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KROHNE
measure the facts

Comparing an ultrasonic gas meter with a turbine meter measuring pure hydrogen in a field situation

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Productie Proces Automatisering
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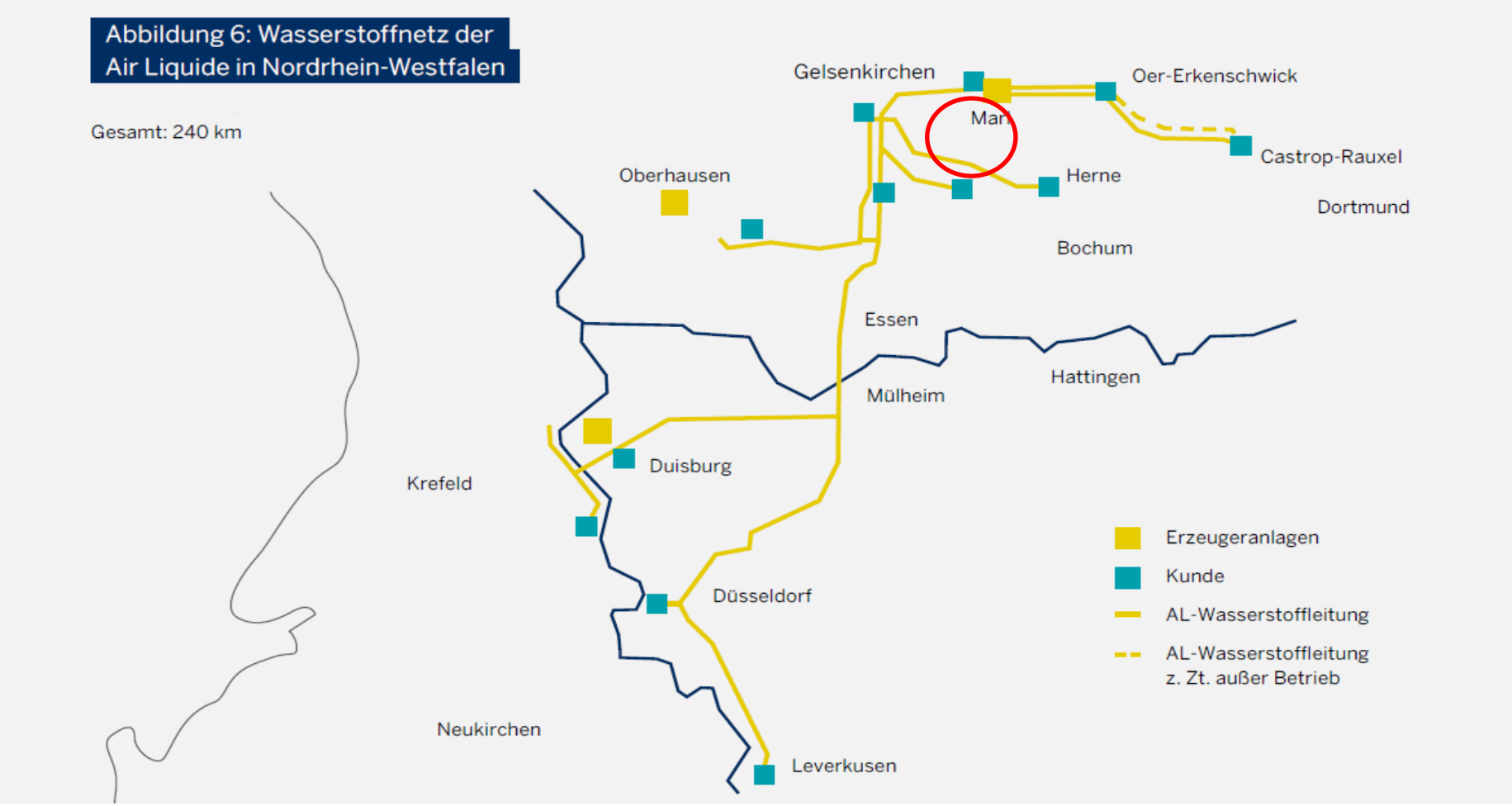
Project organization

- Initiator:
- Dr. Idriz Krajcin,
  Open Grid Europe GmbH

- In cooperation with:
- Stefan Chudoba,
  Evonik Operations GmbH

Hydrogen pipeline network of Air Liquide in Germany



Source:

Wasserstoff Roadmap,

www.wirtschaft.nrw

H2 measurement at Evonik / Marl

Medium: pure Hydrogen

Pipe diameter: DN250

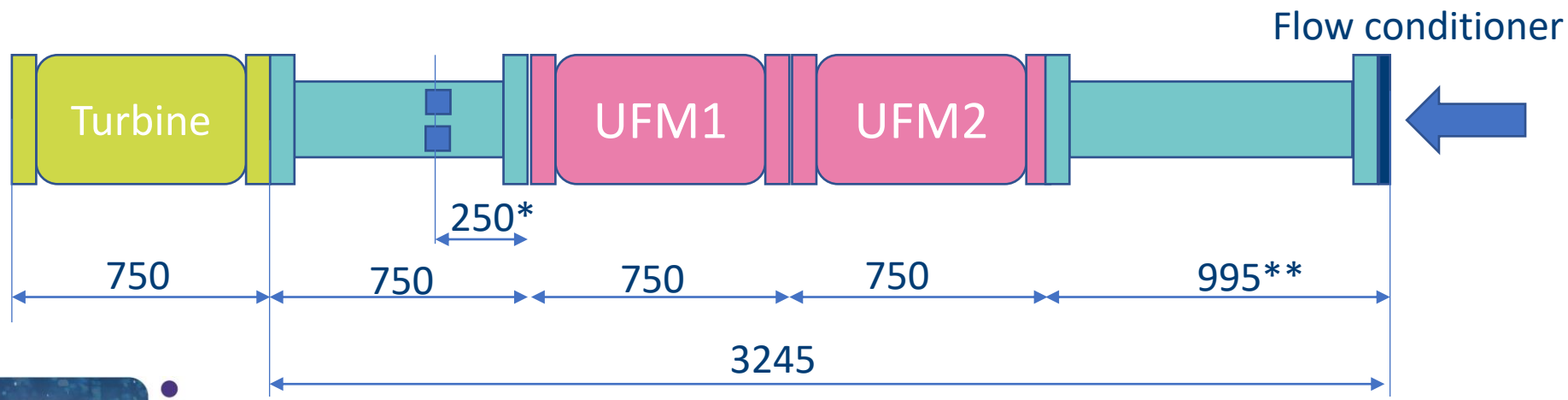
Pressure: 19 bar

Design pressure PN 25/DP40

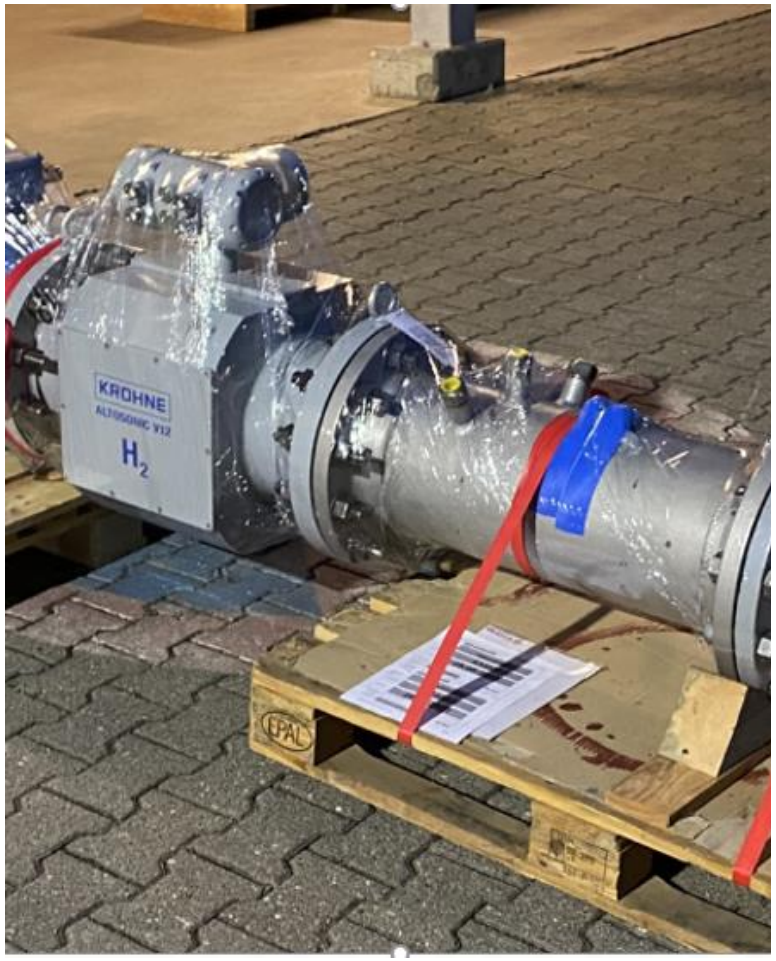
Volumeflow measurement:
Instromet Turbine flowmeter,
Year of manufacturing: 1987

Flow computer:
Elster Z1 / Tabellenwerte

Fieldtest at Evonik / project setup

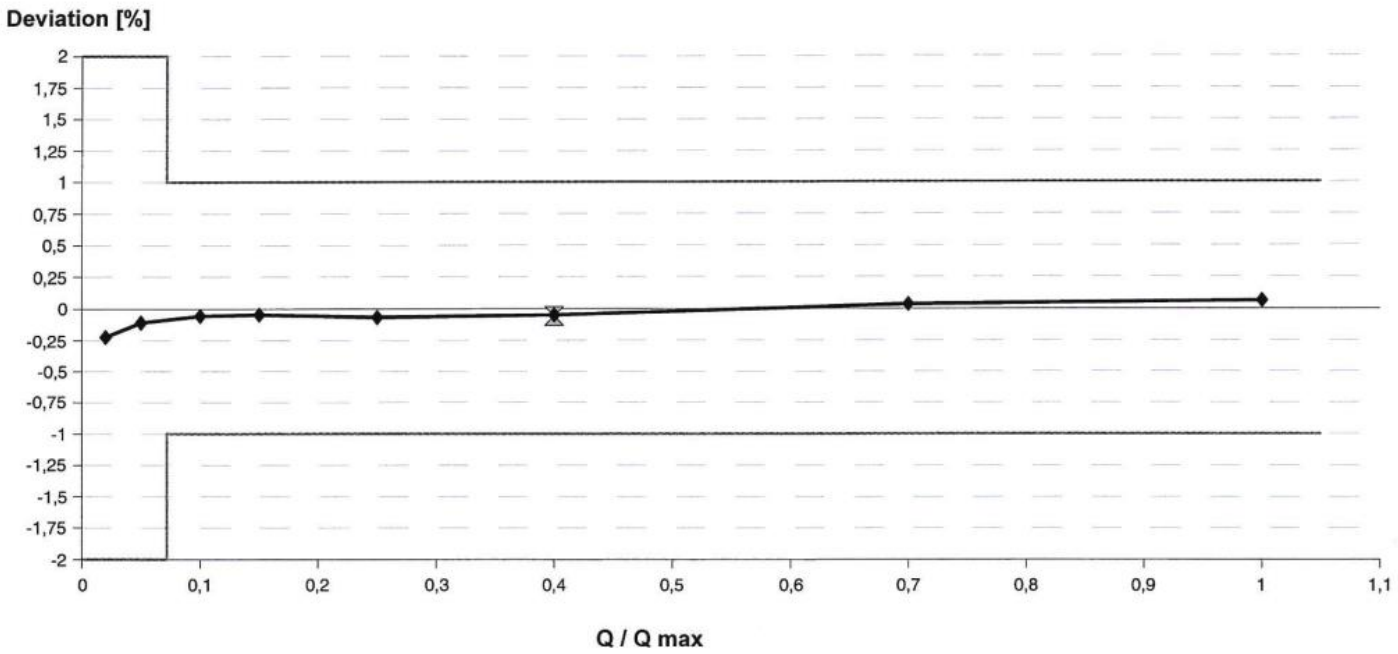


Meterrun verified/calibrated at Pigsar



Error Curve

Type of meter:	Ultrasonic meter	Customer:	Open Grid Europe GmbH	DN:	250 mm	p(abs):	17	bar	HF	2000,00	pulses / m³
Meter no:	A21047592 - forward	Manufacturer:	Krohne	Size:	10"	Q max:	3000	m³/h	HF	2000,00	pulses / m³
Date:	2021-09-28	Gear 1:	-			Q min:	50	m³/h	-		pulses / m³
Inspector:	Hüwener	Gear 2:	-			-		pulses / m³	-		pulses / m³



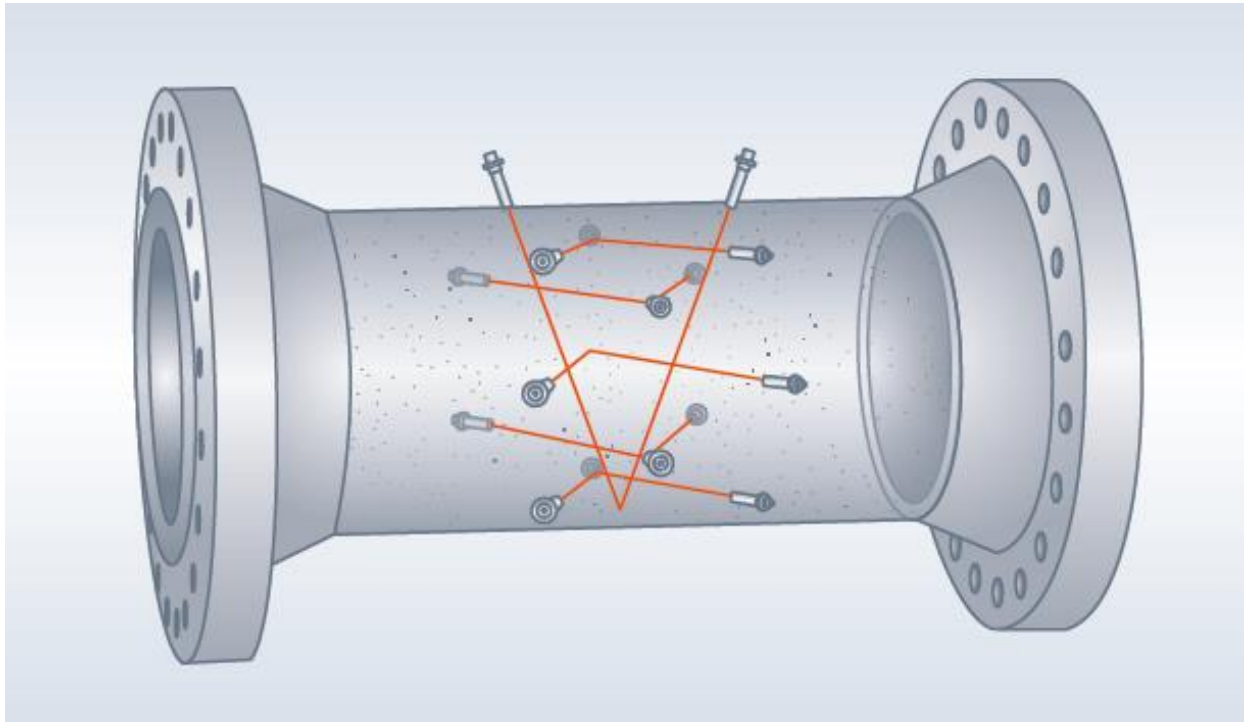
Installation at Evonik-site / Marl, Germany

Design of ultrasonic flowmeter

Path configuration: ALTOSONIC V12:

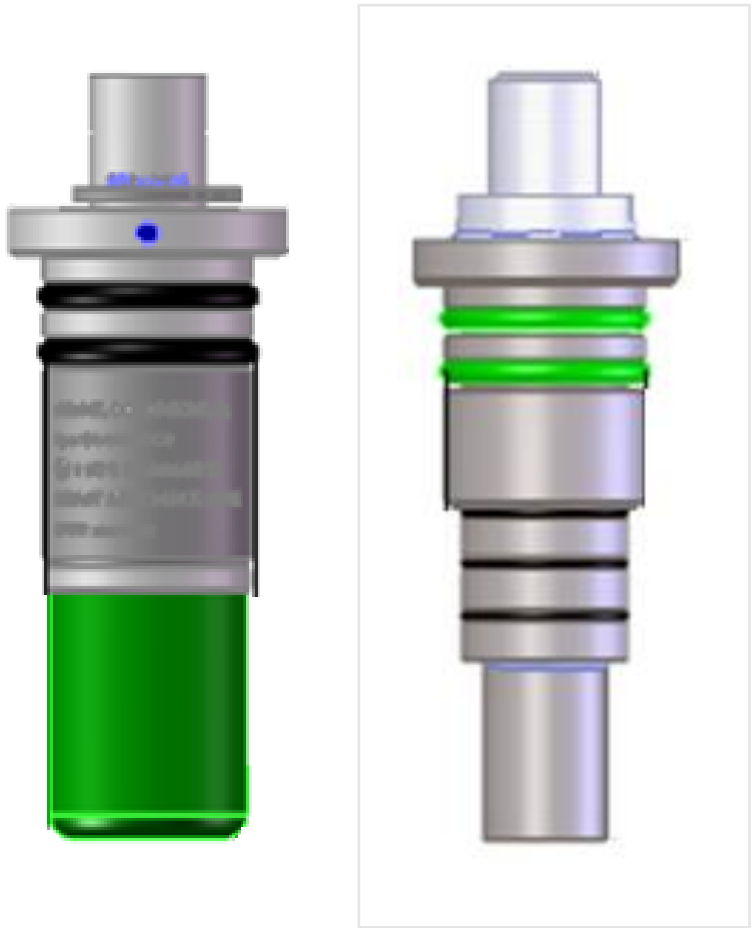
- Flowmeasurement on 5 parallel horizontal planes,
  2 cords per plane, reflective
- Diametric middle path, makes it suitable for low Renolds
- 1 diagnostic vertical path,
  2 cords, reflective

Transducer frequency: 270 kHz



Design of ultrasonic flowmeter

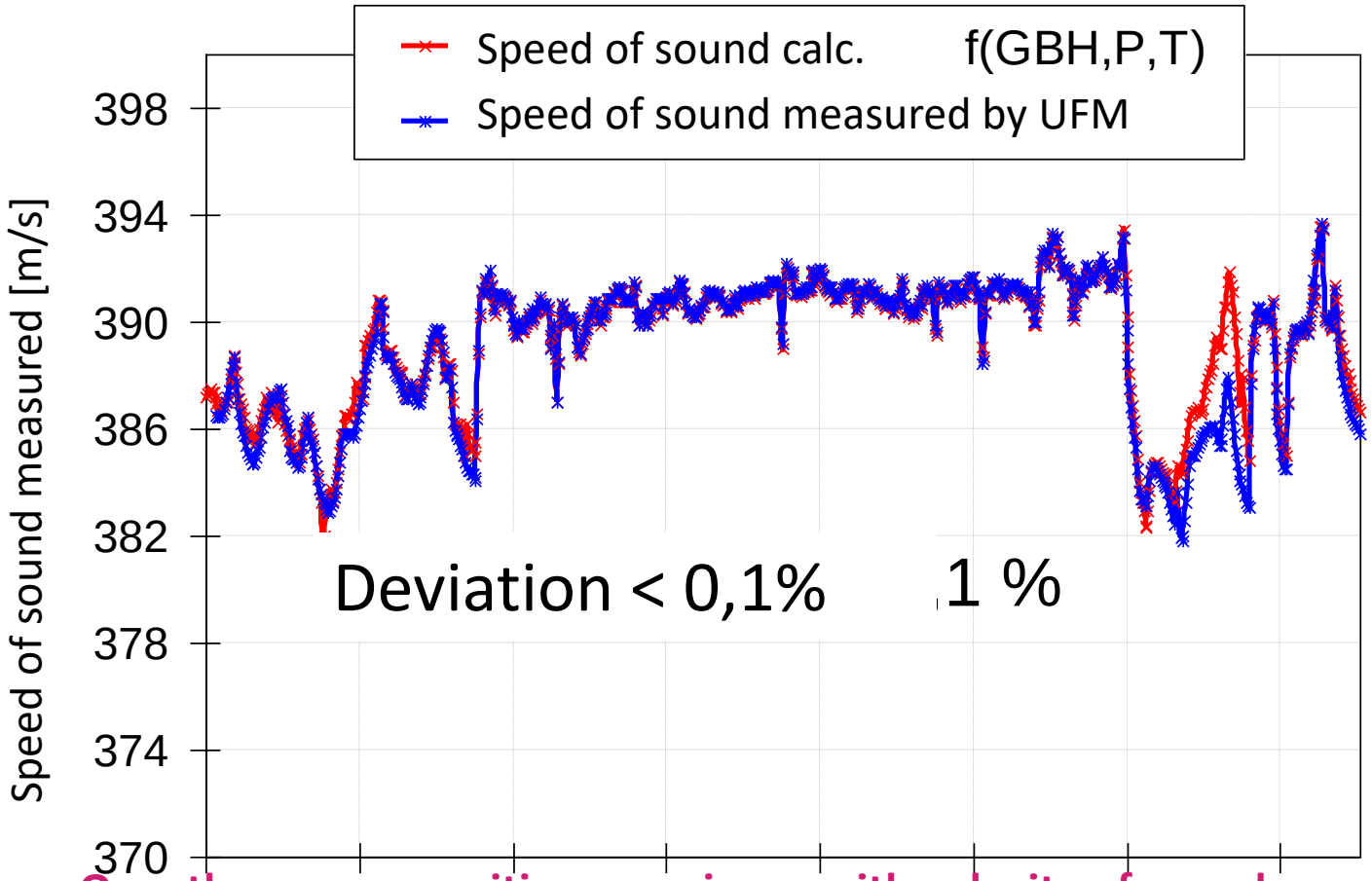
- **Ultrasonic transducers:**
- Epoxy / SS transducers can be used.
- Not resonation based, frequency variation possible
- Lower efficiency, only for pressurised hydrogen
- Titanium
- One frequency / resonation based
- High efficiency, can measure hydrogen at atmospheric pressure
- Hydrogen can cause embrittlement of titanium transducers,
- Application only when:
  - Low design pressure, low mechanical stress
  - Hydrogen is not pure / dry
  - Or temperature is below 80°C.



Evaluation of the velocity of sound

Calculation

$$C = \frac{L}{2} \cdot \left(\frac{1}{t_{MN}} + \frac{1}{t_{NM}} \right)$$



Over the years a positive experience with velocity of sound Measurement of natural gas

Calculation of the velocity of sound of H2 (theory)

Pressure 60 Bar, Temperature: 10°C

H2 [mol %]	100	99,9	99,9	99,85	99,8
O2 [mol %]	0	0,1	0	0,075	0,1
N2 [mol %]	0	0	0,1	0,075	0,1
Sos [m/s]	1334,52	1324,70	1326,01	1320,85	1316,38
	0 %	**-0,74 %**	**-0,64 %**	**-1,02 %**	**-1,36 %**

$$\frac{\Delta y/y}{\Delta x/x}$$

Sensitivity pressure 0,04

Sensitivity temperature 0,4

Sensitivity H2 part **6,5**

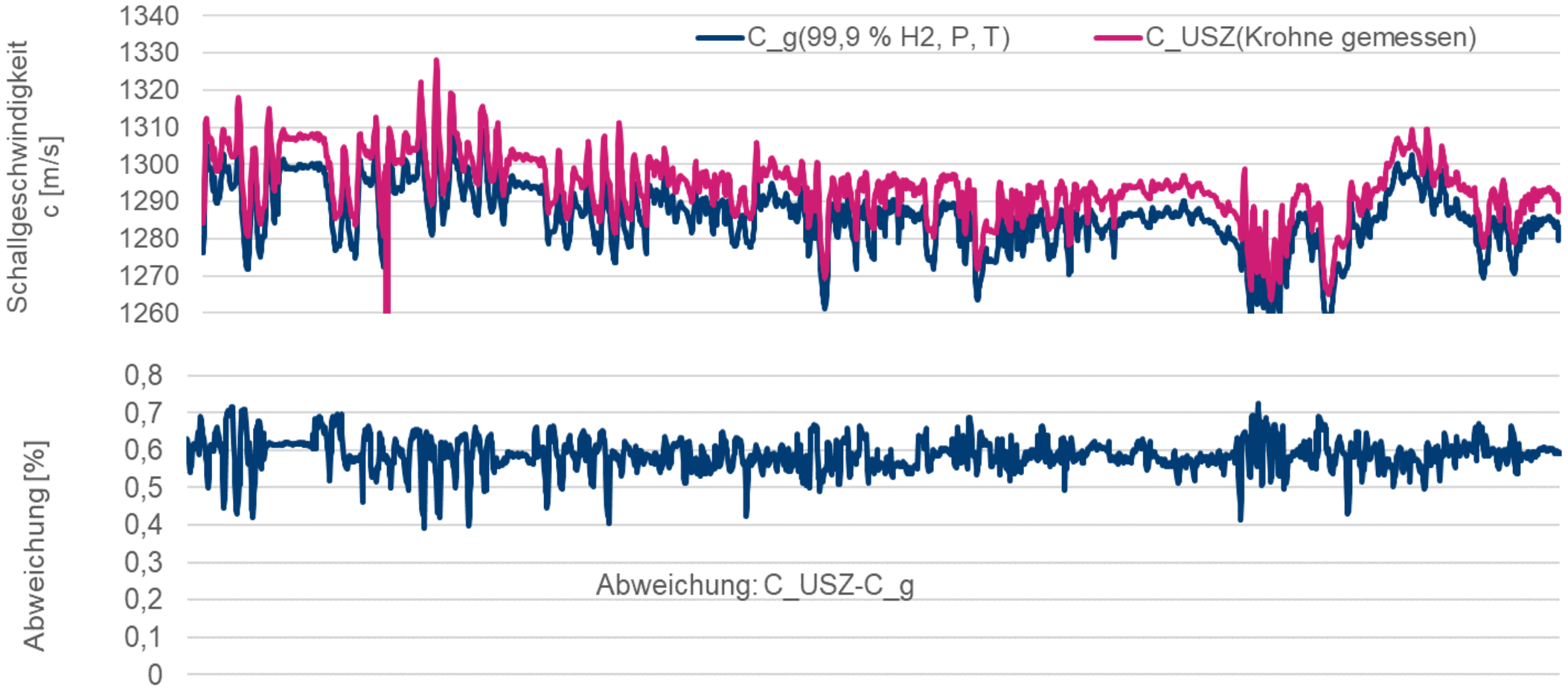
Velocity of sound

H2 ~ 1300 m/s

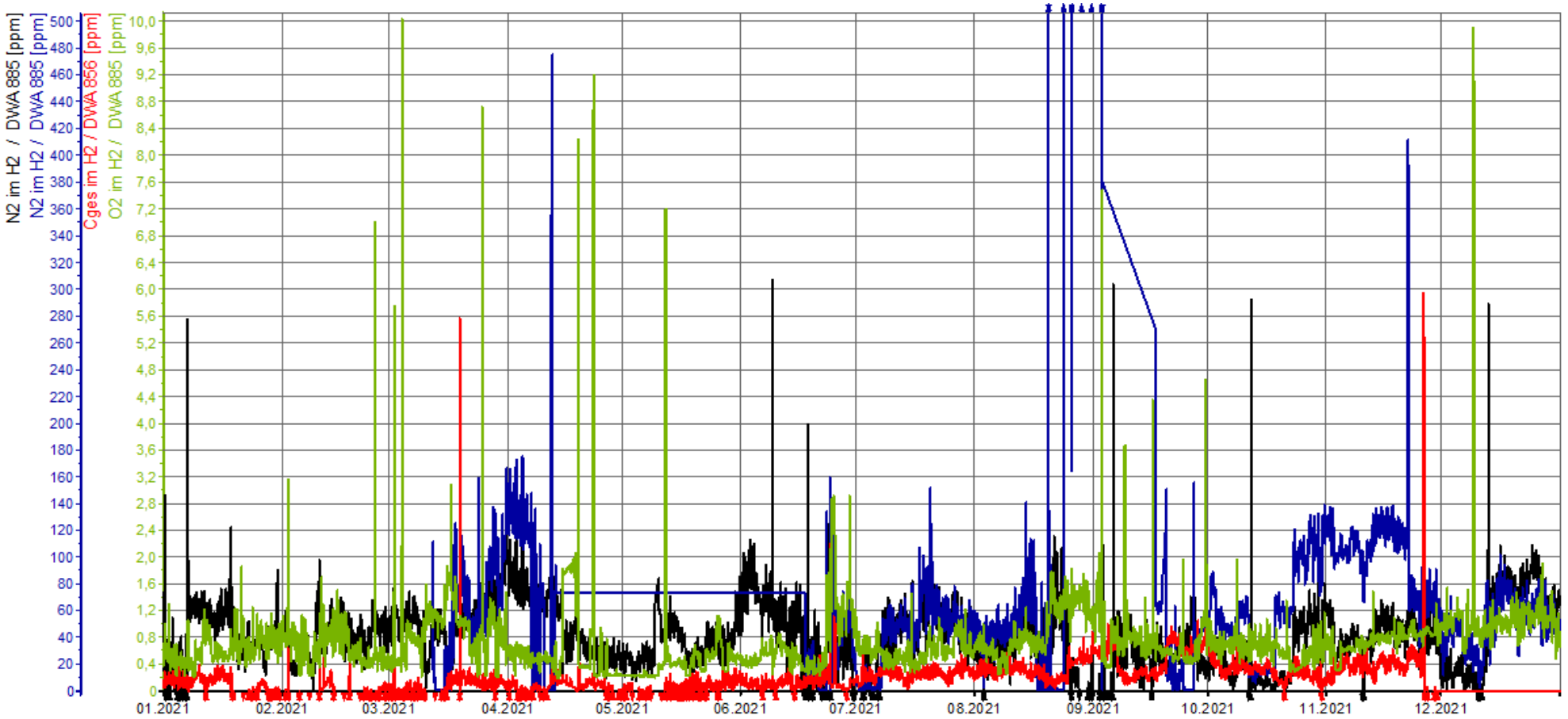
O2 / N2 ~ 330 m/s

Monitoring limit value H2 at 99,9 % purity

(measurement: 13. Oktober 2021 - 10. January 2022)

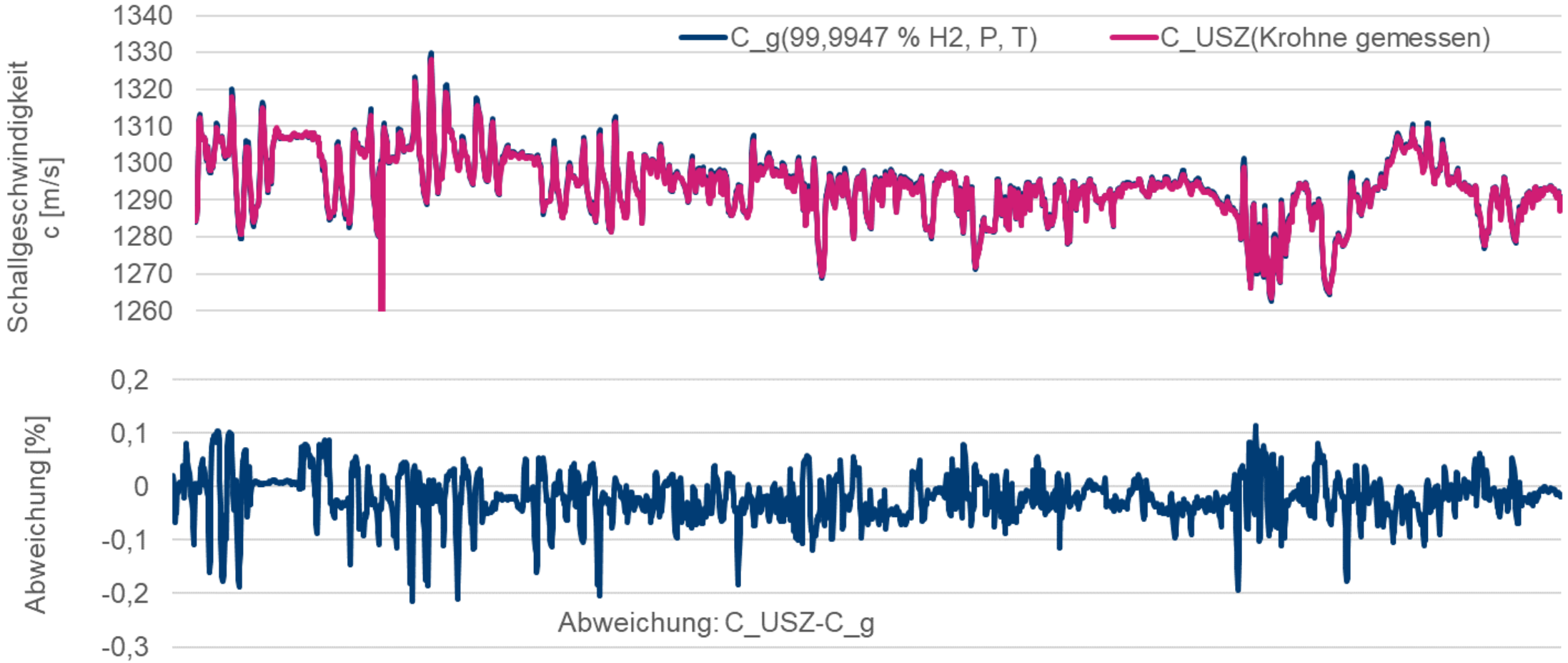


Representative H2 composition at the test site



Measured contamination of approx. 53 ppm

(Measured 13. October 2021 - 10. January 2022)



Determination of Volumes and comparison

$$v_{n,Turbine} = v_{b,Turbine} \frac{P_{Turbine}\, T_N}{T_{Turbine}\, P_N} + \frac{1}{K(P_{Turbine}, T_{Turbine}, x_g)}$$

$$v_{n,UFM1} = v_{b,UFM1} \frac{P_{UFM1}\, T_N}{T_{UFM1}\, P_N} + \frac{1}{K(P_{UFM1}, T_{UFM1}, x_g)}$$

$$Dev_{UFM1} = \frac{v_{n,UFM1} - v_{turbine}}{v_{turbine}} 100\ \%$$

Reynolds Ranges

Hydrogen has a lower standard density and thus a lower Reynolds number at the same flowrate, factor: 6,87

Re x 10^6	**0,01**	**0,03**	**0,1**	**0,19**	**0,25**	**0,3**	**0,51**	**0,75**	**1,27**	**2,04**	**3,53**	**5,06**
NG m³/h	5	20	62	110	150	175	300	450	750	1200	2100	3000
H2 m³/h	41	123	411	780	1030							

Turbine Q_{min} = 200 m³/h, Q_{max} = 4.000 m³/h

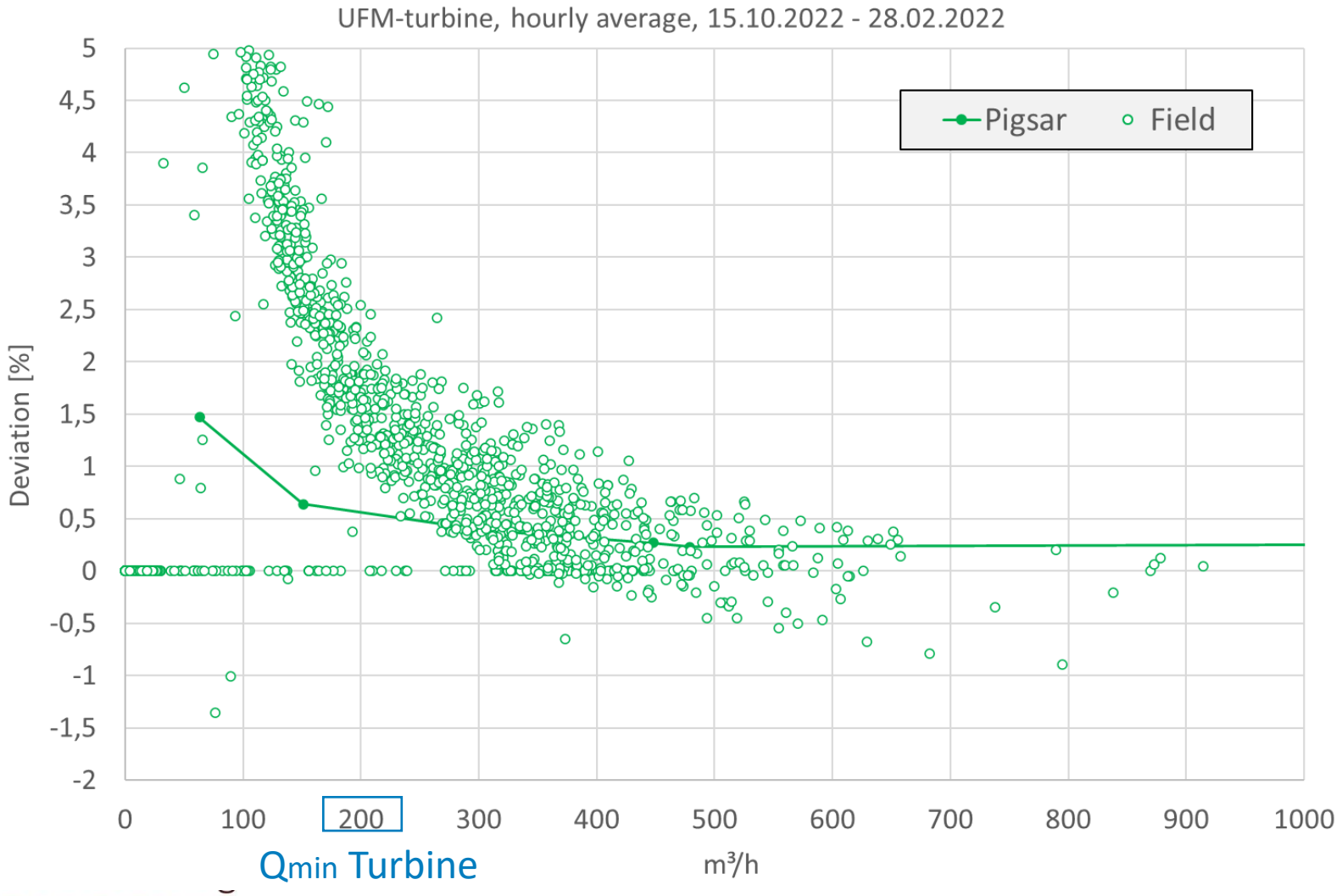
Calibration at Pigsar: Natural gas, 16 bar

Initial flow measurement result

Comparison of the difference between turbine and ultrasonic flowmeter against flowrate.

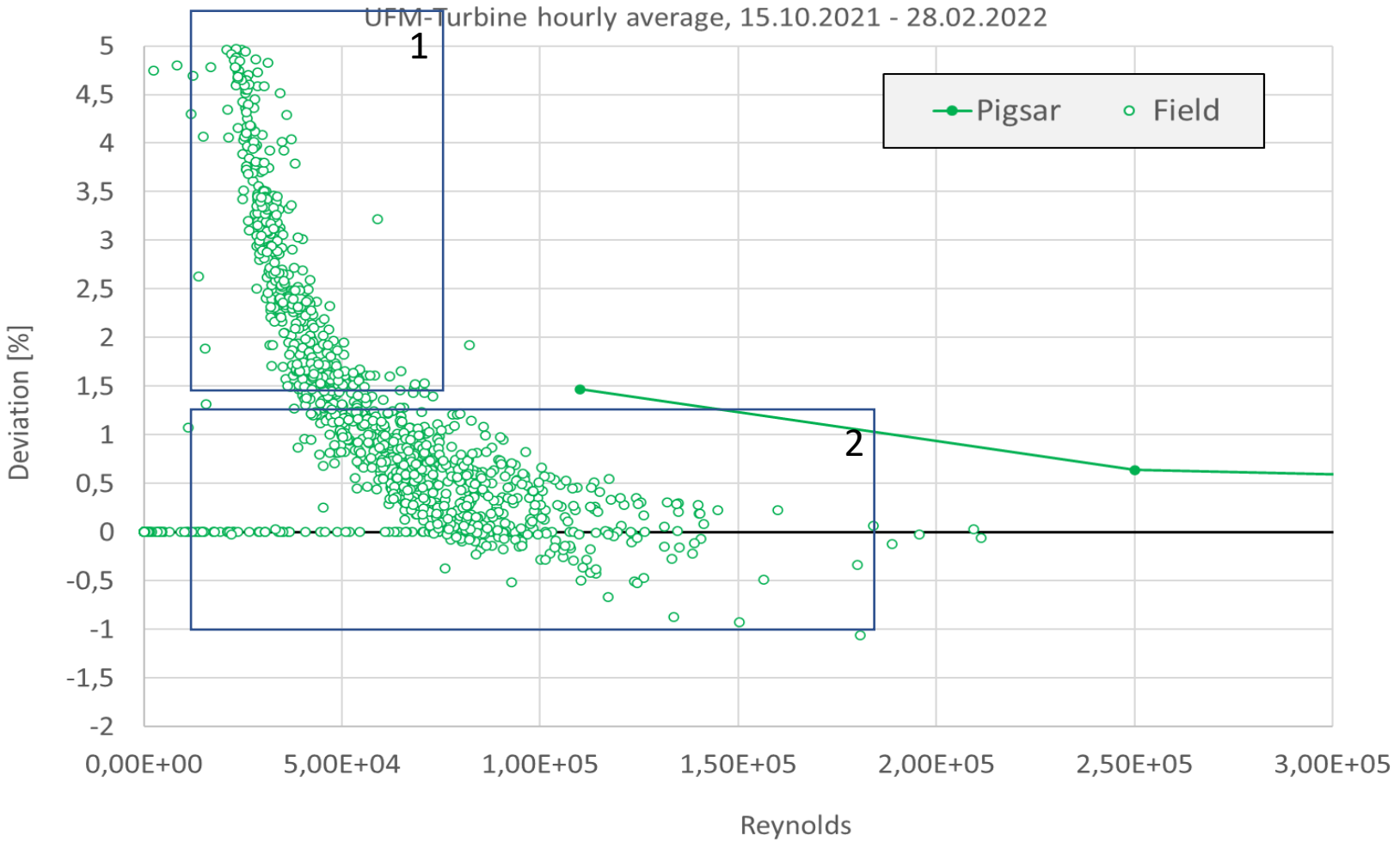
Each point is an average over one hour

Due to difference in density the results must be compared against Reynolds.



Initial flow measurement result

1. Low flowrate measured until end of 2021 is outside turbine range
2. At higher flowrate UFM shows deviation and spreading

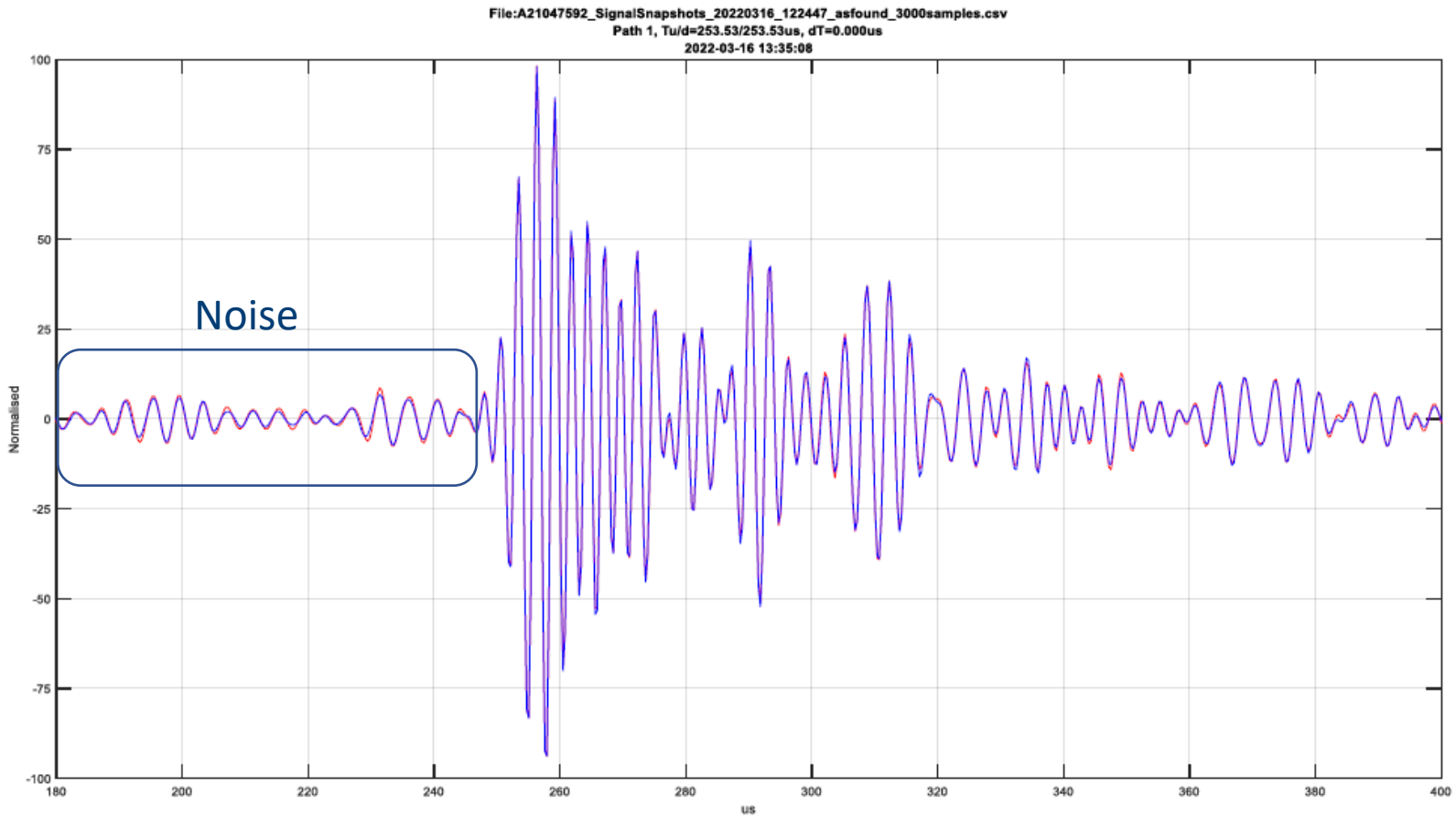


Optimization ultrasonic signal

The noise signal can be reduced by adjusting filter settings and transducer frequency.

Expected result:

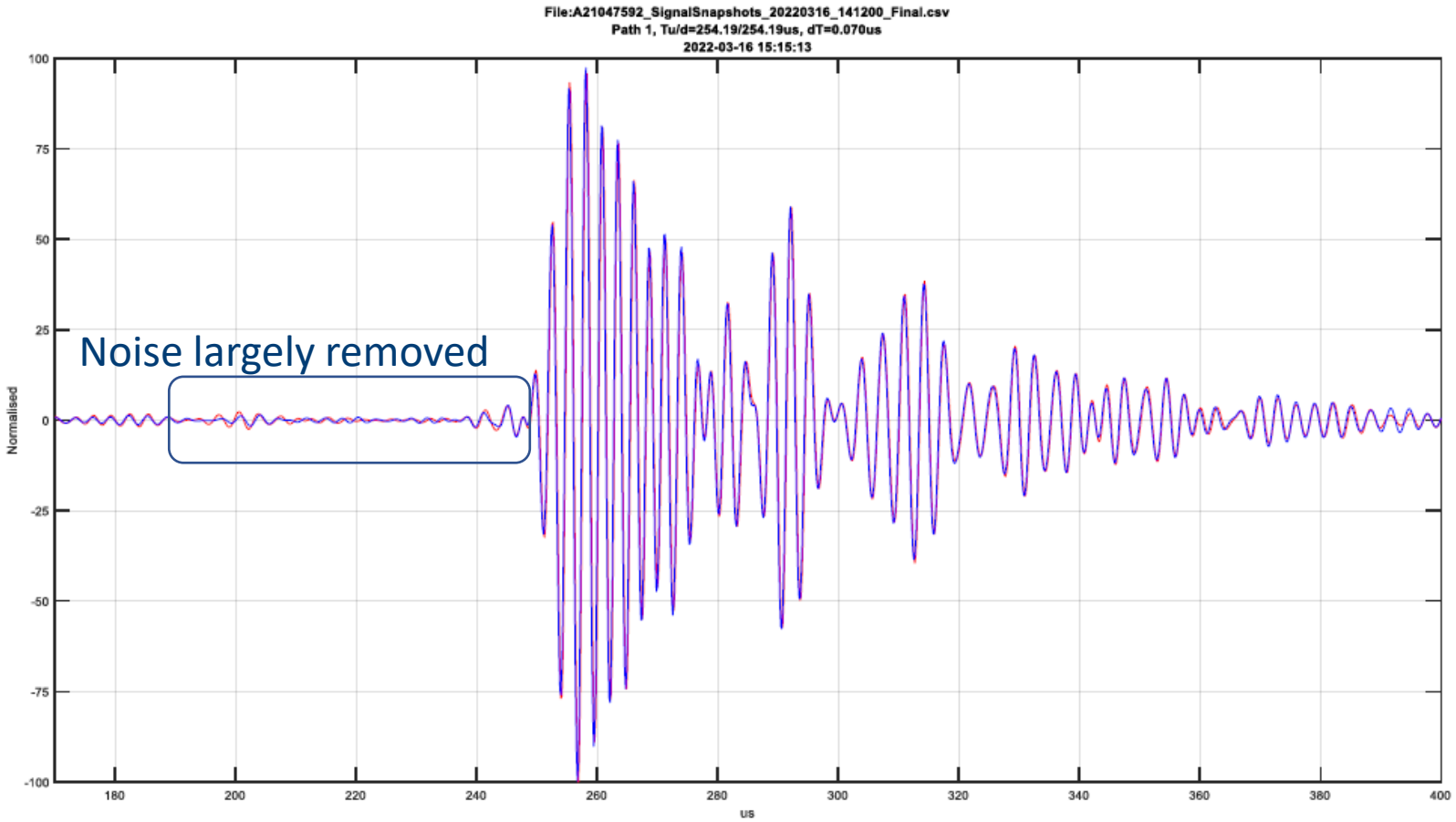
- Reduction of the deviation
- 50% reduction of scatter in the measurement results.



Optimization ultrasonic signal

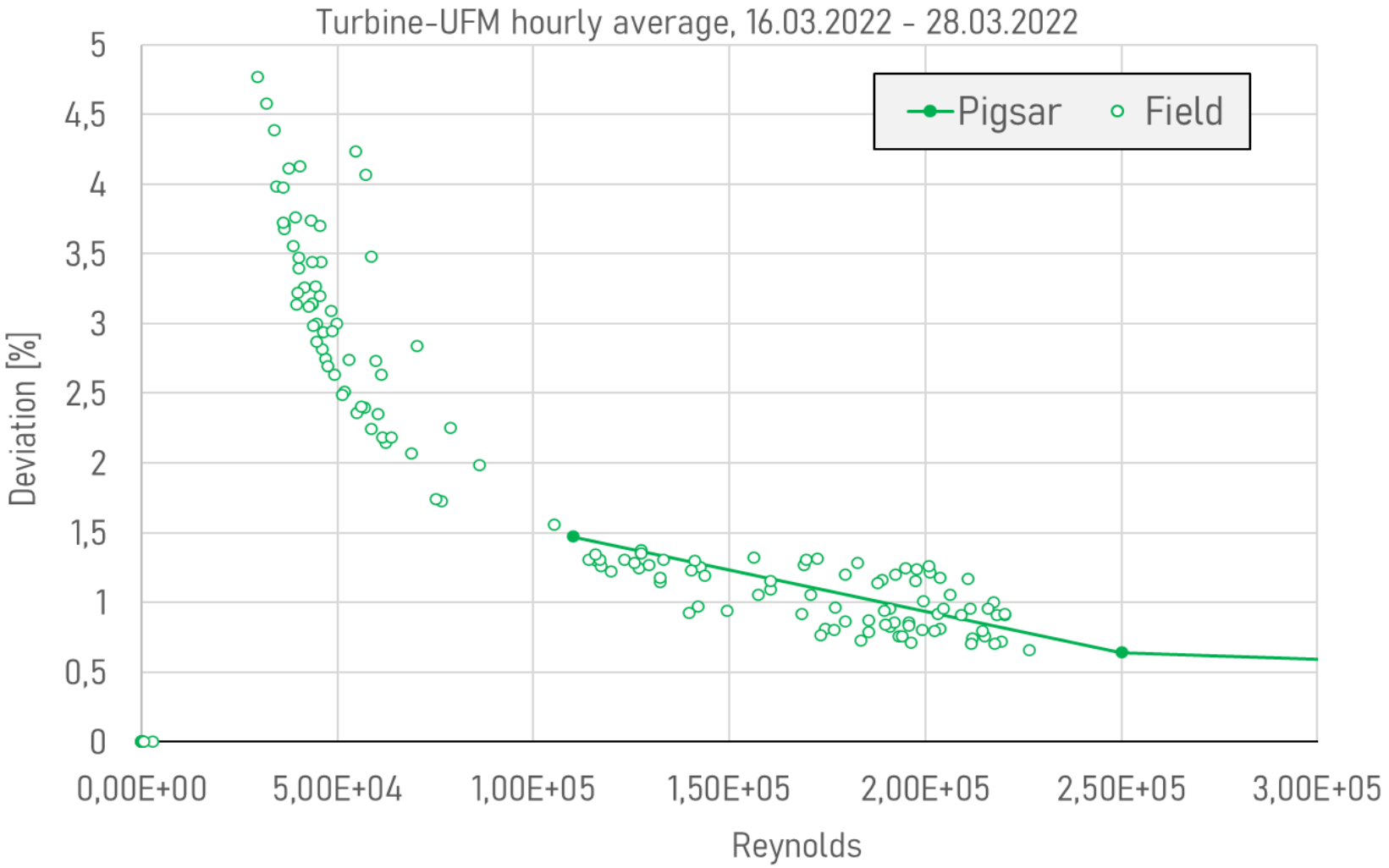
Signal Snapshot after optimization March 15, 2022

By changing filter parameters, the noise has largely been removed



Flowmeasurement result after optimization

After the optimization, the deviation with the turbine and the variation between the measurement results have strongly been reduced.

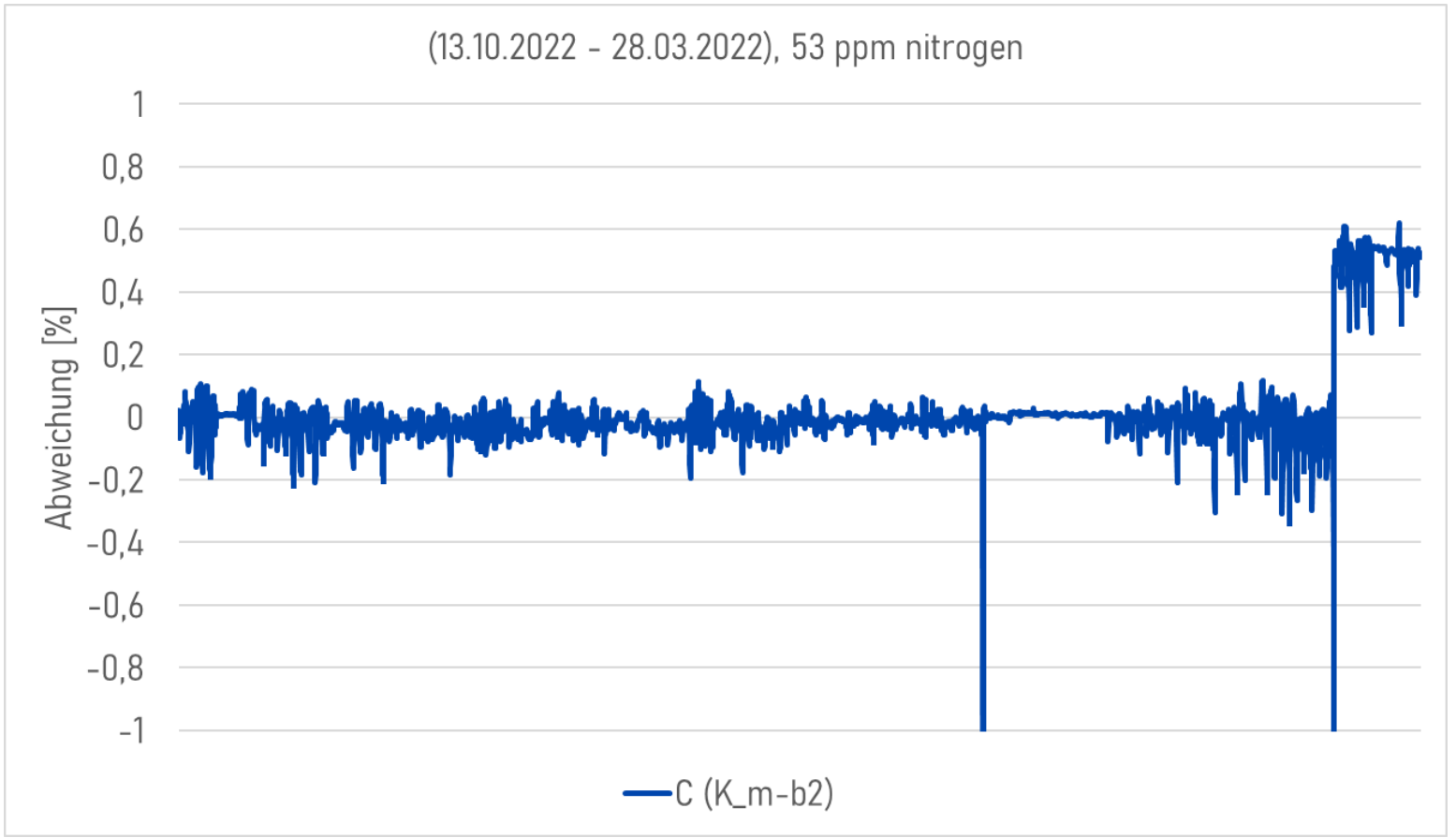


Changes in speed of sound measurement

Speed of sound increased after optimization of flow

Probably due to insufficient accuracy in determination of delay time.

- Related to the shorter transit time for hydrogen compared to natural gas

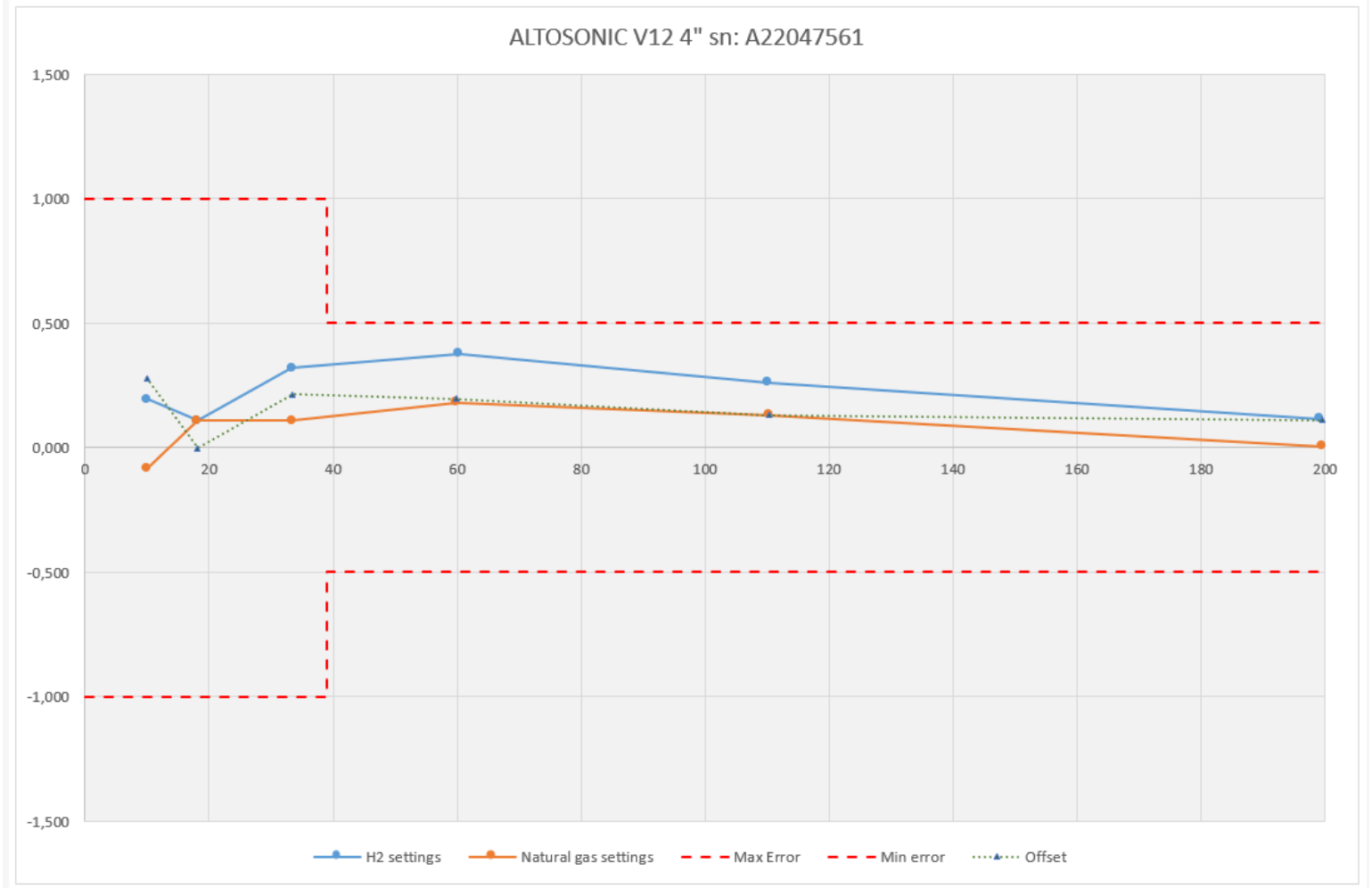


What about the calibration?

Has the adjustment of parameters changed the calibration?

A 4” ALTOSONIC V12 was calibrated on natural gas with standard settings (orange line) and then verified with the modified settings for hydrogen (blue line)

The max. deviation is < 0,2%



Summary and outlook

Monitoring of hydrogen purity:

- The test of the Ultrasonic gas meter sound velocity measurement is very promising
- A method for dry calibration as detailed procedure is being worked out with users, the PTB and manufacturers.

Volume flow measurement:

- Comparison of natural gas->H2, Reynolds must be considered.
- Evaluation of the ultrasonic gas meter in the Qmin range is satisfactory for this test
- Further optimizations and lessons learned from the project will be used in the further improvement of the ultrasonic flow meter for hydrogen

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Bedankt voor uw aandacht