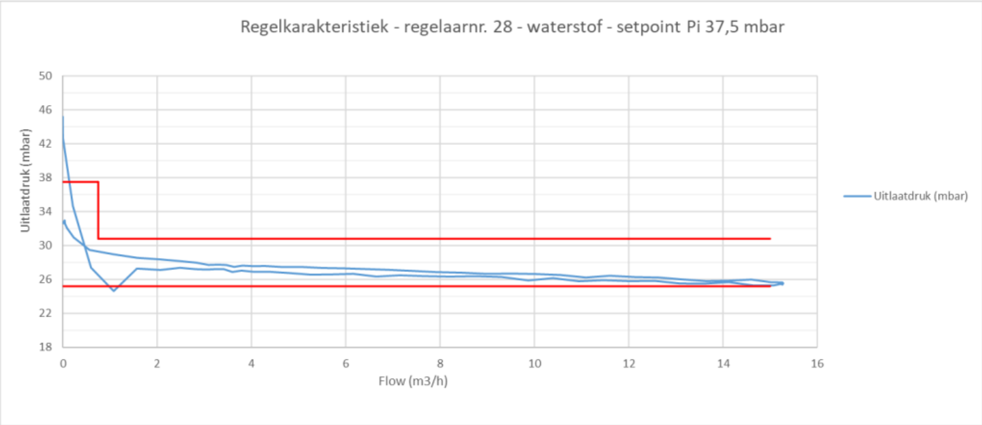

Verloop drukken bij variatie debiet - regelaarnr. 26 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

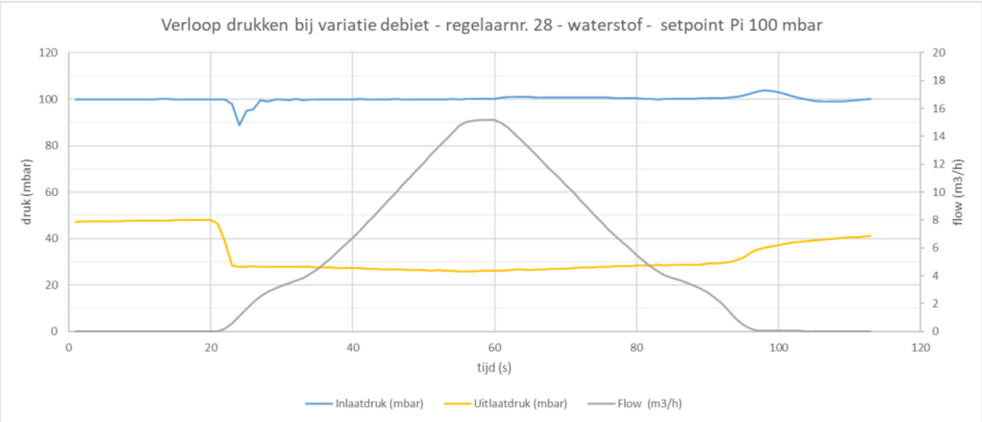

Regelkarakteristiek - regelaarnr. 26 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

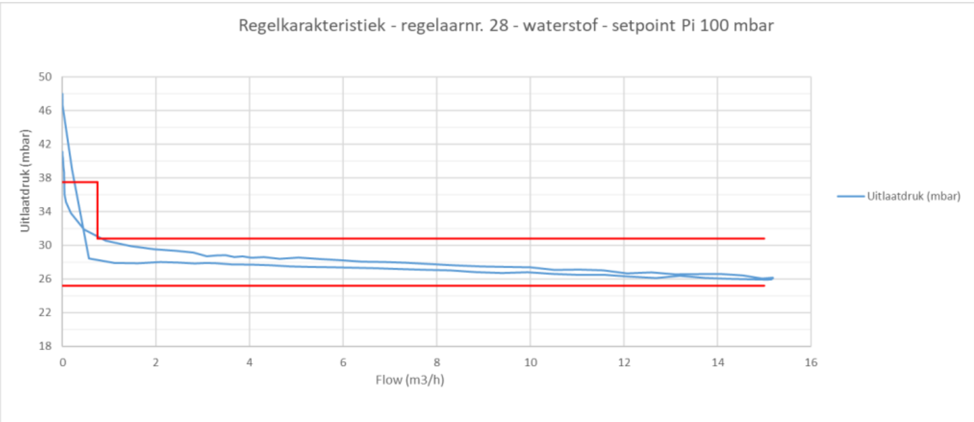

Verloop drukken bij variatie debiet - regelaarnr. 26 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

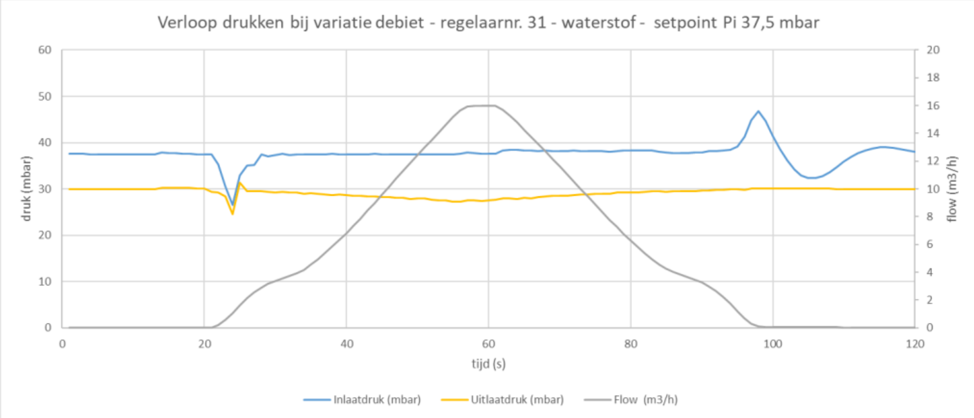

Regelkarakteristiek - regelaarnr. 26 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

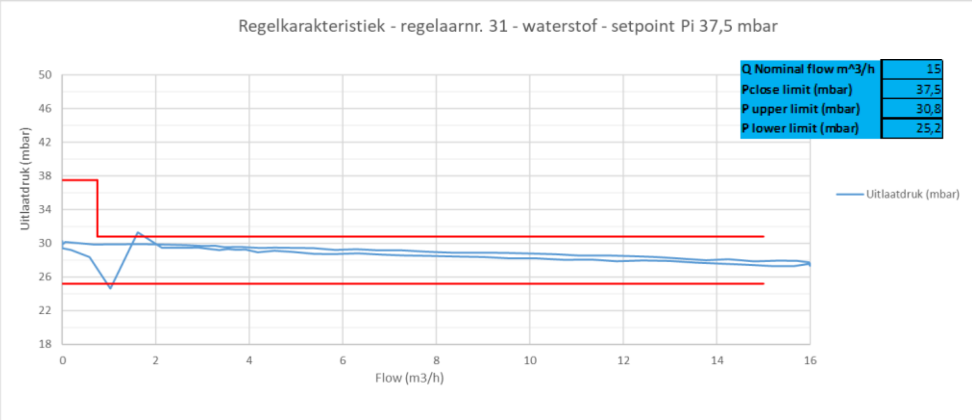

Verloop drukken bij variatie debiet - regelaarnr. 28 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

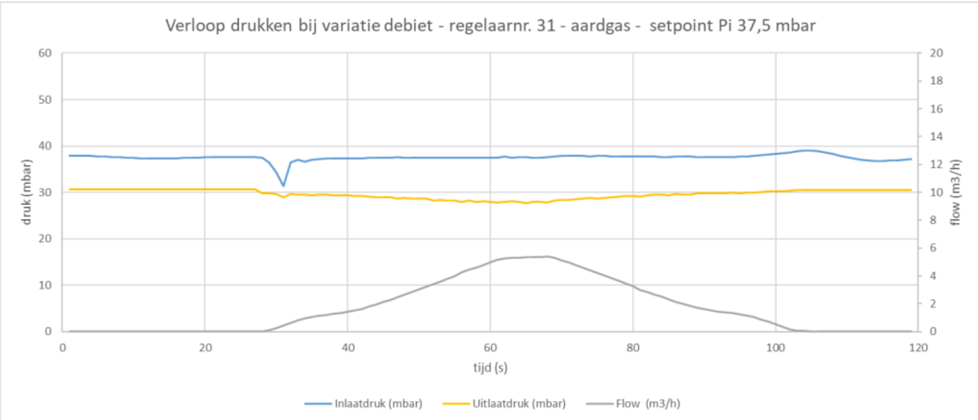

Regelkarakteristiek - regelaarnr. 28 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

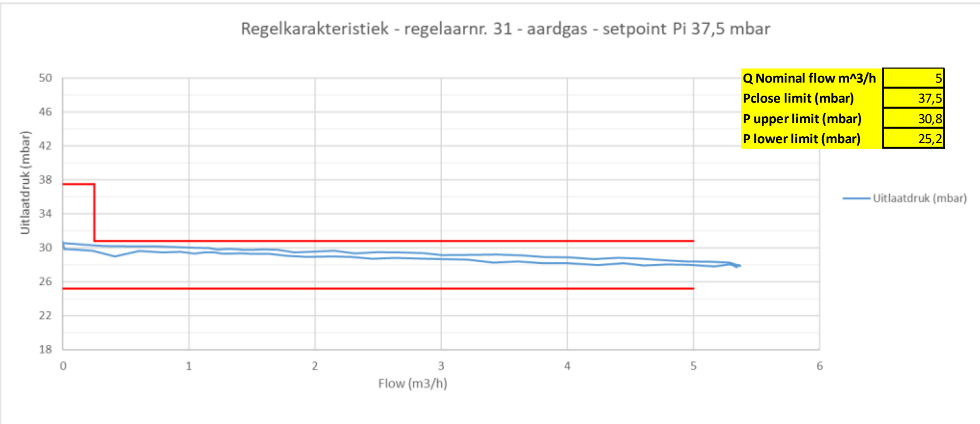

Verloop drukken bij variatie debiet - regelaarnr. 28 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

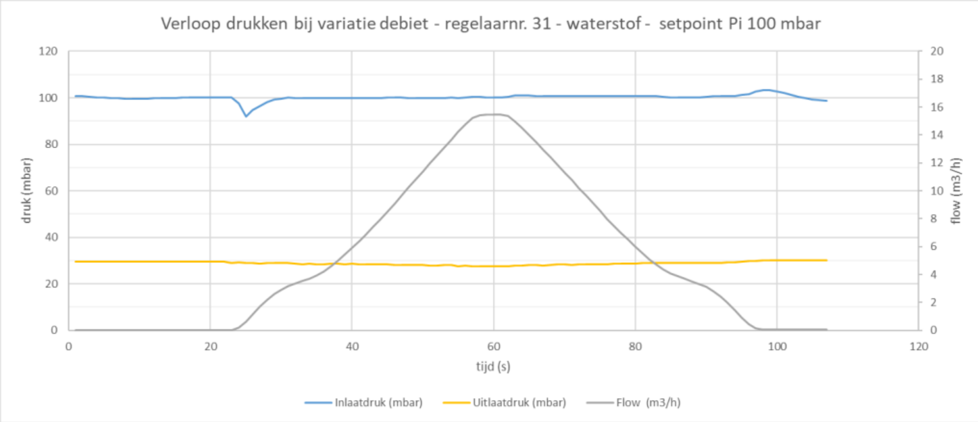

Regelkarakteristiek - regelaarnr. 28 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

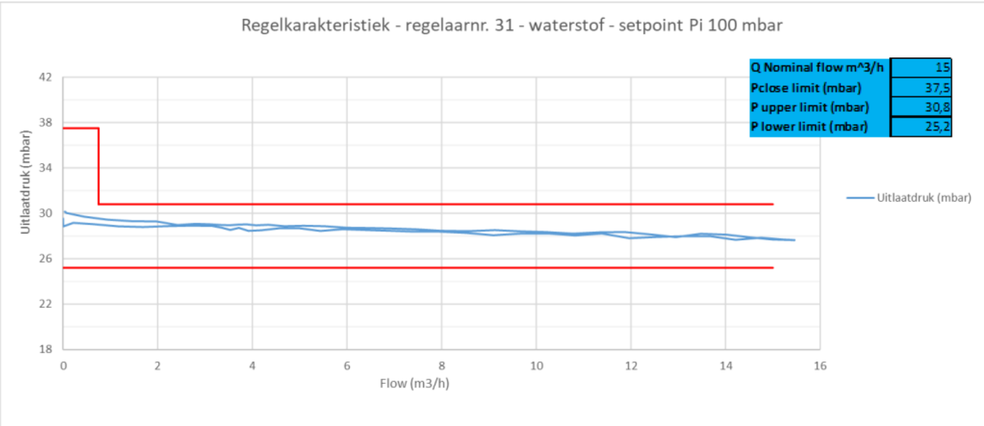

Verloop drukken bij variatie debiet - regelaarnr. 31 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

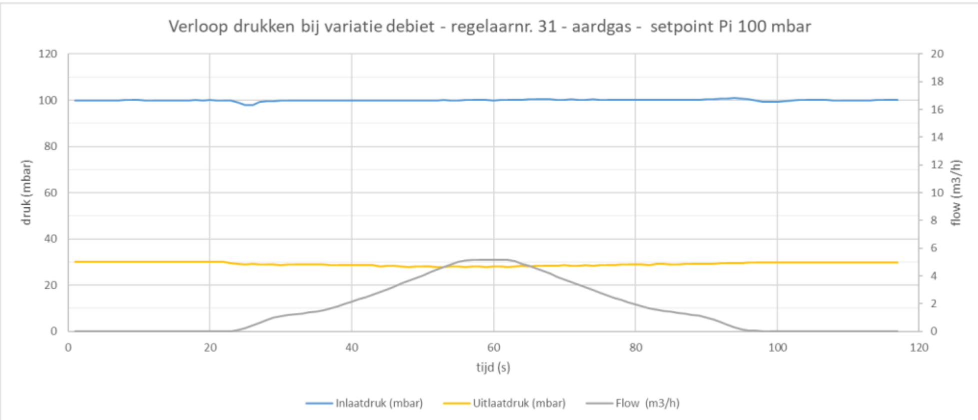

Regelkarakteristiek - regelaarnr. 31 - waterstof - setpoint Pi 37,5 mbar
Q Nominal flow m^3/h 15
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

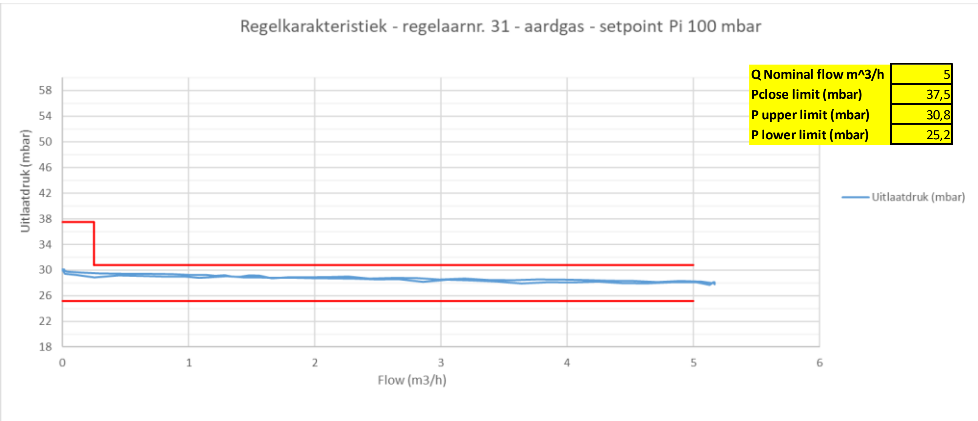

Verloop drukken bij variatie debiet - regelaarnr. 31 - aardgas - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

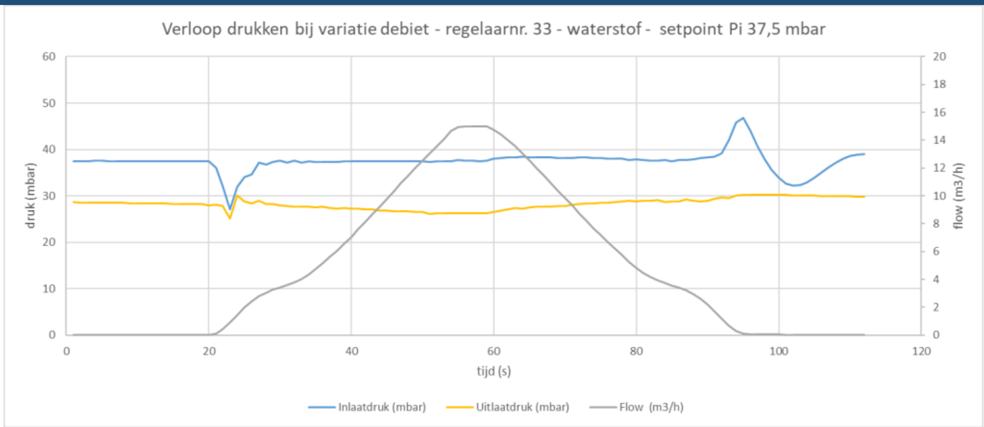

Regelkarakteristiek - regelaarnr. 31 - aardgas - setpoint Pi 37,5 mbar
Q Nominal flow m^3/h 5
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

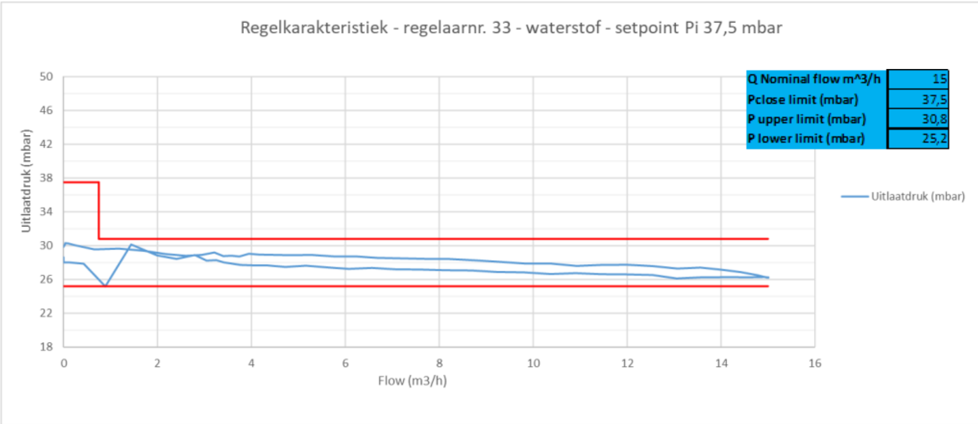

Verloop drukken bij variatie debiet - regelaarnr. 31 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

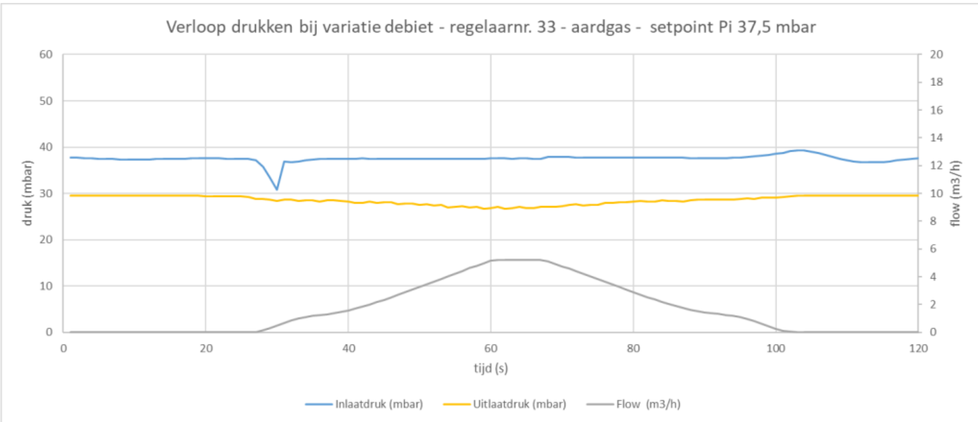

Regelkarakteristiek - regelaarnr. 31 - waterstof - setpoint Pi 100 mbar
Q Nominal flow m^3/h 15
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

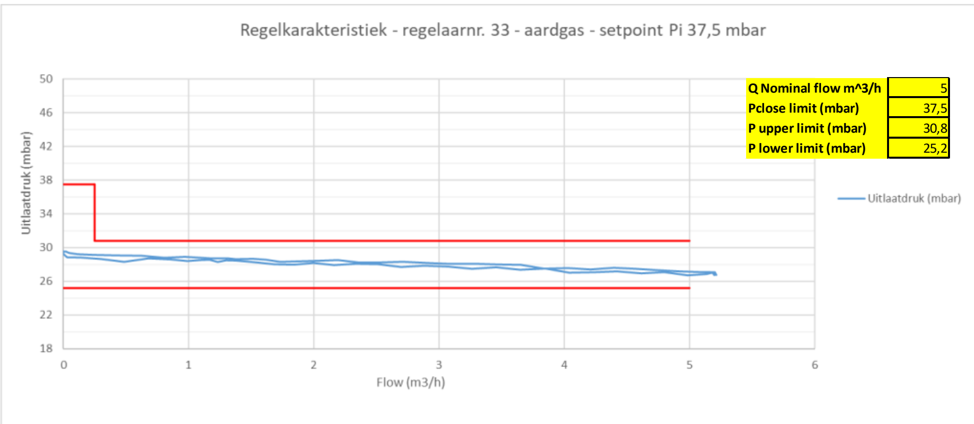

Verloop drukken bij variatie debiet - regelaarnr. 31 - aardgas - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

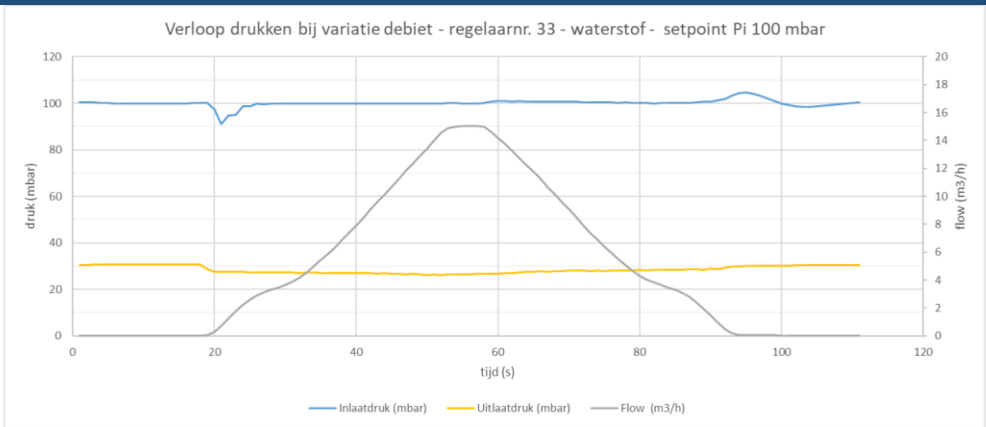

Regelkarakteristiek - regelaarnr. 31 - aardgas - setpoint Pi 100 mbar
Q Nominal flow m^3/h 5
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

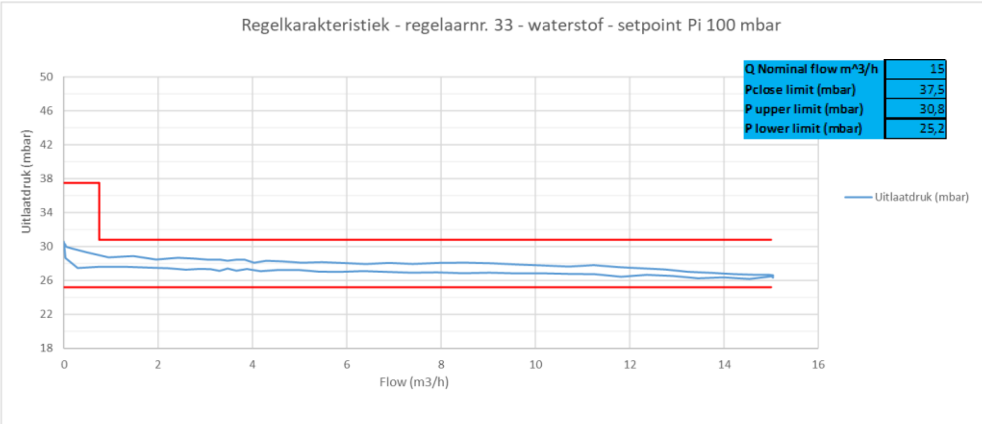

Verloop drukken bij variatie debiet - regelaarnr. 33 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

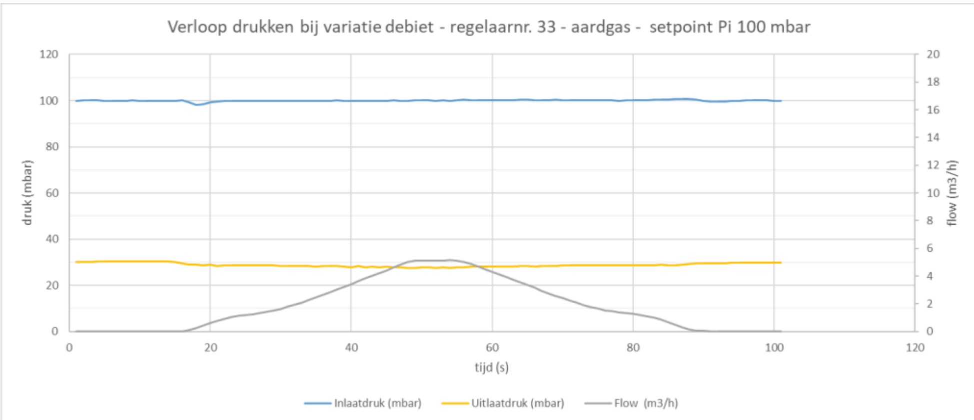

Regelkarakteristiek - regelaarnr. 33 - waterstof - setpoint Pi 37,5 mbar
Q Nominal flow m^3/h 15
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

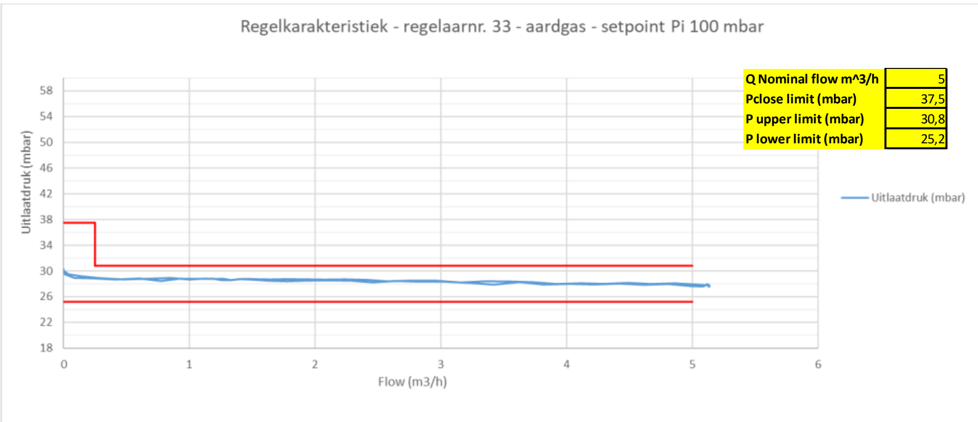

Verloop drukken bij variatie debiet - regelaarnr. 33 - aardgas - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

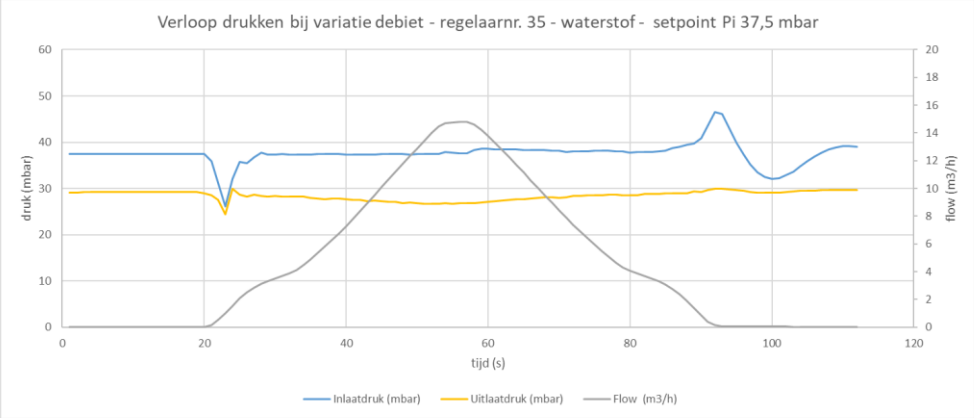

Regelkarakteristiek - regelaarnr. 33 - aardgas - setpoint Pi 37,5 mbar
Q Nominal flow m^3/h 5
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

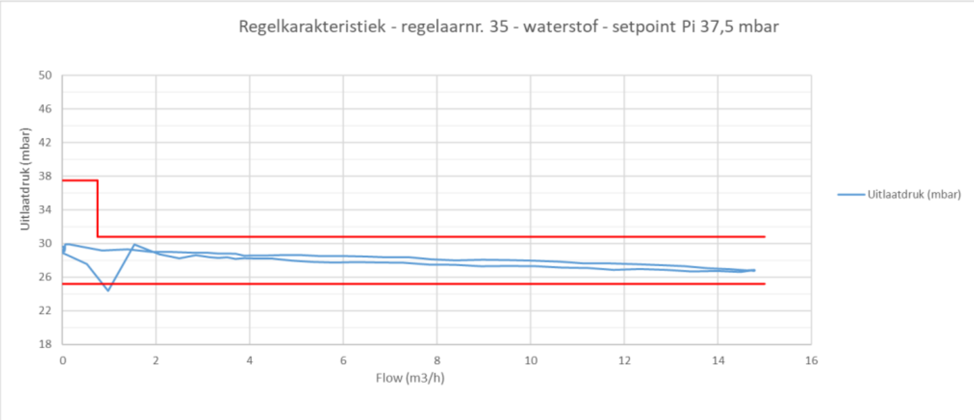

Verloop drukken bij variatie debiet - regelaarnr. 33 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

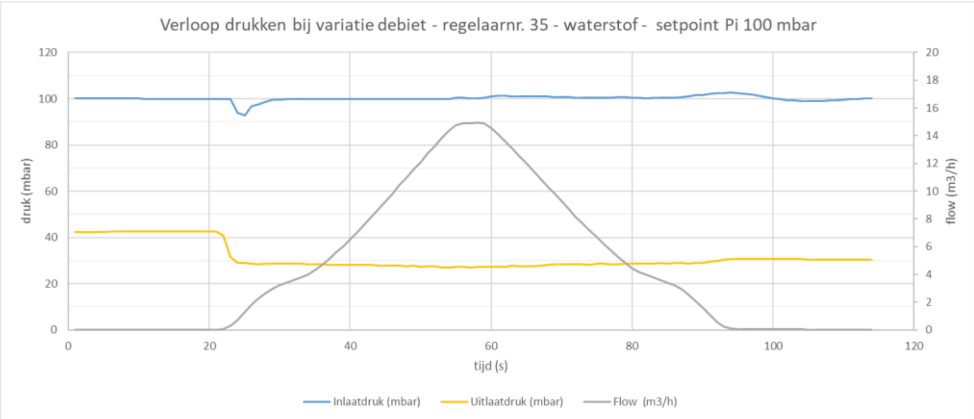

Regelkarakteristiek - regelaarnr. 33 - waterstof - setpoint Pi 100 mbar
Q Nominal flow m^3/h 15
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

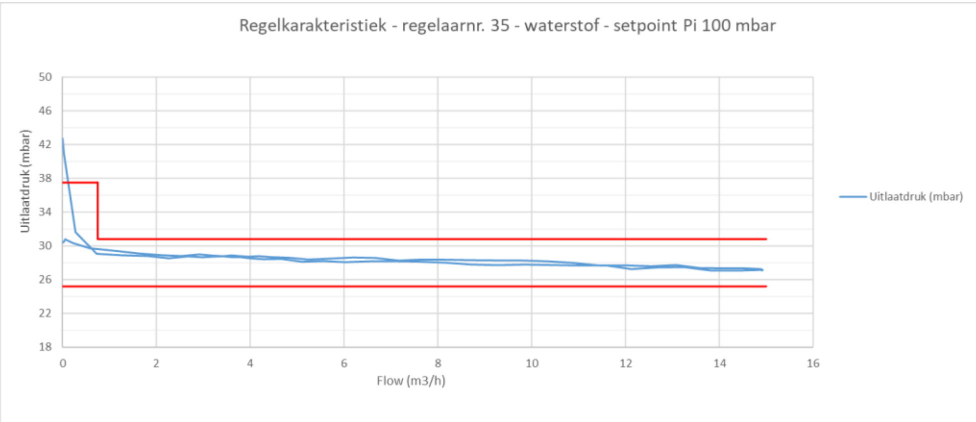

Verloop drukken bij variatie debiet - regelaarnr. 33 - aardgas - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

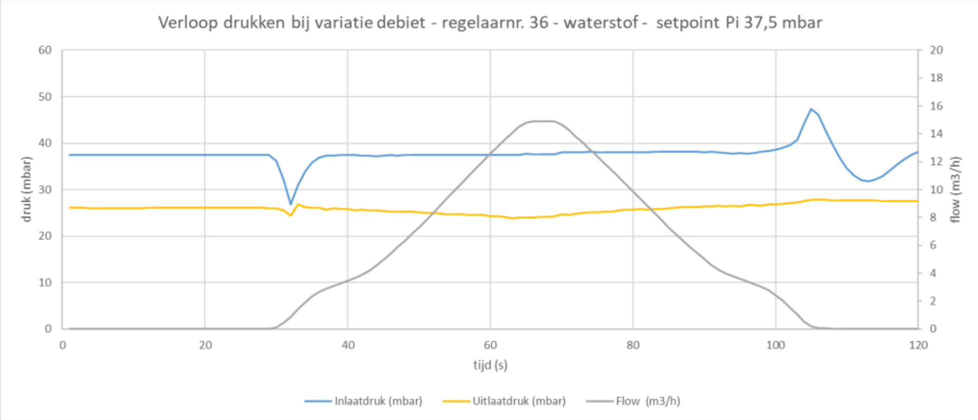

Regelkarakteristiek - regelaarnr. 33 - aardgas - setpoint Pi 100 mbar
Q Nominal flow m^3/h 5
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

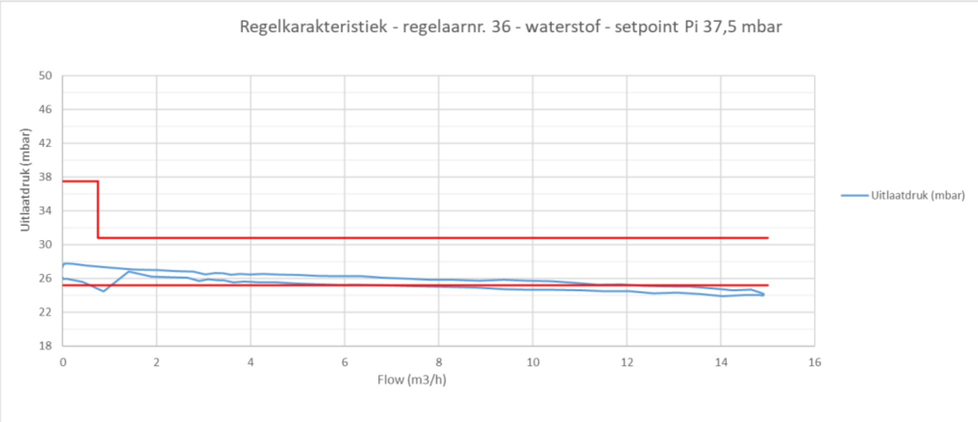

Verloop drukken bij variatie debiet - regelaarnr. 35 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

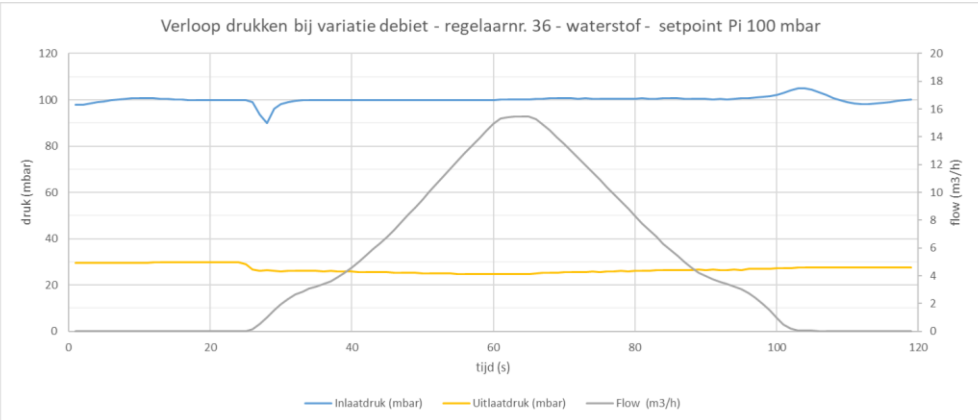

Regelkarakteristiek - regelaarnr. 35 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

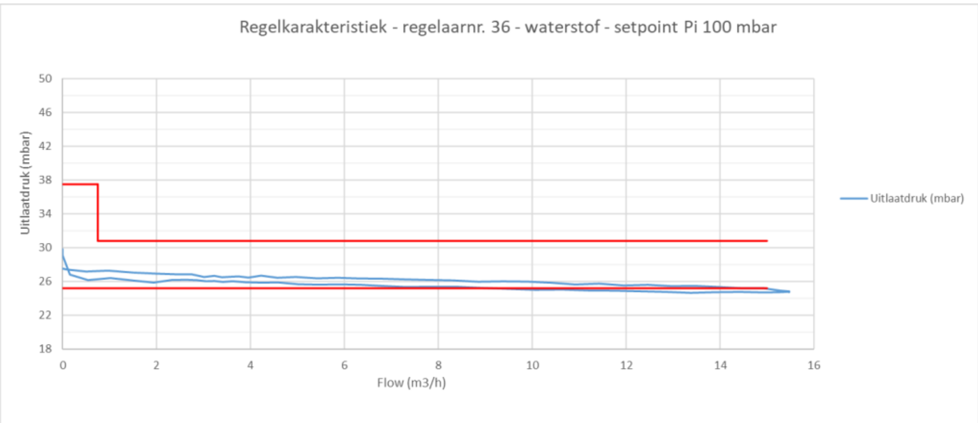

Verloop drukken bij variatie debiet - regelaarnr. 35 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

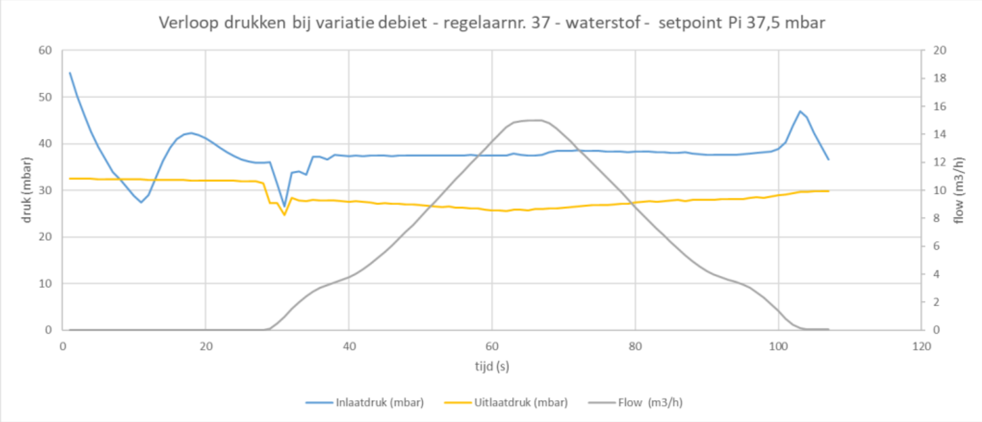

Regelkarakteristiek - regelaarnr. 35 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

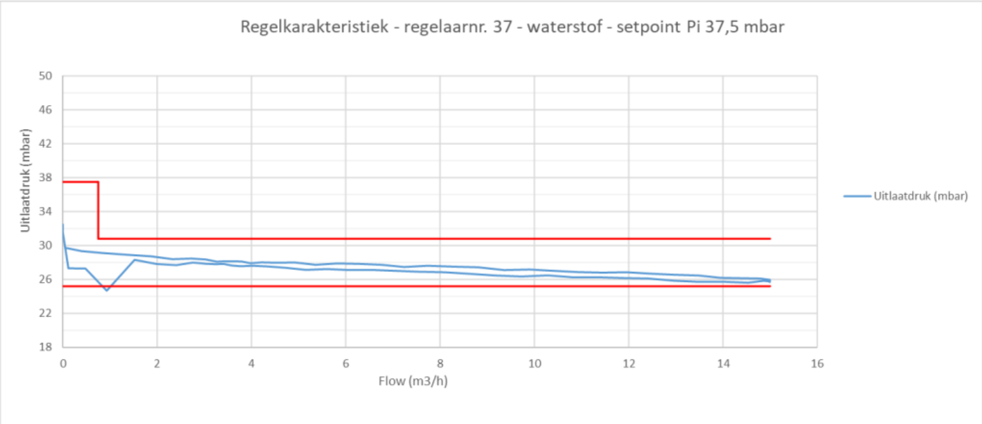

Verloop drukken bij variatie debiet - regelaarnr. 36 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

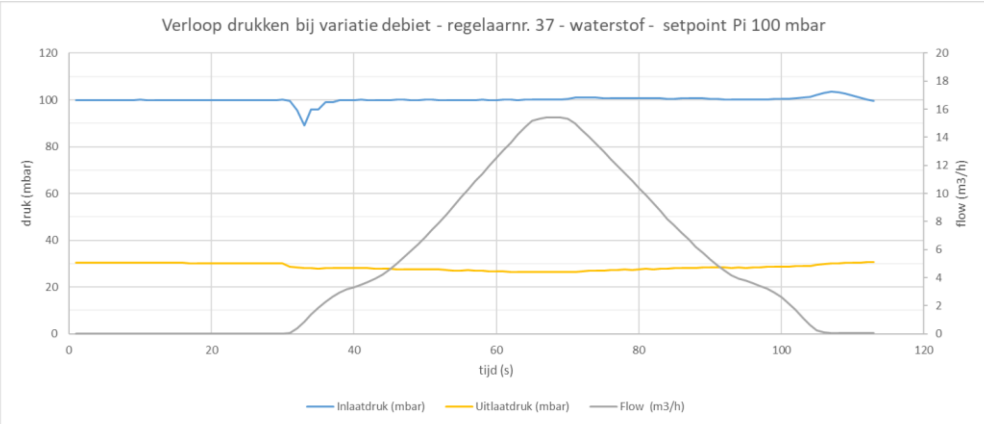

Regelkarakteristiek - regelaarnr. 36 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

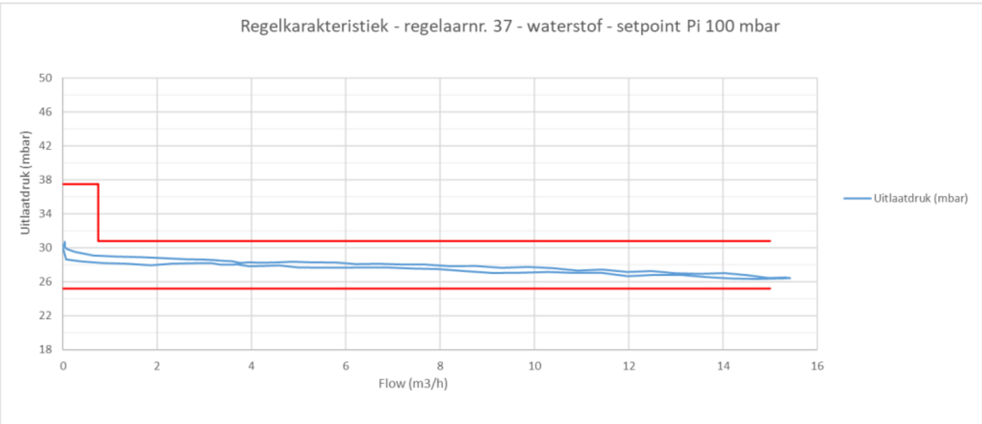

Verloop drukken bij variatie debiet - regelaarnr. 36 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

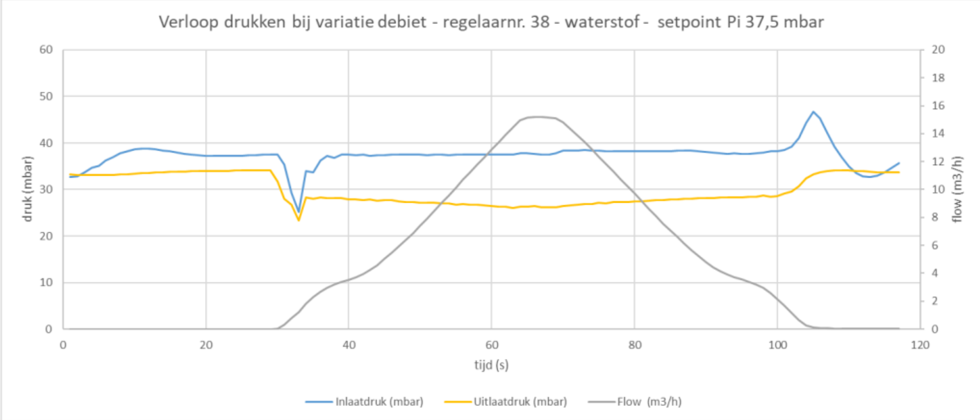

Regelkarakteristiek - regelaarnr. 36 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

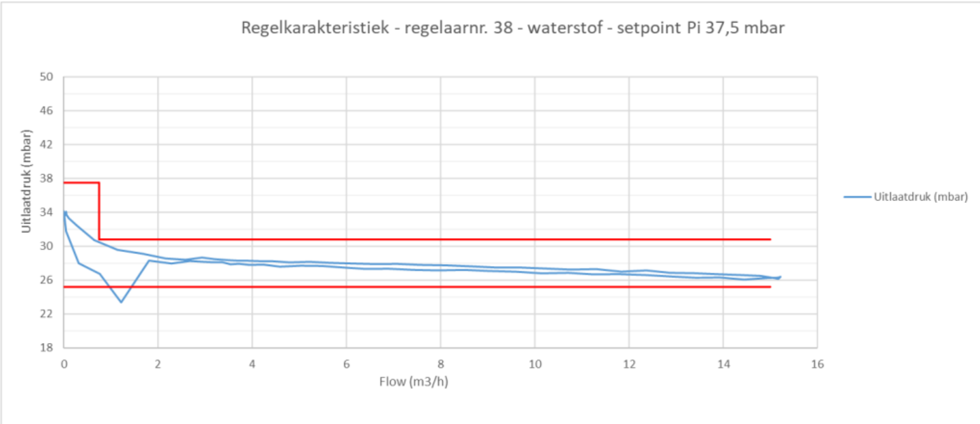

Verloop drukken bij variatie debiet - regelaarnr. 37 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

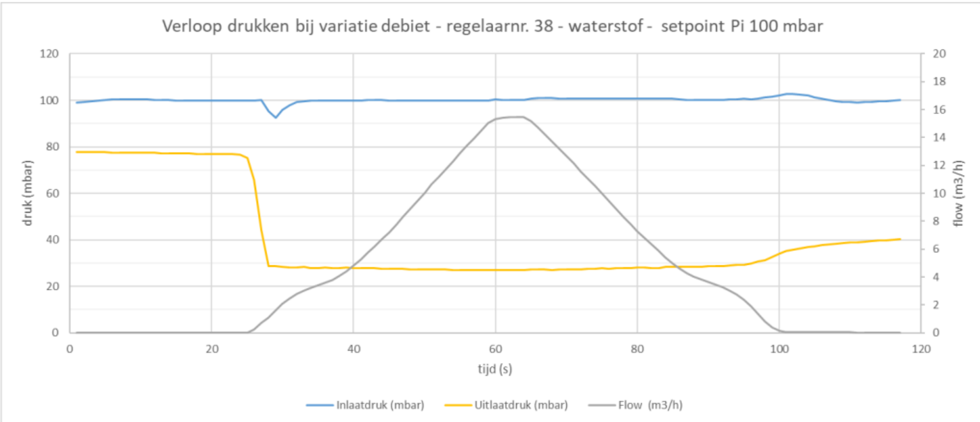

Regelkarakteristiek - regelaarnr. 37 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

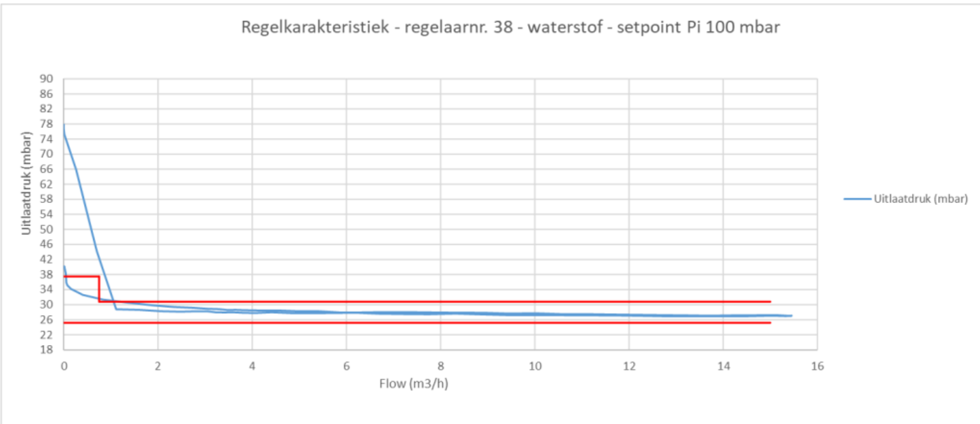

Verloop drukken bij variatie debiet - regelaarnr. 37 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

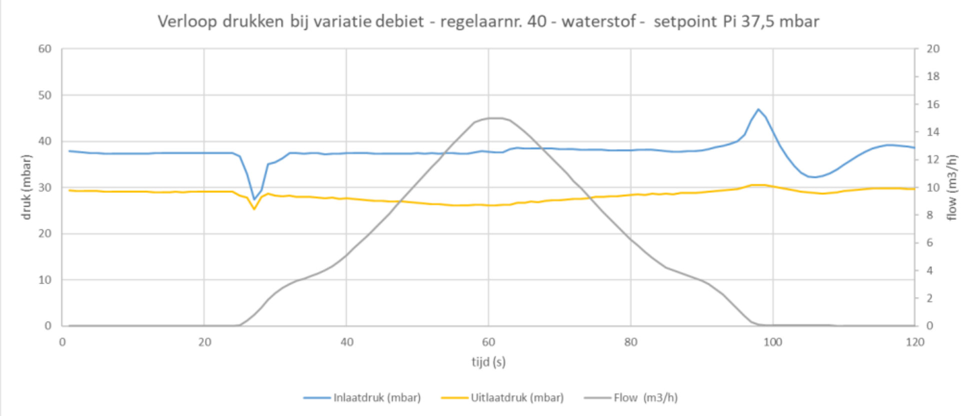

Regelkarakteristiek - regelaarnr. 37 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

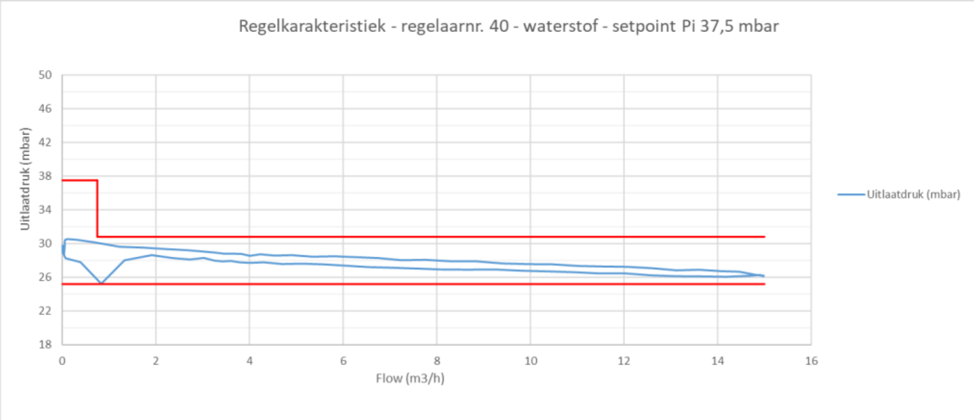

Verloop drukken bij variatie debiet - regelaarnr. 38 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

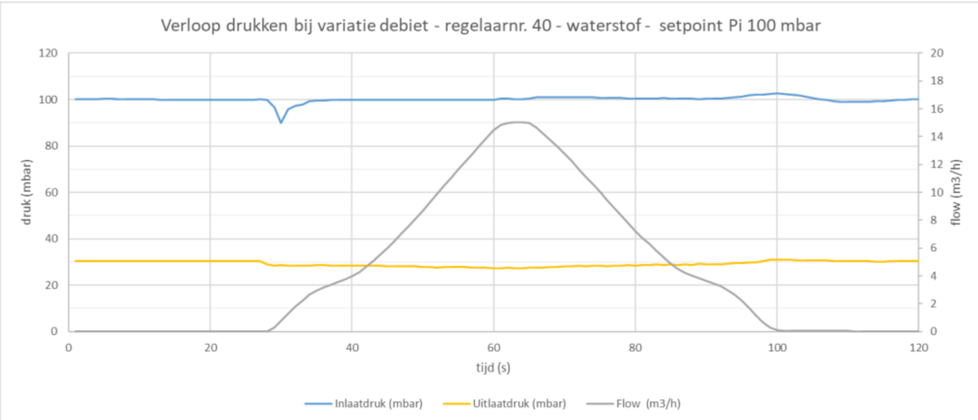

Regelkarakteristiek - regelaarnr. 38 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

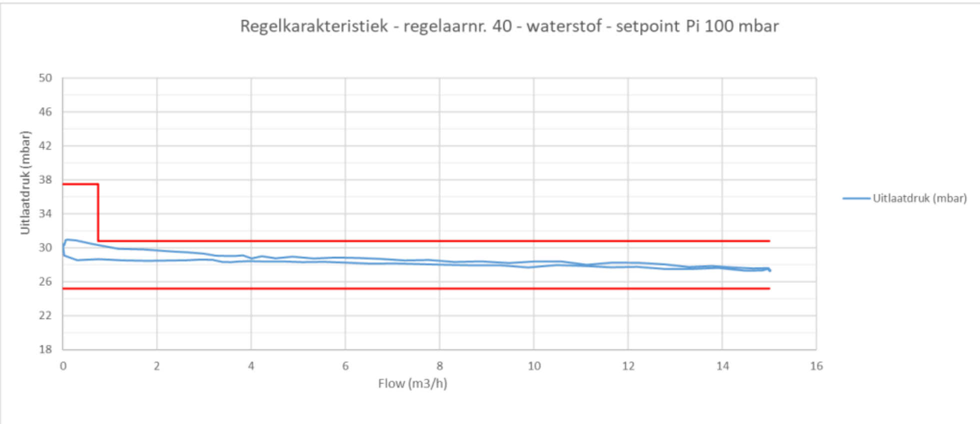

Verloop drukken bij variatie debiet - regelaarnr. 38 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

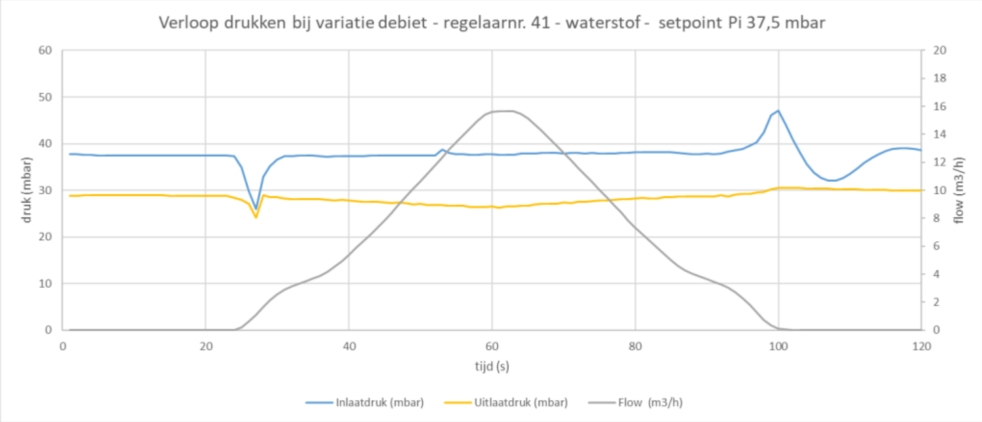

Regelkarakteristiek - regelaarnr. 38 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

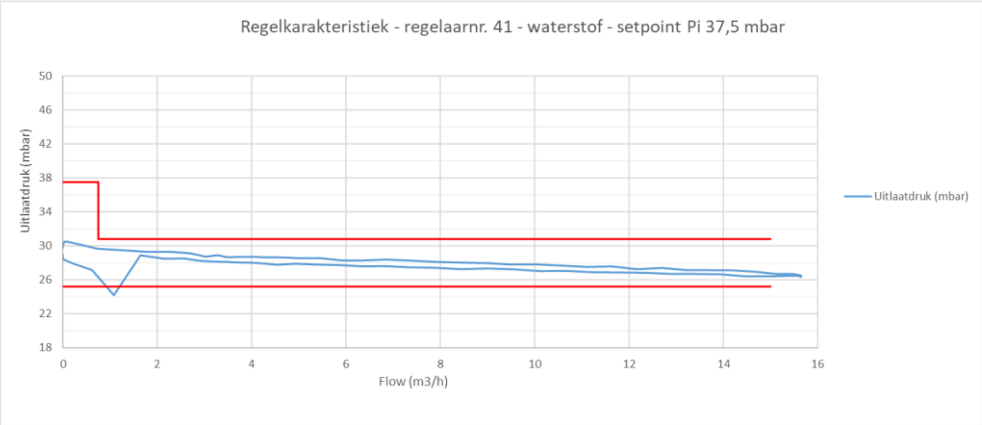

Verloop drukken bij variatie debiet - regelaarnr. 40 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

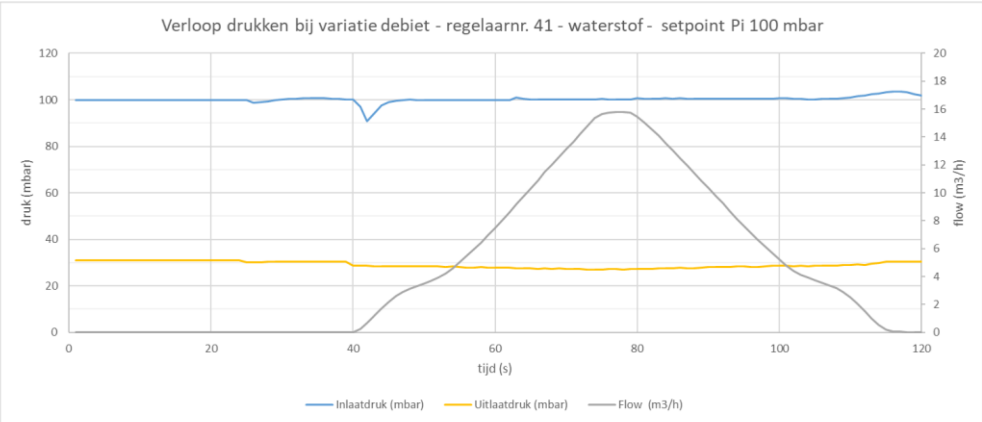

Regelkarakteristiek - regelaarnr. 40 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

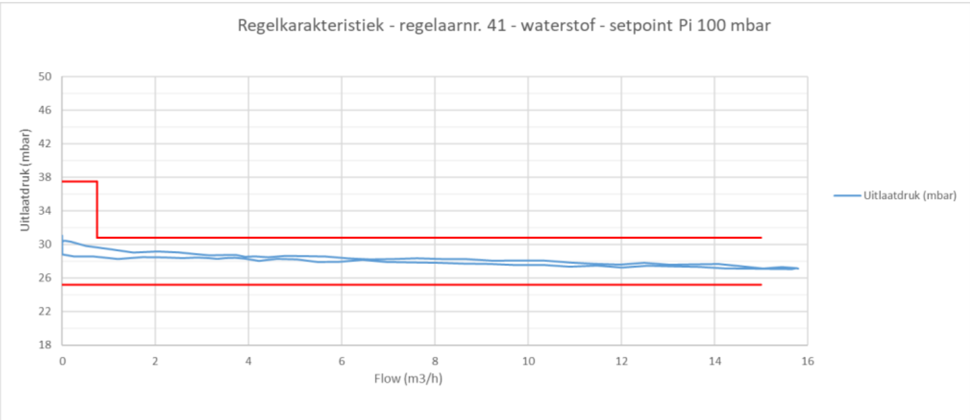

Verloop drukken bij variatie debiet - regelaarnr. 40 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

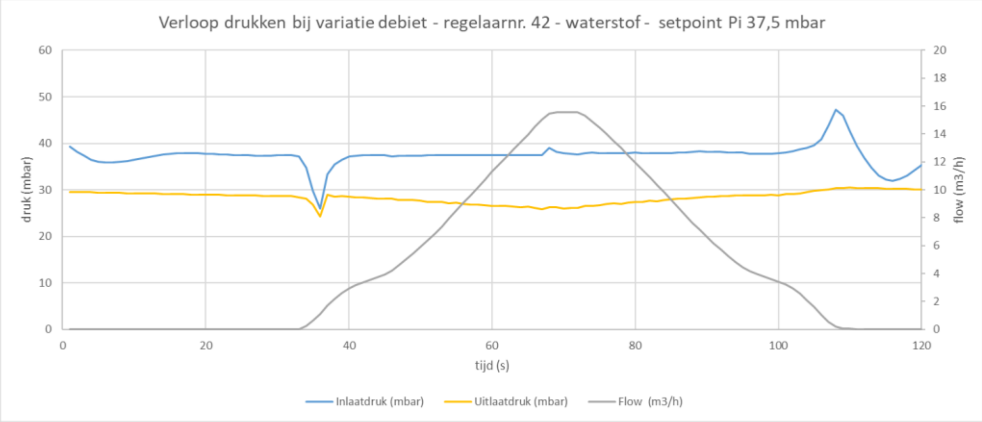

Regelkarakteristiek - regelaarnr. 40 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

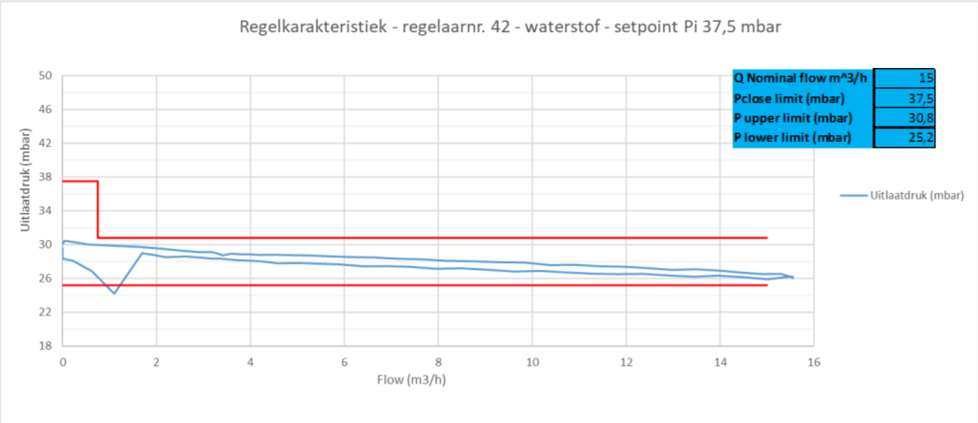

Verloop drukken bij variatie debiet - regelaarnr. 41 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

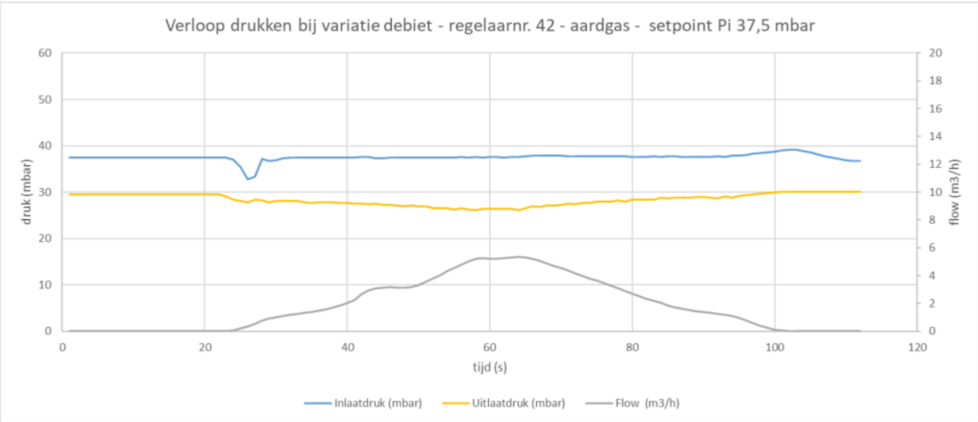

Regelkarakteristiek - regelaarnr. 41 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

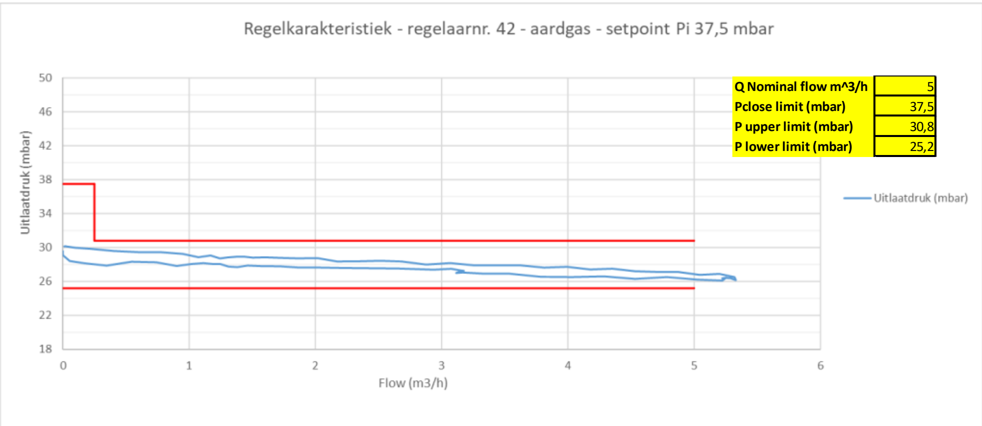

Verloop drukken bij variatie debiet - regelaarnr. 41 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

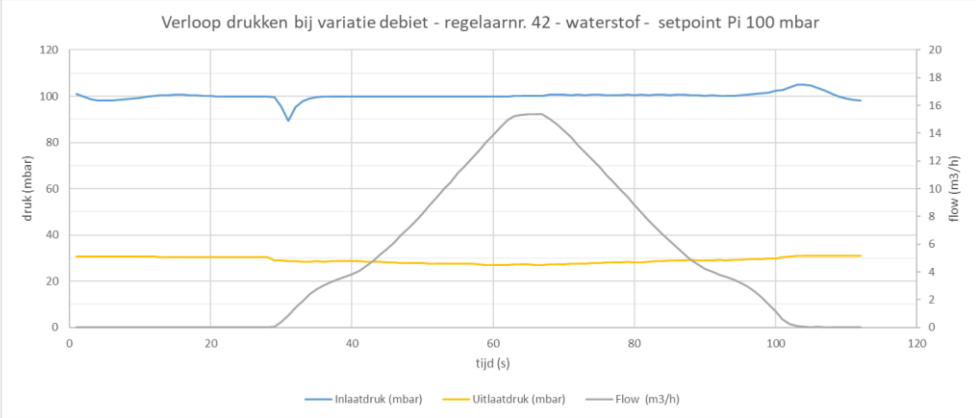

Regelkarakteristiek - regelaarnr. 41 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

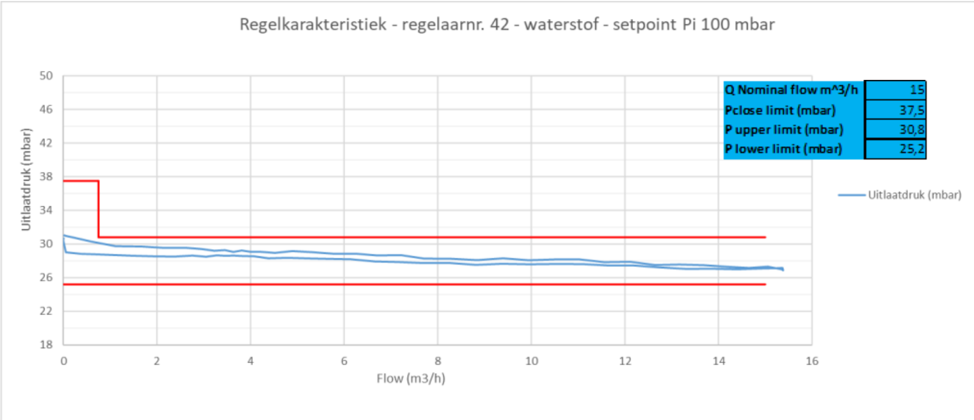

Verloop drukken bij variatie debiet - regelaarnr. 42 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

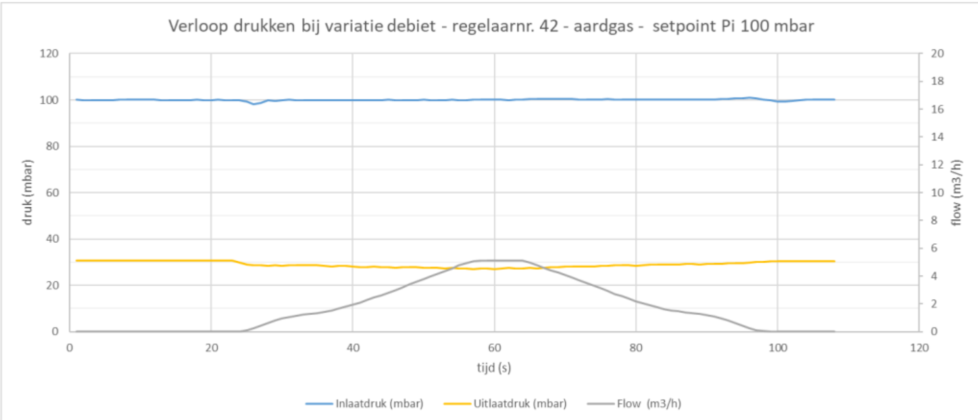

Regelkarakteristiek - regelaarnr. 42 - waterstof - setpoint Pi 37,5 mbar
Q Nominal flow m^3/h 15
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)

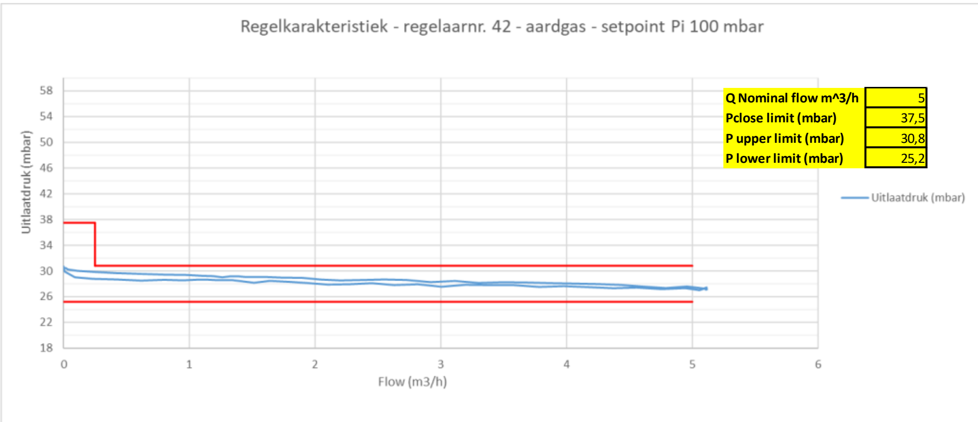

Verloop drukken bij variatie debiet - regelaarnr. 42 - aardgas - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

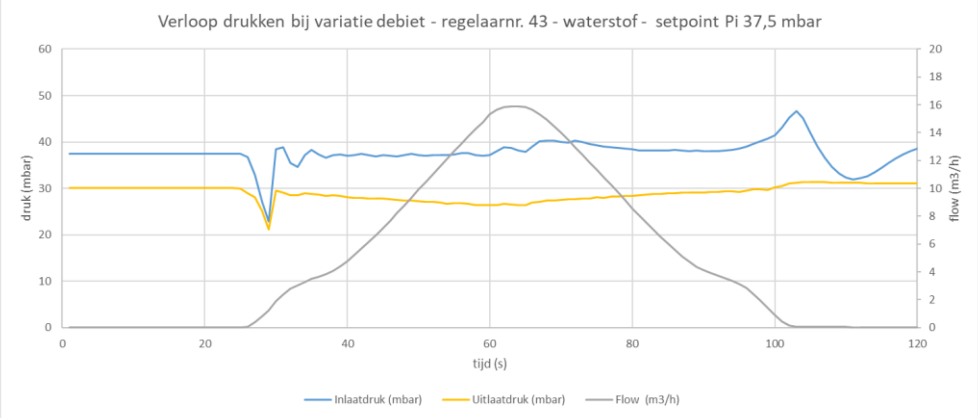

Regelkarakteristiek - regelaarnr. 42 - aardgas - setpoint Pi 37,5 mbar
Q Nominal flow m^3/h 5
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)

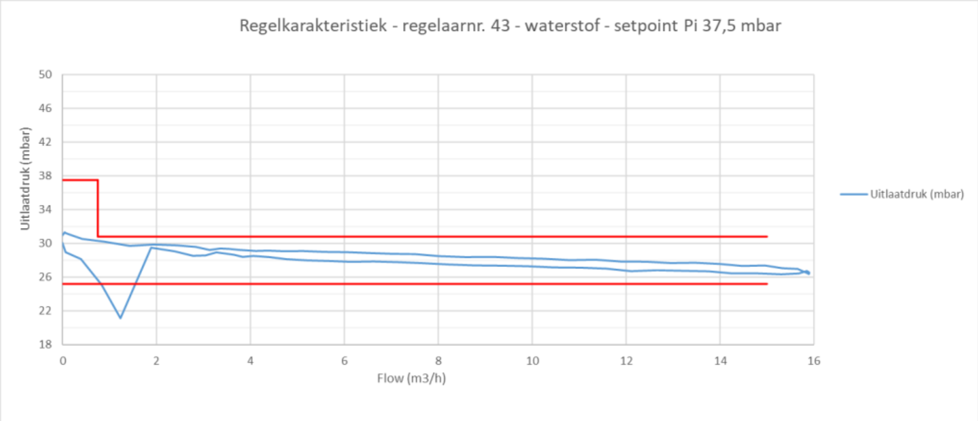

Verloop drukken bij variatie debiet - regelaarnr. 42 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

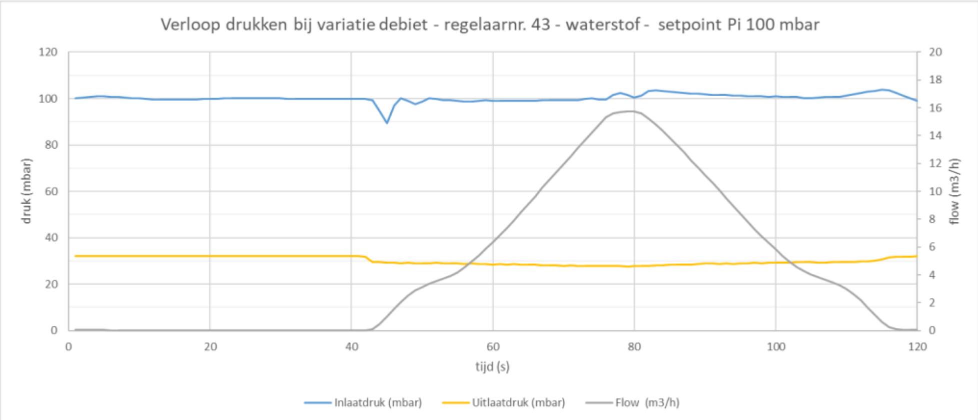

Regelkarakteristiek - regelaarnr. 42 - waterstof - setpoint Pi 100 mbar
Q Nominal flow m^3/h 15
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)

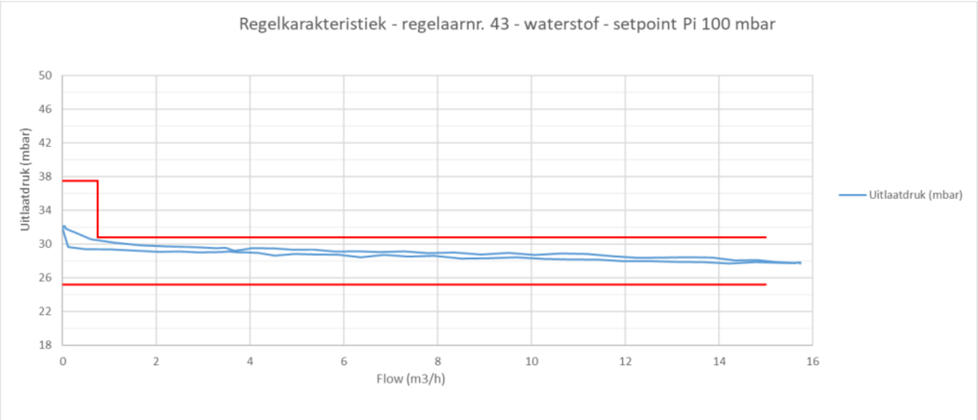

Verloop drukken bij variatie debiet - regelaarnr. 42 - aardgas - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

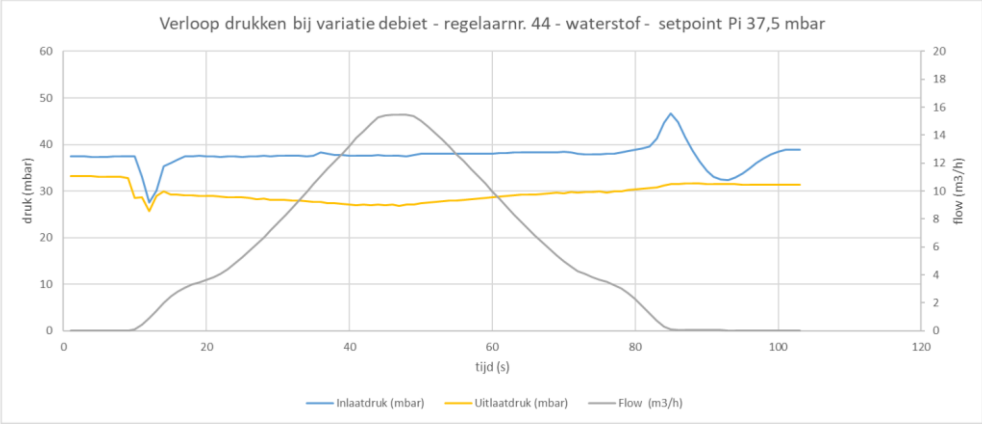

Regelkarakteristiek - regelaarnr. 42 - aardgas - setpoint Pi 100 mbar
Q Nominal flow m^3/h 5
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)

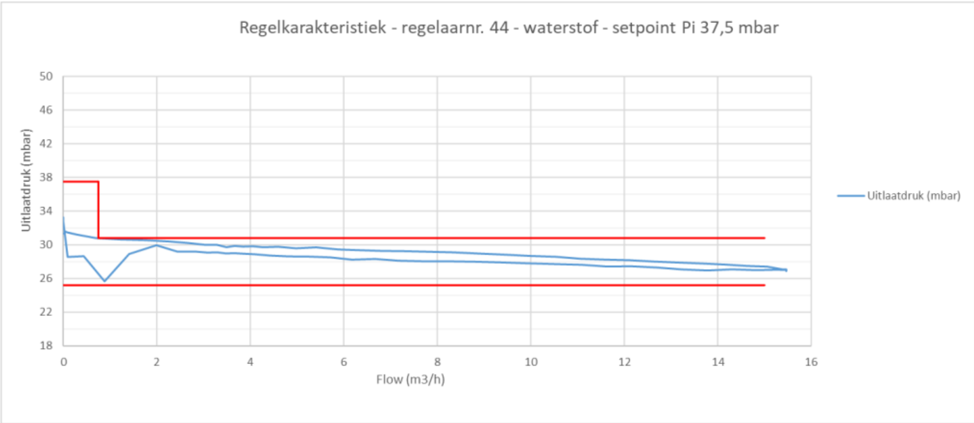

Verloop drukken bij variatie debiet - regelaarnr. 43 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

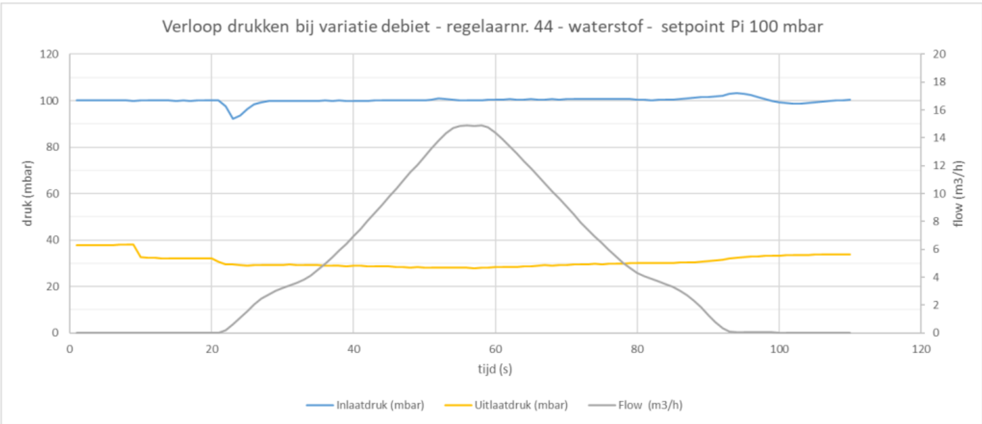

Regelkarakteristiek - regelaarnr. 43 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

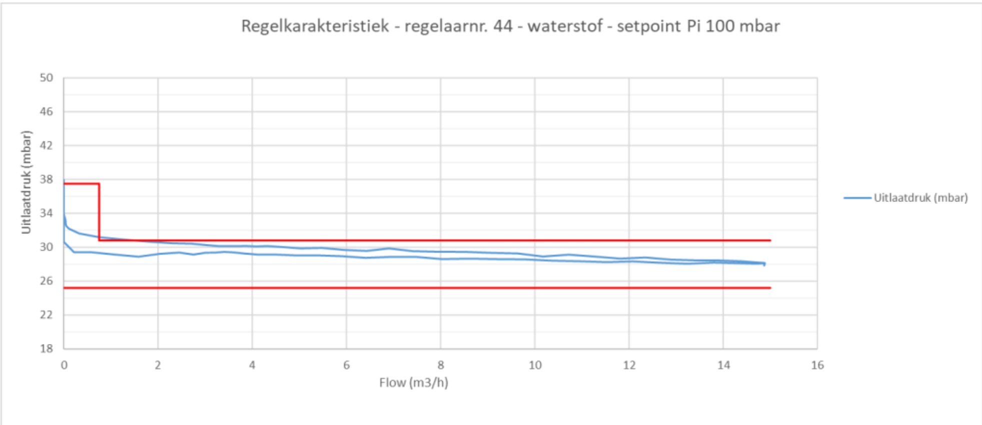

Verloop drukken bij variatie debiet - regelaarnr. 43 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

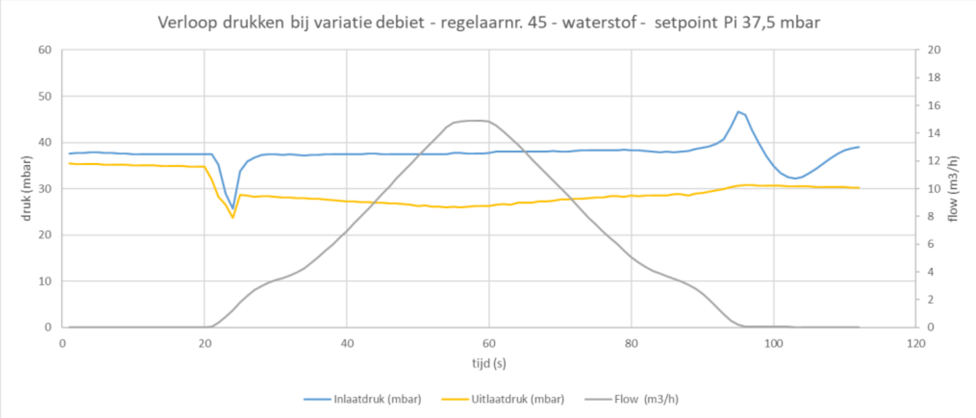

Regelkarakteristiek - regelaarnr. 43 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

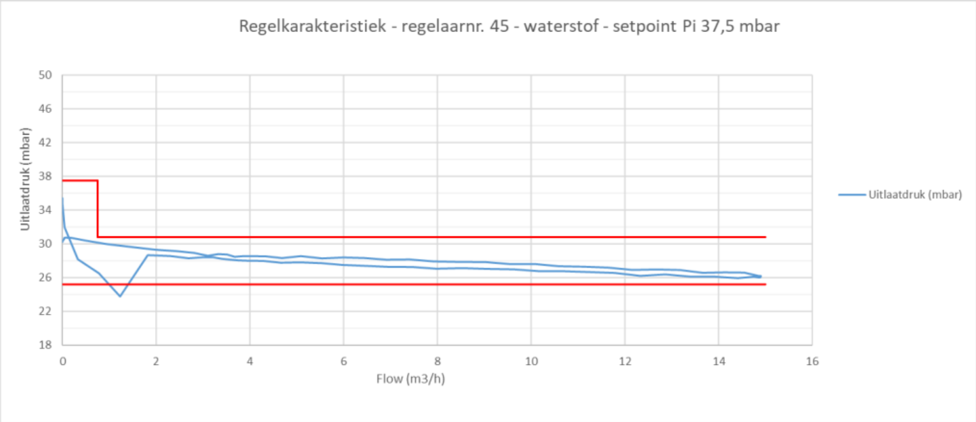

Verloop drukken bij variatie debiet - regelaarnr. 44 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

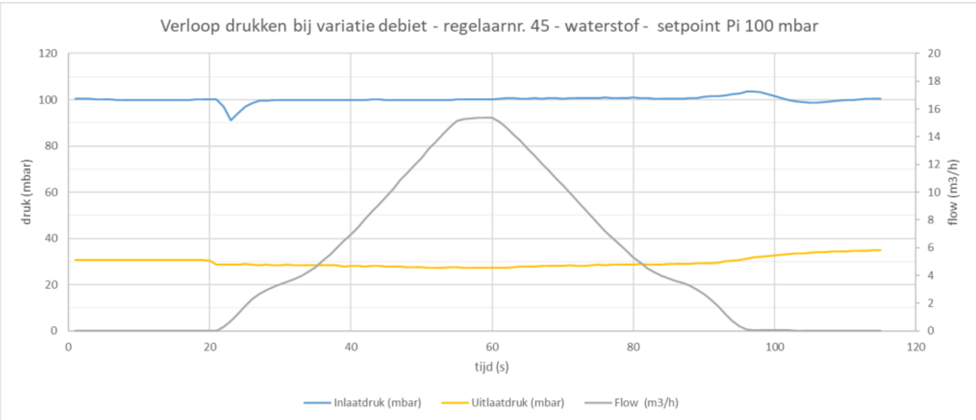

Regelkarakteristiek - regelaarnr. 44 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

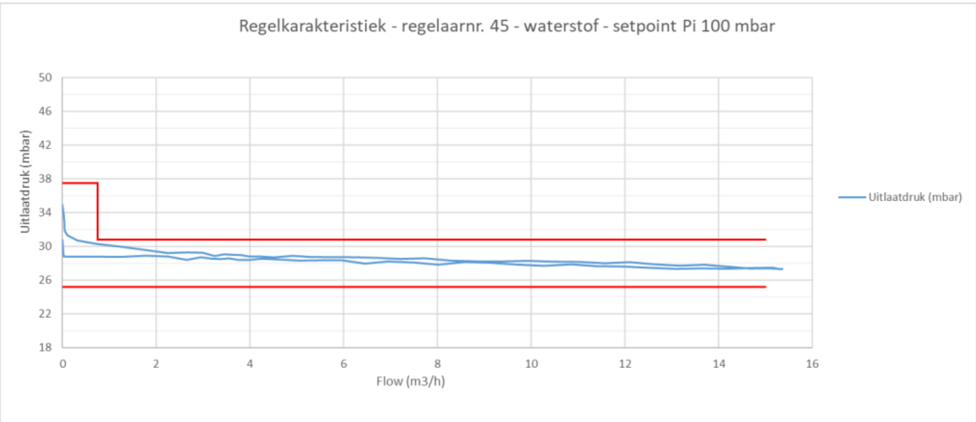

Verloop drukken bij variatie debiet - regelaarnr. 44 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

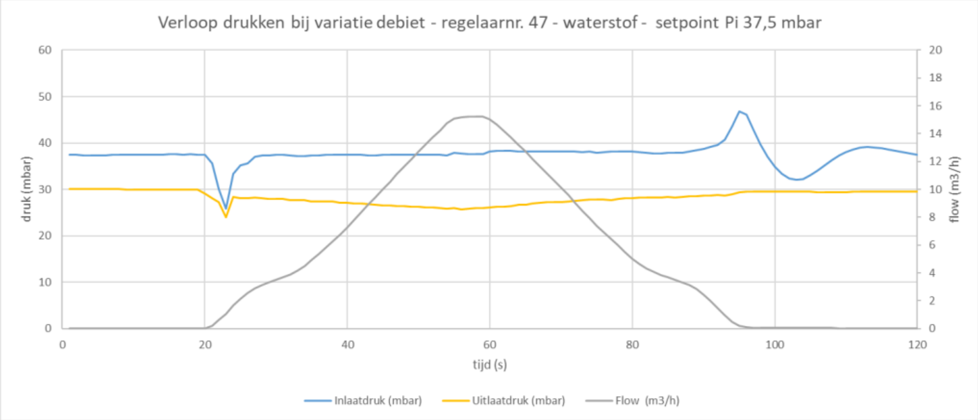

Regelkarakteristiek - regelaarnr. 44 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

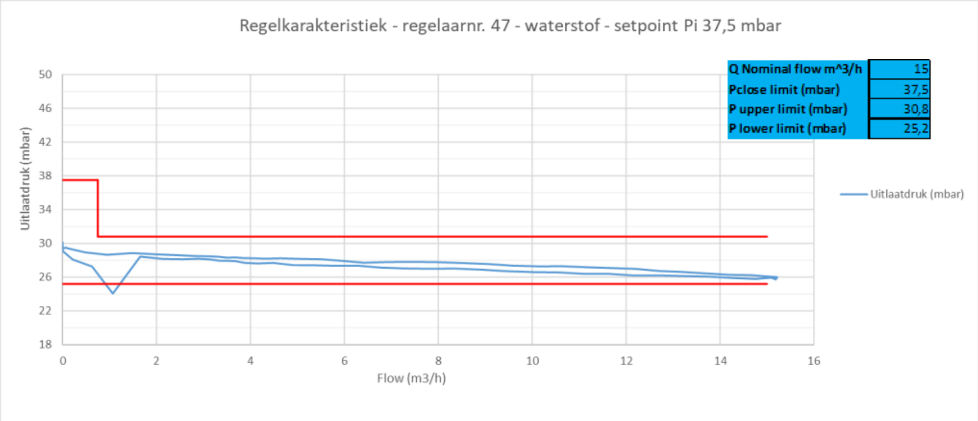

Verloop drukken bij variatie debiet - regelaarnr. 45 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

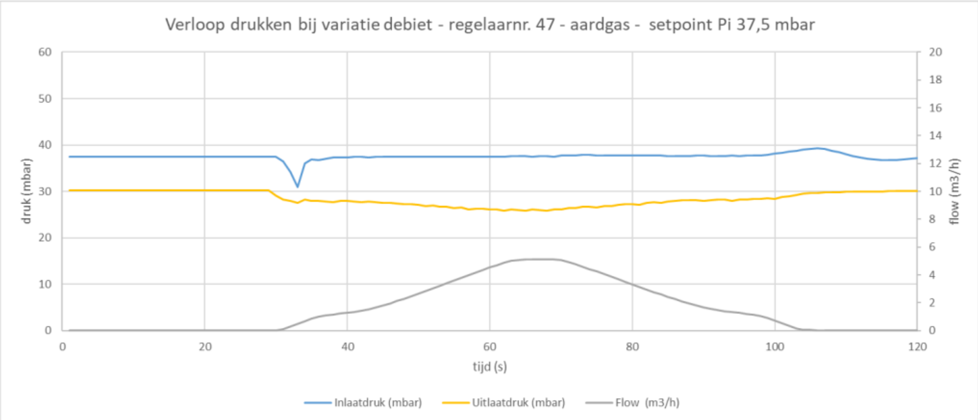

Regelkarakteristiek - regelaarnr. 45 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

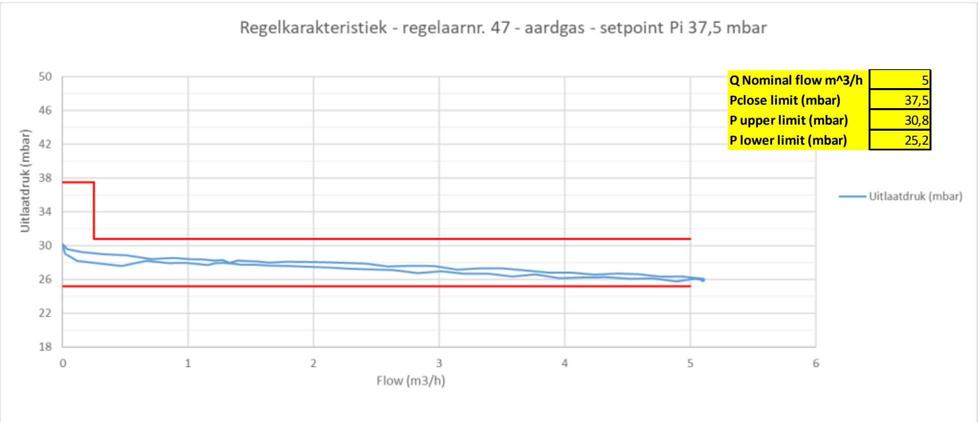

Verloop drukken bij variatie debiet - regelaarnr. 45 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

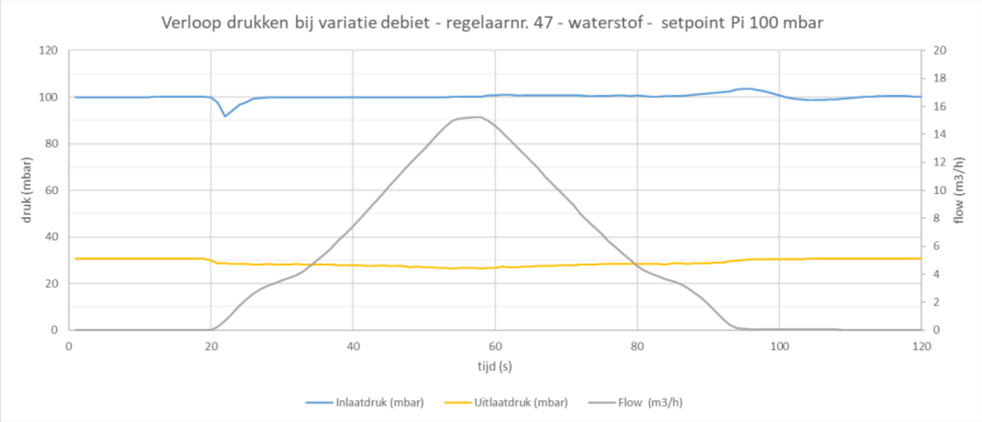

Regelkarakteristiek - regelaarnr. 45 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

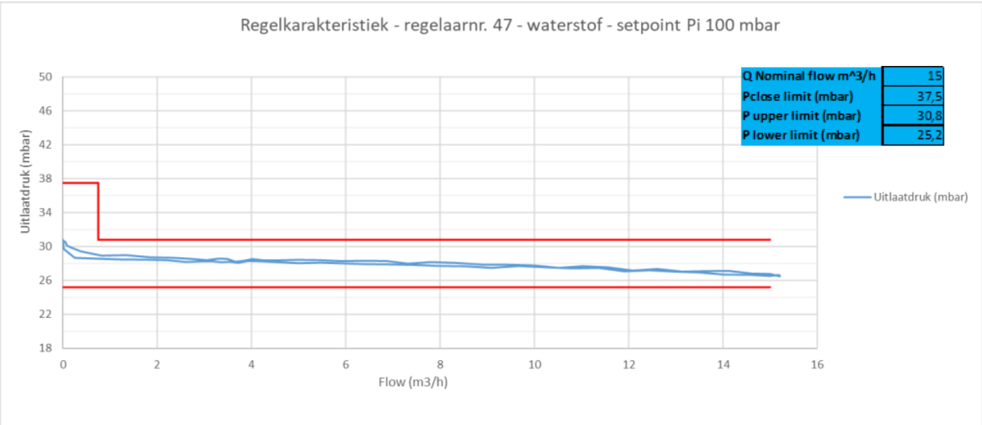

Verloop drukken bij variatie debiet - regelaarnr. 47 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

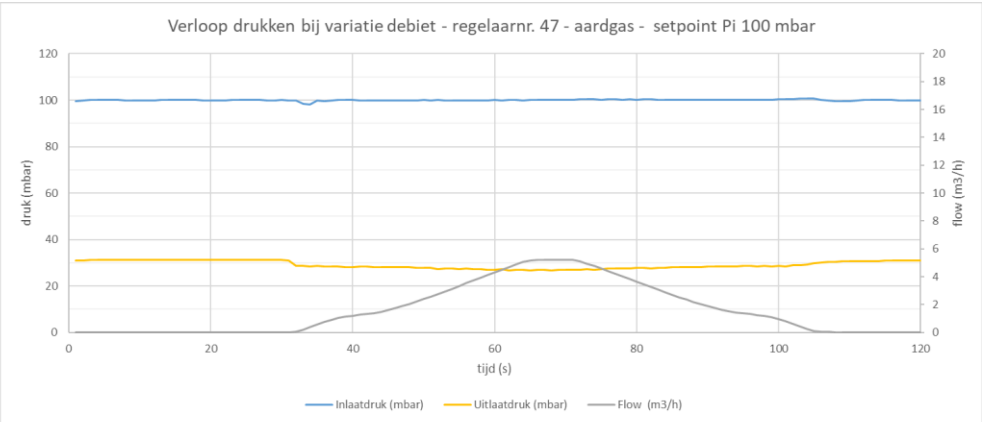

Regelkarakteristiek - regelaarnr. 47 - waterstof - setpoint Pi 37,5 mbar
Q Nominal flow m^3/h 15
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)

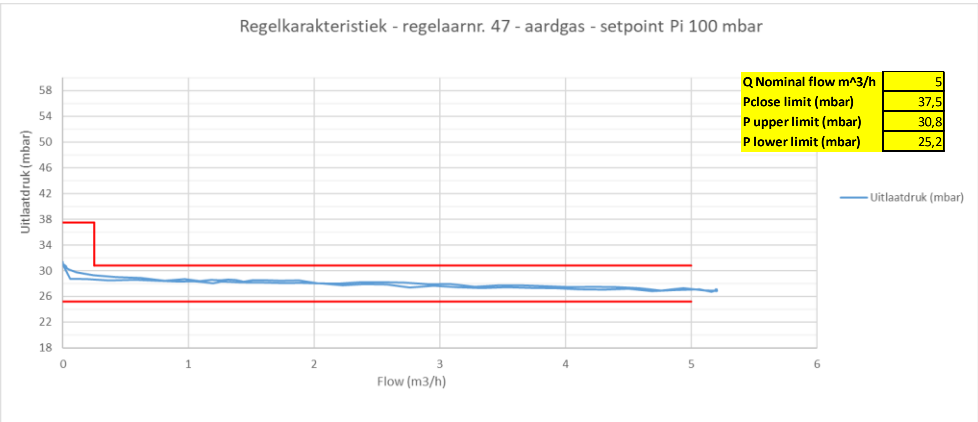

Verloop drukken bij variatie debiet - regelaarnr. 47 - aardgas - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

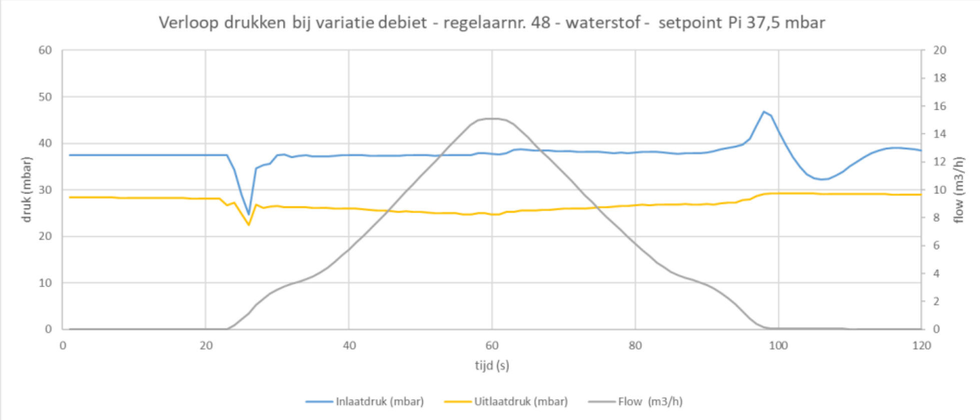

Regelkarakteristiek - regelaarnr. 47 - aardgas - setpoint Pi 37,5 mbar
Q Nominal flow m^3/h 5
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)

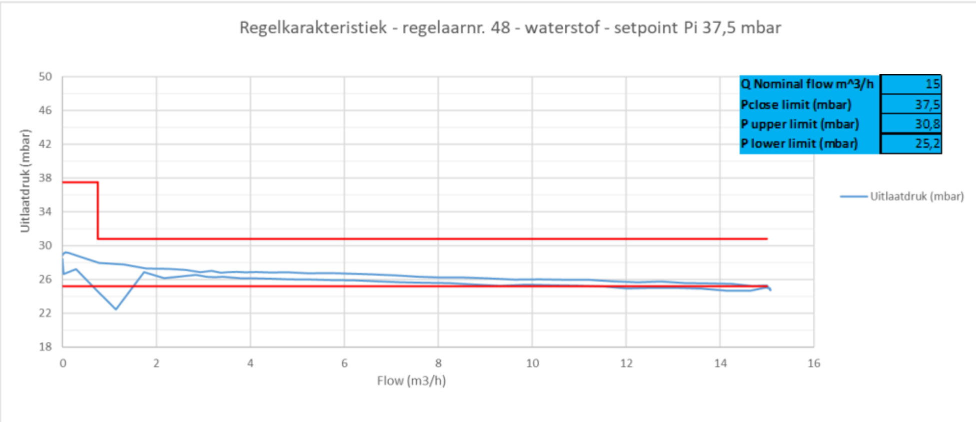

Verloop drukken bij variatie debiet - regelaarnr. 47 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

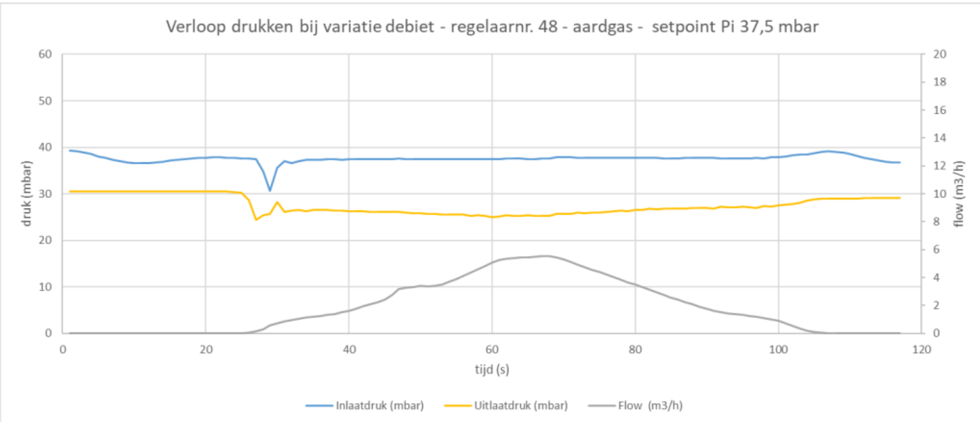

Regelkarakteristiek - regelaarnr. 47 - waterstof - setpoint Pi 100 mbar
Q Nominal flow m^3/h 15
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

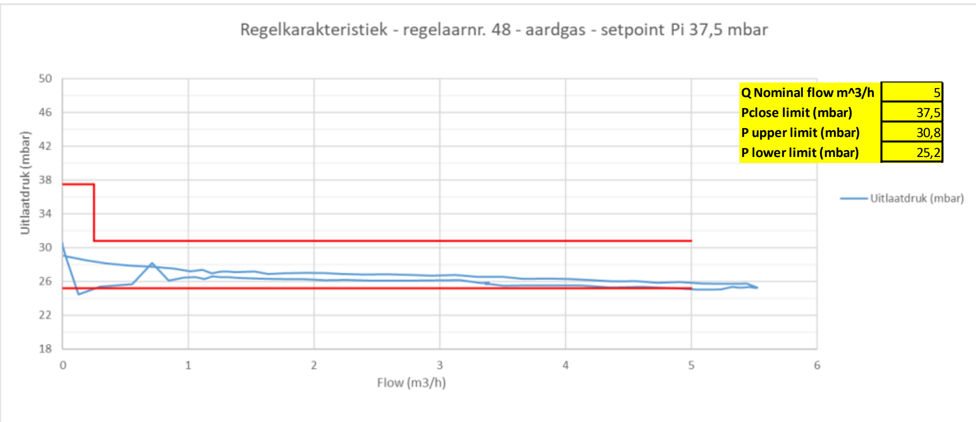

Verloop drukken bij variatie debiet - regelaarnr. 47 - aardgas - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

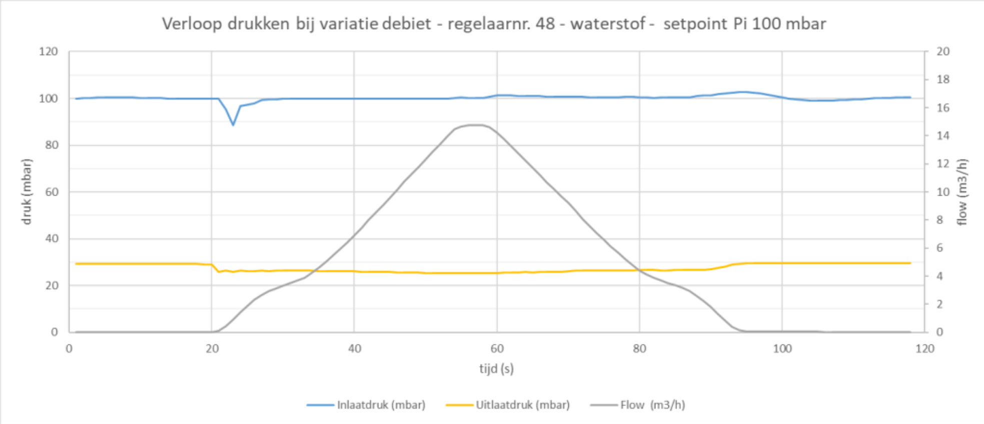

Regelkarakteristiek - regelaarnr. 47 - aardgas - setpoint Pi 100 mbar
Q Nominal flow m^3/h 5
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

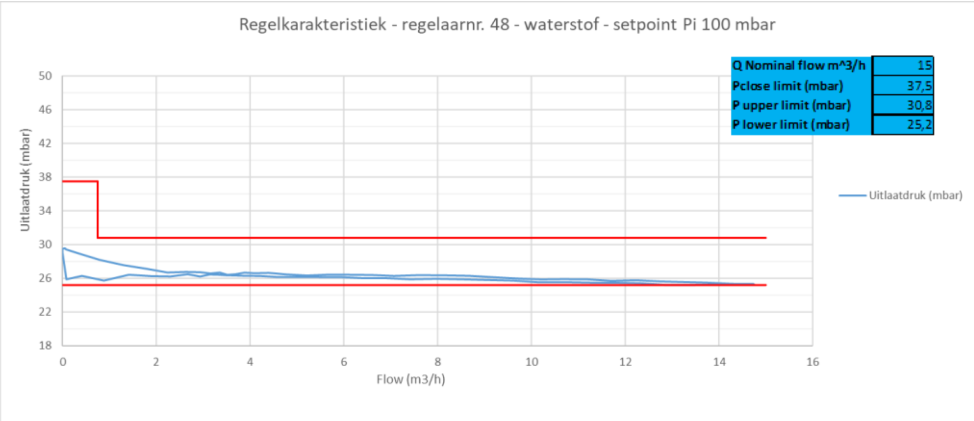

Verloop drukken bij variatie debiet - regelaarnr. 48 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

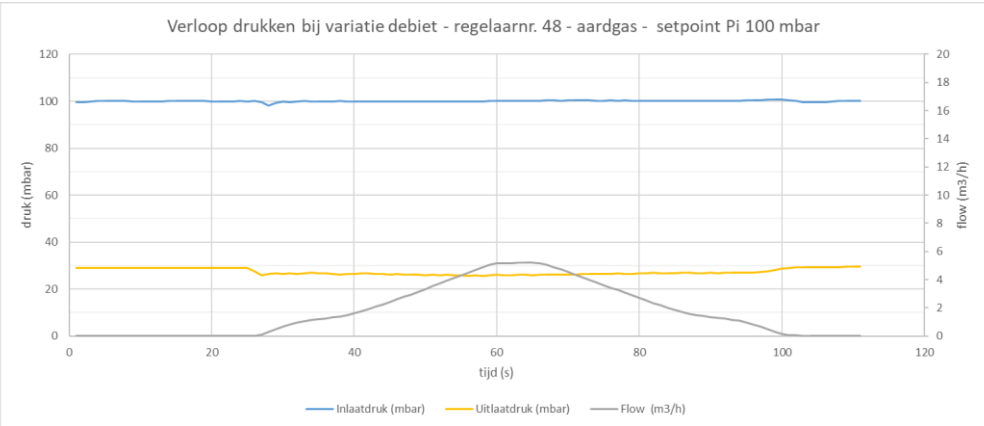

Regelkarakteristiek - regelaarnr. 48 - waterstof - setpoint Pi 37,5 mbar
Q Nominal flow m^3/h 15
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)

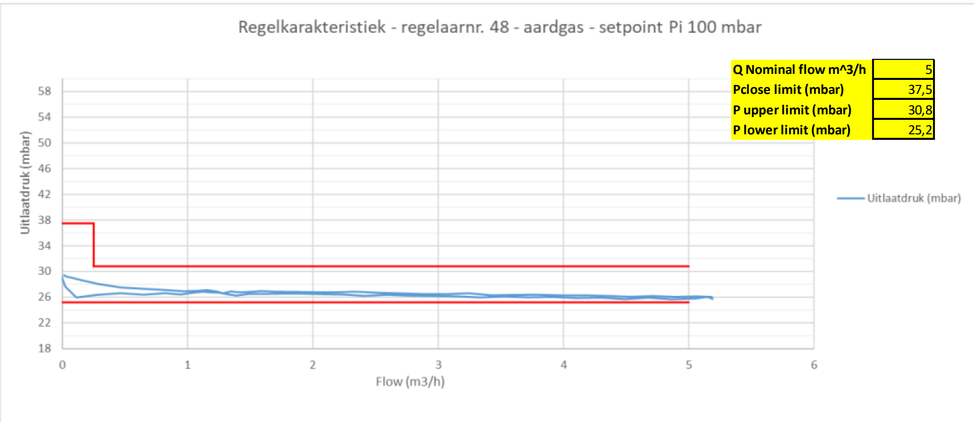

Verloop drukken bij variatie debiet - regelaarnr. 48 - aardgas - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

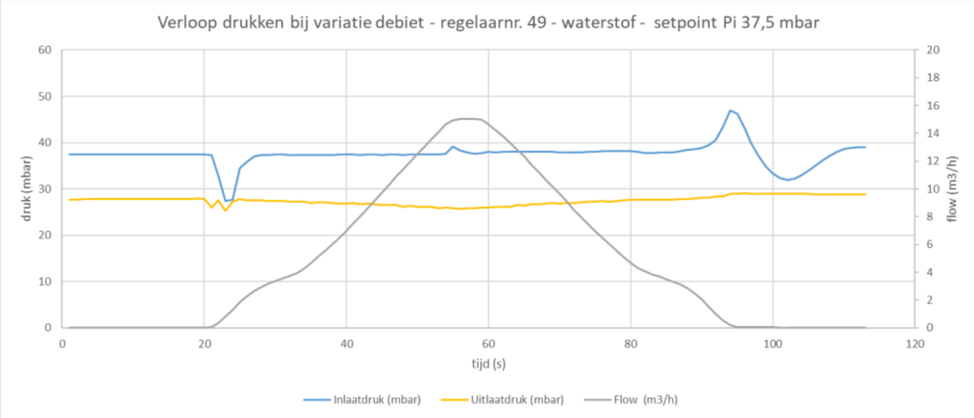

Regelkarakteristiek - regelaarnr. 48 - aardgas - setpoint Pi 37,5 mbar
Q Nominal flow m^3/h 5
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)

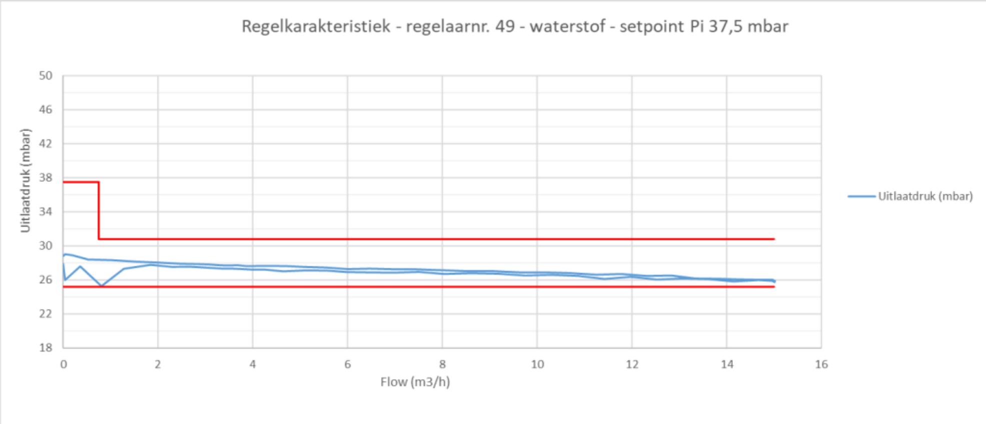

Verloop drukken bij variatie debiet - regelaarnr. 48 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

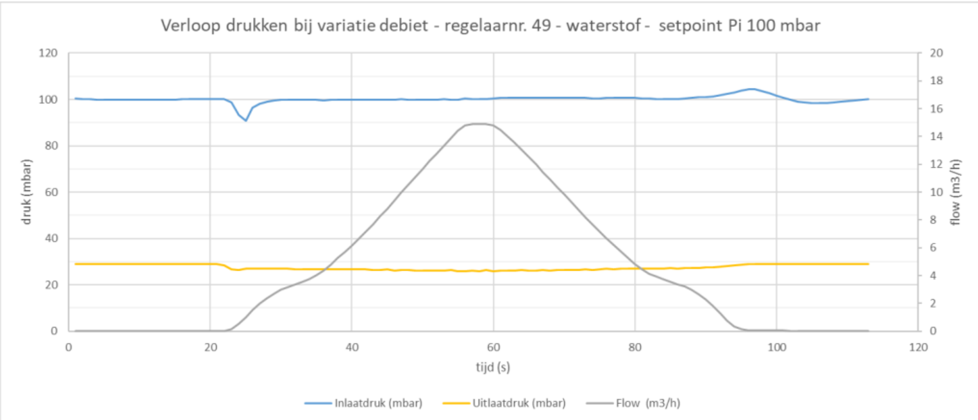

Regelkarakteristiek - regelaarnr. 48 - waterstof - setpoint Pi 100 mbar
Q Nominal flow m^3/h 15
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)

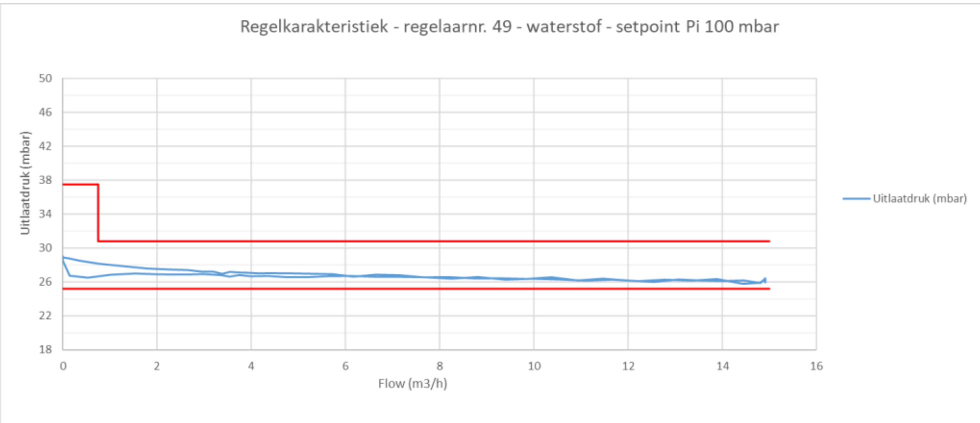

Verloop drukken bij variatie debiet - regelaarnr. 48 - aardgas - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

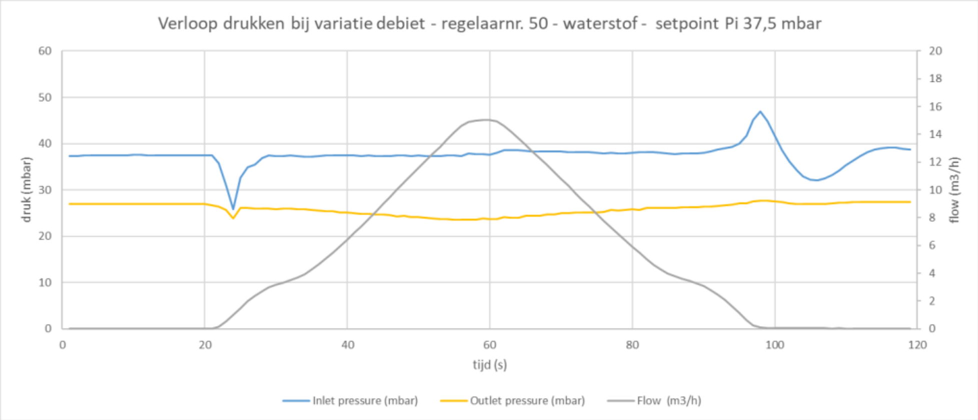

Regelkarakteristiek - regelaarnr. 48 - aardgas - setpoint Pi 100 mbar
Q Nominal flow m^3/h 5
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)

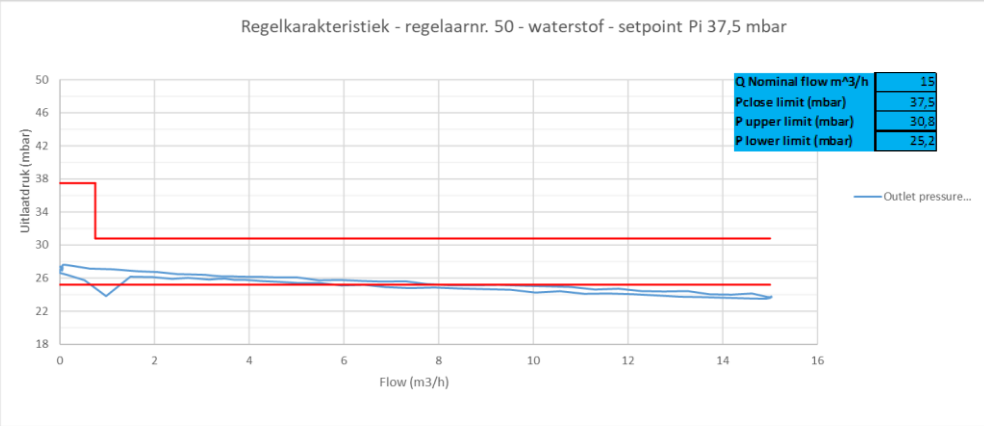

Verloop drukken bij variatie debiet - regelaarnr. 49 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

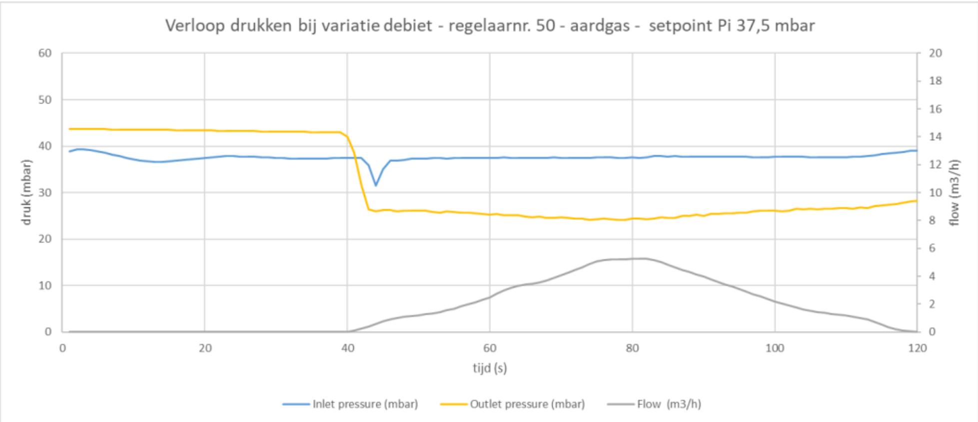

Regelkarakteristiek - regelaarnr. 49 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

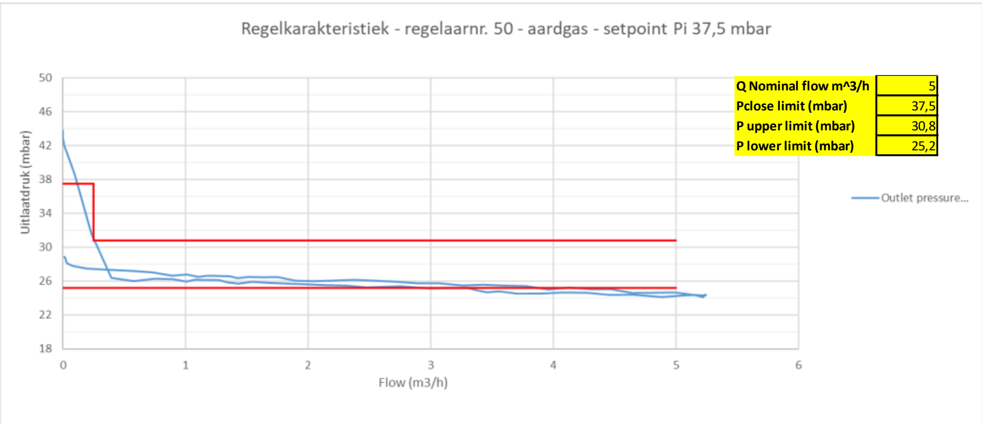

Verloop drukken bij variatie debiet - regelaarnr. 49 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

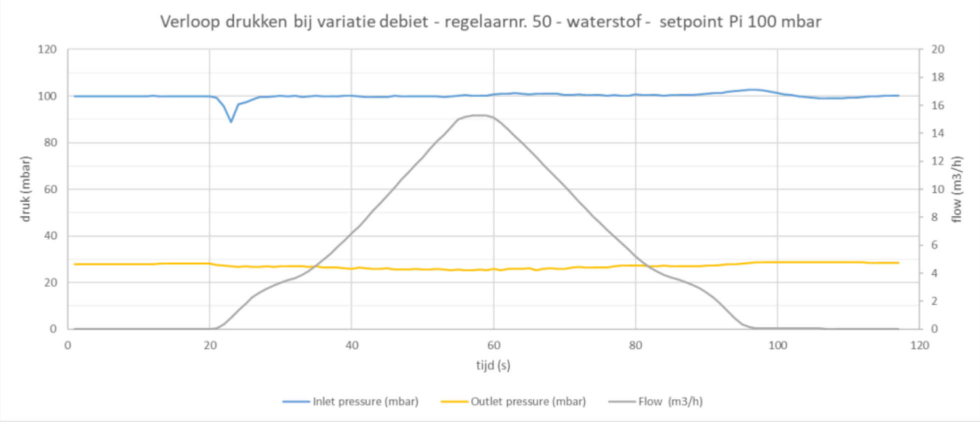

Regelkarakteristiek - regelaarnr. 49 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

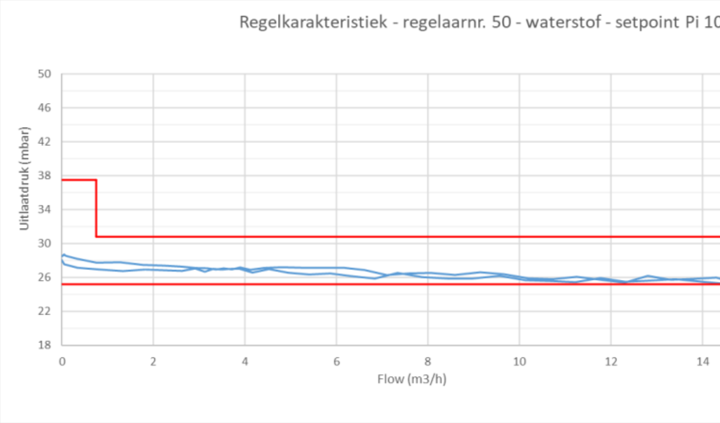

Verloop drukken bij variatie debiet - regelaarnr. 50 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlet pressure (mbar)
Outlet pressure (mbar)
Flow (m3/h)


Regelkarakteristiek - regelaarnr. 50 - waterstof - setpoint Pi 37,5 mbar
Q Nominal flow m^3/h 15
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Outlet pressure...

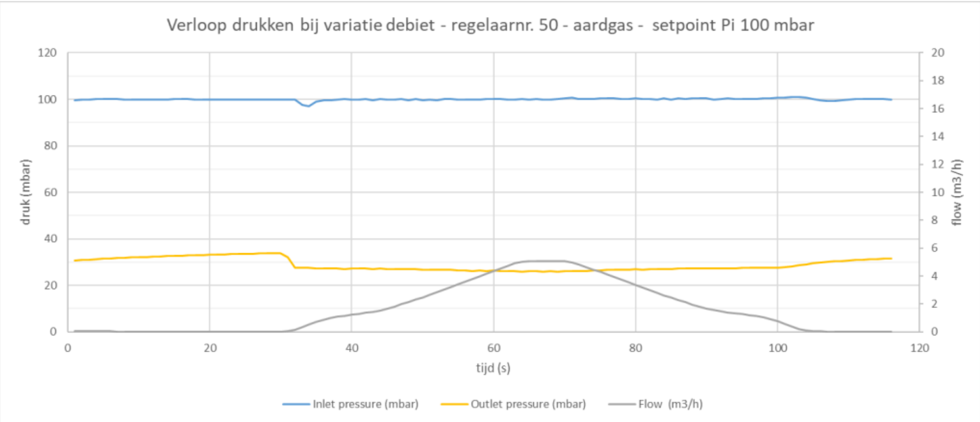

Verloop drukken bij variatie debiet - regelaarnr. 50 - aardgas - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlet pressure (mbar)
Outlet pressure (mbar)
Flow (m3/h)

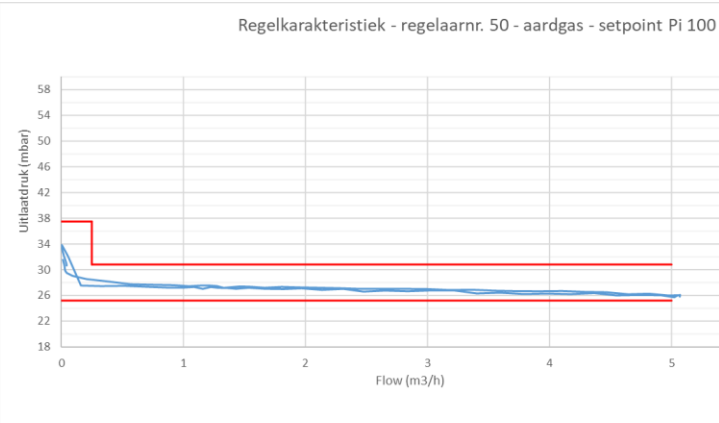

Regelkarakteristiek - regelaarnr. 50 - aardgas - setpoint Pi 37,5 mbar
Q Nominal flow m^3/h 5
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Outlet pressure...



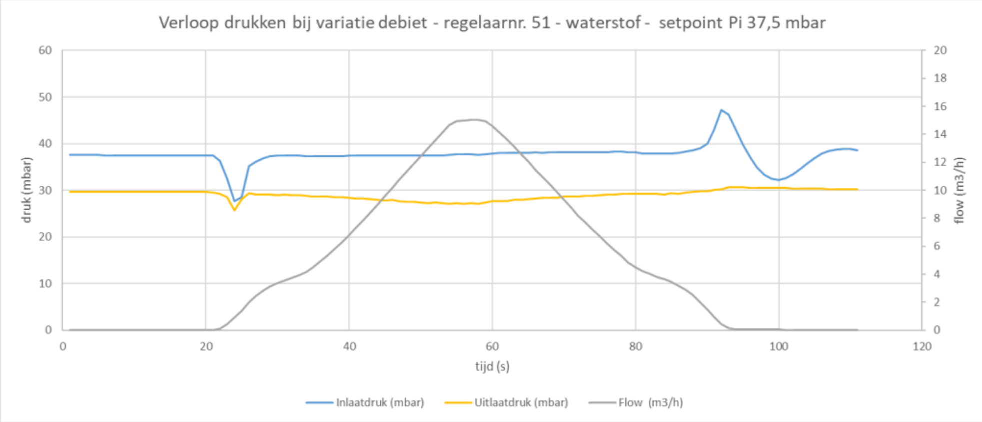


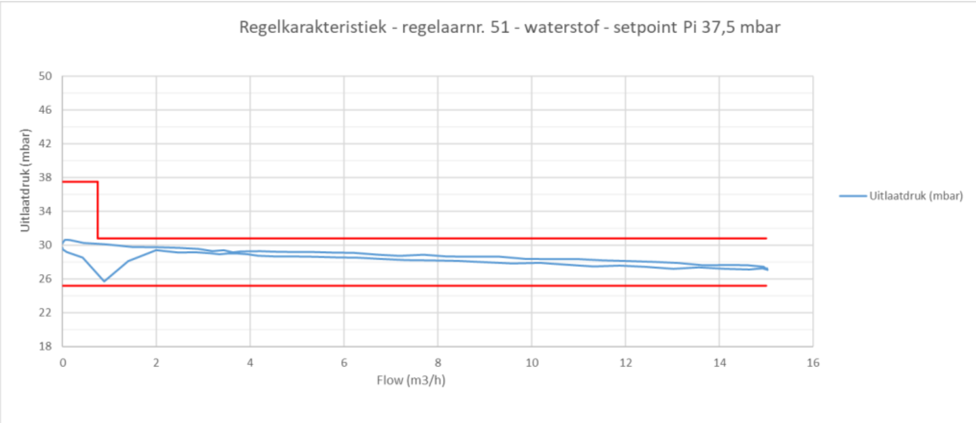
Q Nominal flow m^3/h	15
Pclose limit (mbar)	37,5
P upper limit (mbar)	30,8
P lower limit (mbar)	25,2

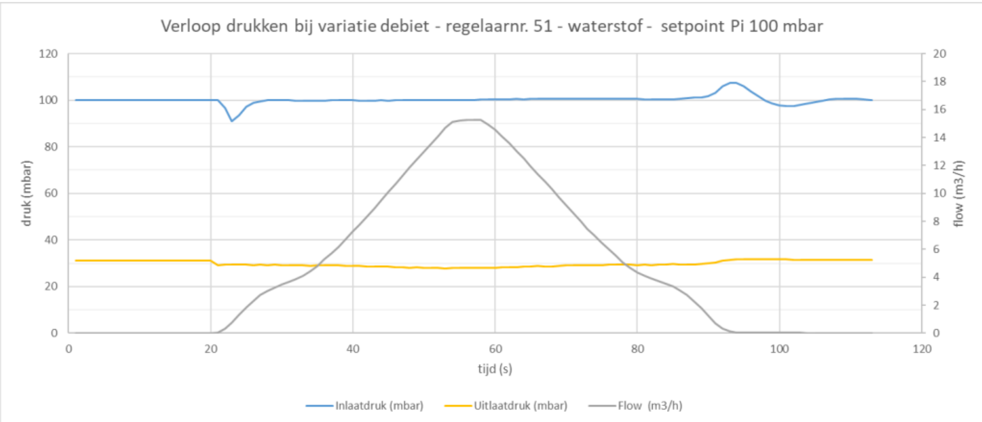


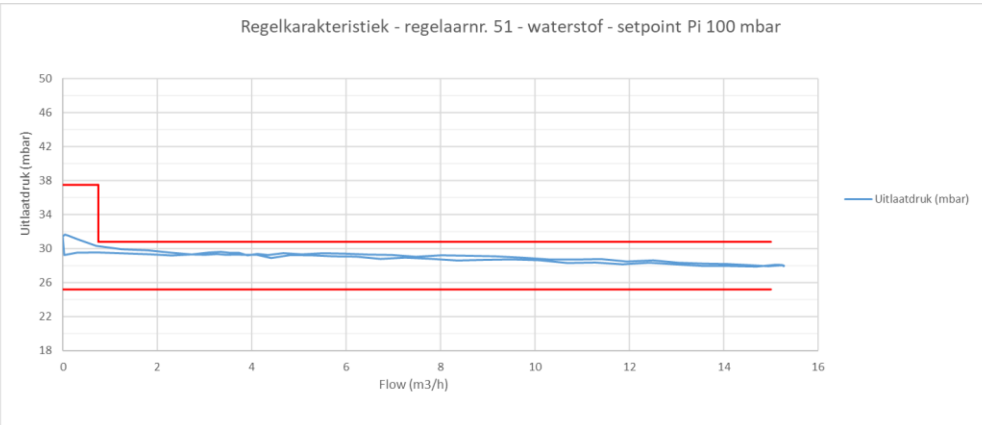


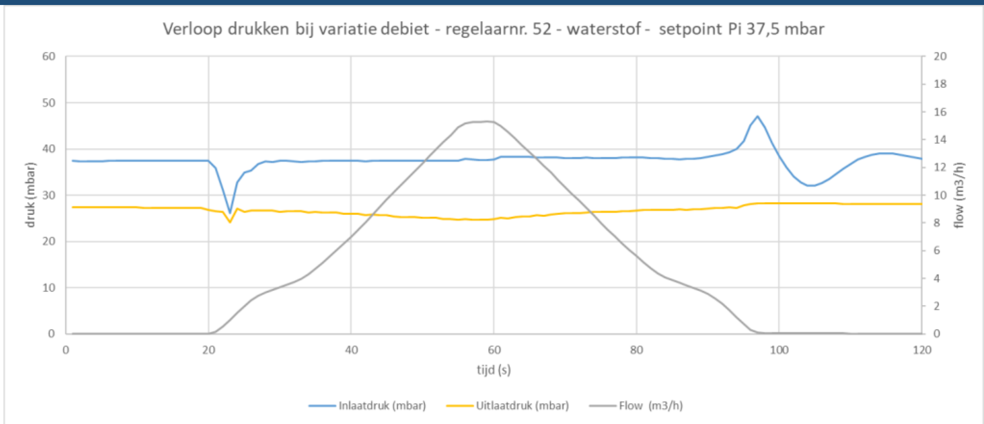
Q Nominal flow m^3/h	5
Pclose limit (mbar)	37,5
P upper limit (mbar)	30,8
P lower limit (mbar)	25,2

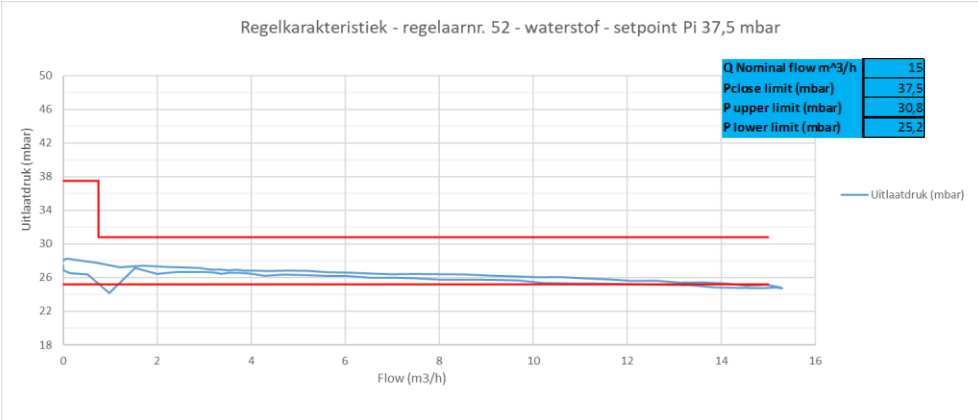

Verloop drukken bij variatie debiet - regelaarnr. 51 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

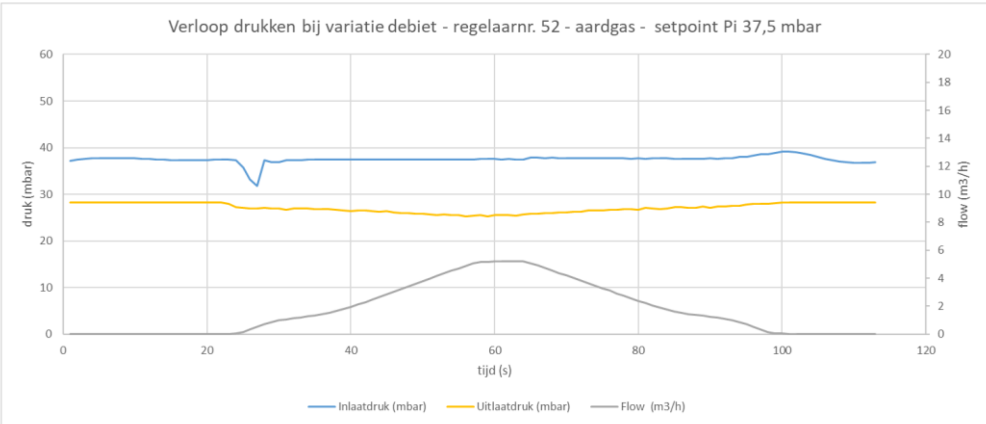

Regelkarakteristiek - regelaarnr. 51 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

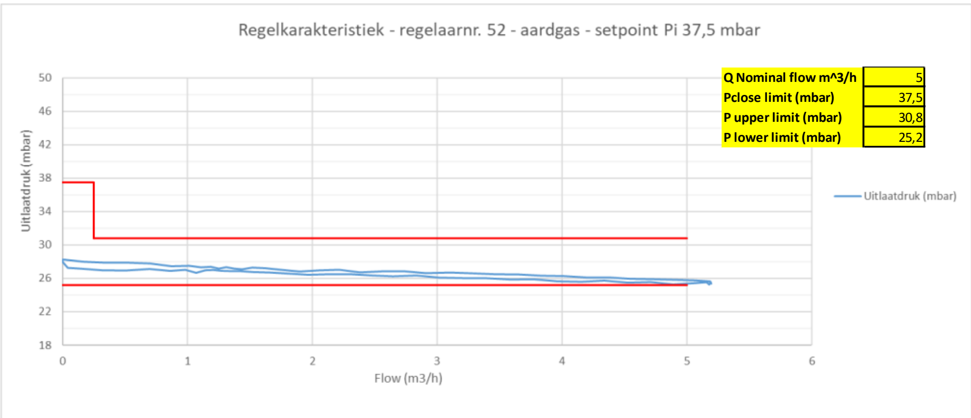

Verloop drukken bij variatie debiet - regelaarnr. 51 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

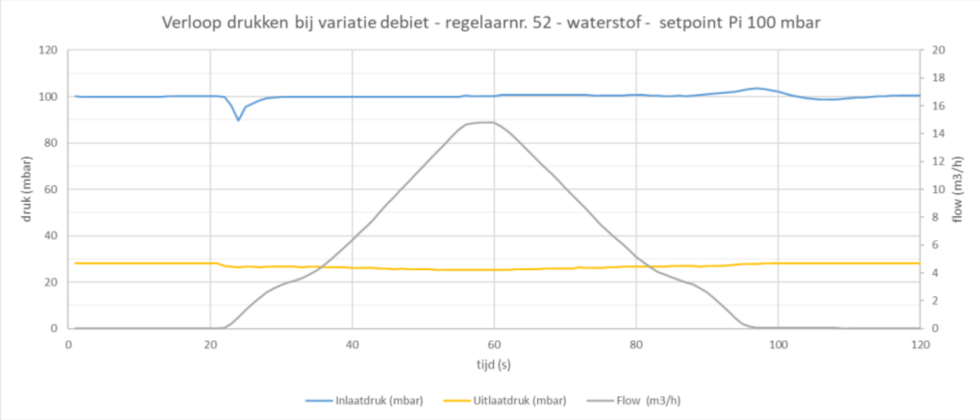

Regelkarakteristiek - regelaarnr. 51 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

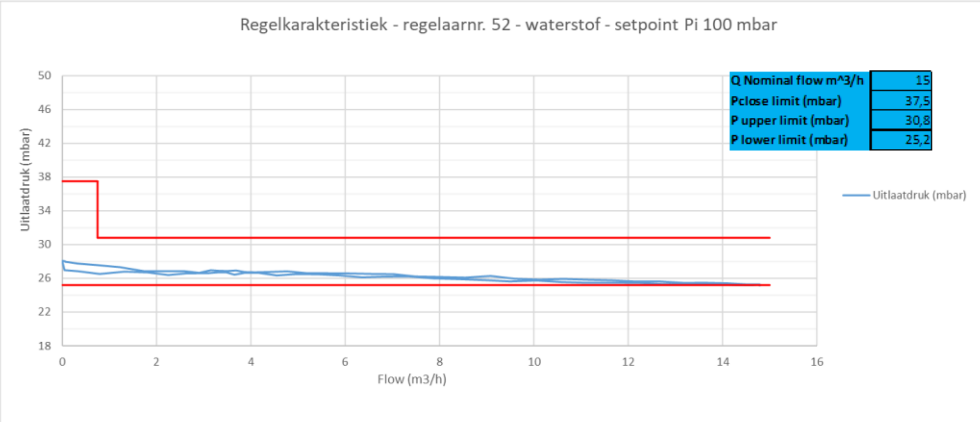

Verloop drukken bij variatie debiet - regelaarnr. 52 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

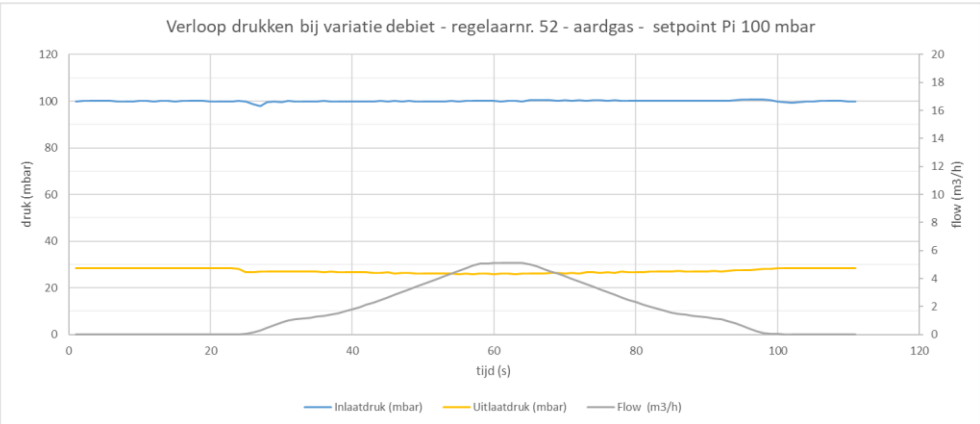

Regelkarakteristiek - regelaarnr. 52 - waterstof - setpoint Pi 37,5 mbar
Q Nominal flow m^3/h 15
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

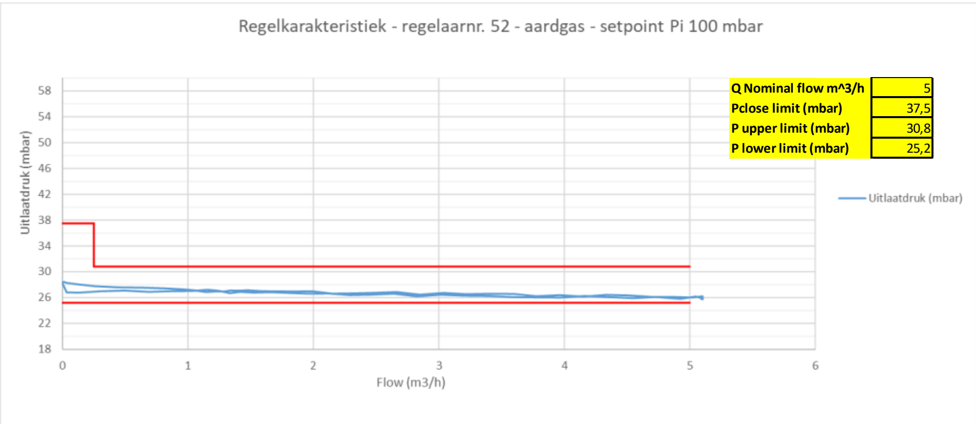

Verloop drukken bij variatie debiet - regelaarnr. 52 - aardgas - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

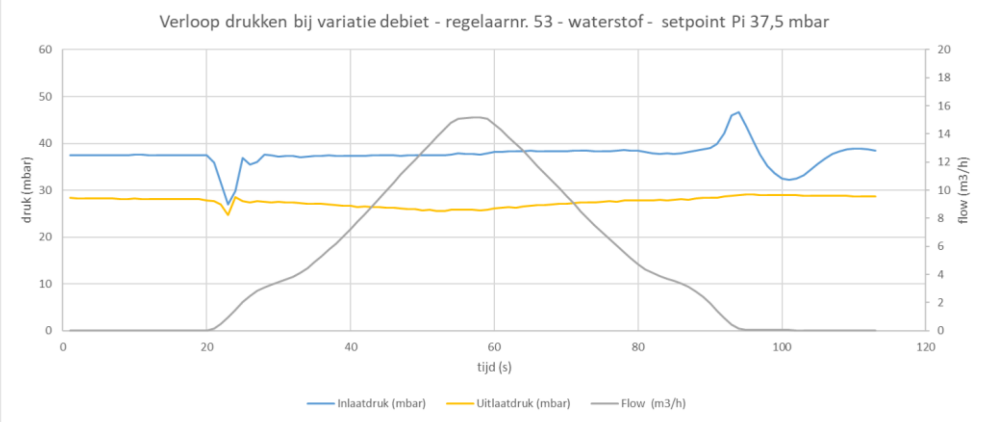

Regelkarakteristiek - regelaarnr. 52 - aardgas - setpoint Pi 37,5 mbar
Q Nominal flow m^3/h 5
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

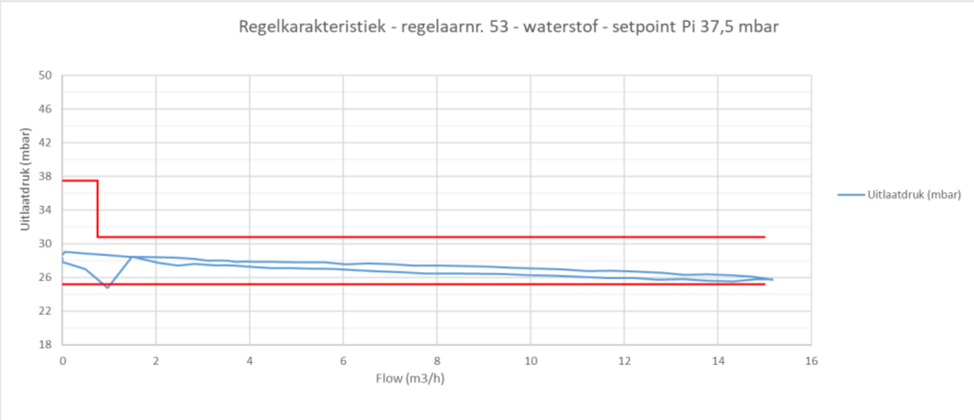

Verloop drukken bij variatie debiet - regelaarnr. 52 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)

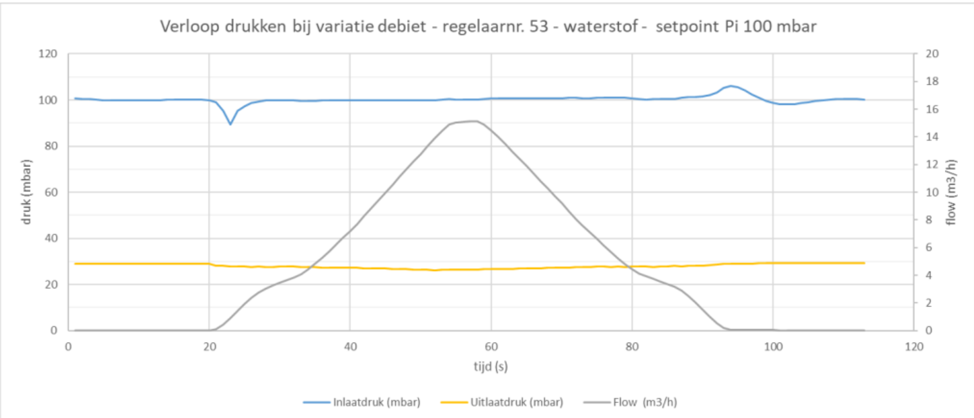

Regelkarakteristiek - regelaarnr. 52 - waterstof - setpoint Pi 100 mbar
Q Nominal flow m^3/h 15
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)

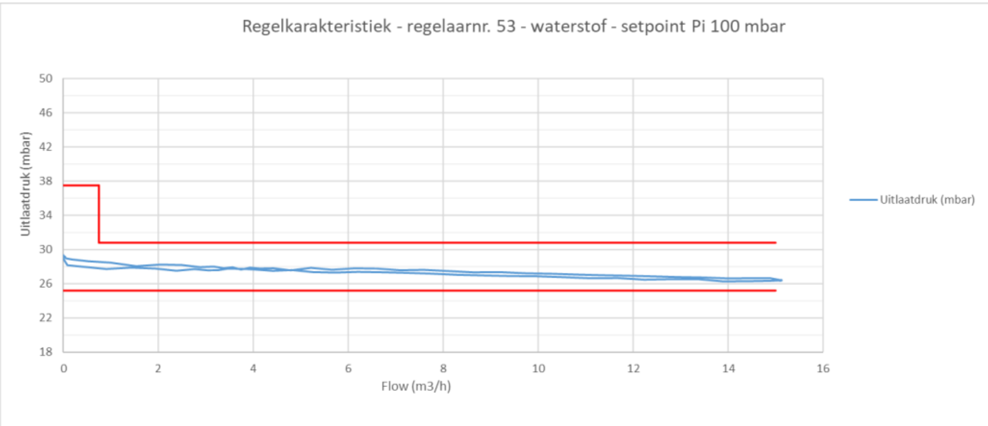

Verloop drukken bij variatie debiet - regelaarnr. 52 - aardgas - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)


Regelkarakteristiek - regelaarnr. 52 - aardgas - setpoint Pi 100 mbar
Q Nominal flow m^3/h 5
Pclose limit (mbar) 37,5
P upper limit (mbar) 30,8
P lower limit (mbar) 25,2
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)


Verloop drukken bij variatie debiet - regelaarnr. 53 - waterstof - setpoint Pi 37,5 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)


Regelkarakteristiek - regelaarnr. 53 - waterstof - setpoint Pi 37,5 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)


Verloop drukken bij variatie debiet - regelaarnr. 53 - waterstof - setpoint Pi 100 mbar
druk (mbar)
flow (m3/h)
tijd (s)
Inlaatdruk (mbar)
Uitlaatdruk (mbar)
Flow (m3/h)


Regelkarakteristiek - regelaarnr. 53 - waterstof - setpoint Pi 100 mbar
Uitlaatdruk (mbar)
Flow (m3/h)
Uitlaatdruk (mbar)