REDUCTION OF METHANE EMISSION WITH PLEXOR

Energie mit Zukunft.
Umwelt und Verantwortung.

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ø	Average Value
AF	Assessment Factor
CBM	Condition-Based Maintenance
CP	Closing Pressure
DSO	Distribution System Operator
EF	Emission Factor
FI	Functional Inspection
GCL	Gas Control Line
GPRS	Gas Pressure Regulating Station
LP	Low Pressure
MP	Medium Pressure
OM	Operation and Maintenance
SP	Setpoint
SRV	Safety Relief Valve
SSV	Slam Shut Valve
W&S	Wigersma & Sikkema

1 Introduction

The environmental friendliness of (natural) gas as an energy carrier is repeatedly questioned by some parties, both nationally and internationally, and the climate debate, which has been growing for years, has brought new importance to the topic. Above all, the European Commission's Green Deal [1], which aims to achieve climate neutrality for the EU by 2050, has greatly increased attention to the issue of methane emissions.

In addition, the European Commission published the EU Methane Strategy [2] in October 2020. Its goal is to reduce EU methane emissions by 35-37% by 2030 compared to 2005 levels.

The determination and verification of methane emissions is to be improved, and their reporting be mandatory, based on the Oil and Gas Methane Partnership (OGMP 2.0 Framework) [3]. Although various sectors are included, the energy sector in particular is seen as having the potential to reduce methane emissions in a cost-effective manner. The first legislative proposals are expected in December 2021.

Methane emissions from the gas distribution network are already at a very low level today, at 0.15 % of the gas volume distributed in Germany [4]. However, gas distribution has the highest methane emissions in the German natural gas value chain (approx. 85.7 kt in 2017 [5]).

The main reasons for this are the large number of pipeline kilometres and facilities, the heterogeneity and the complexity of the network and the limited possibilities for preventive detection of wear. Therefore, the consideration of methane emissions is becoming increasingly important for distribution system operators (DSOs).

Reduction of methane emissions has already been practised by German DSOs for many years. In the past, the focus was mainly on the safety aspect, but nowadays environmental protection considerations are gaining in importance.

In the ME-Red DSO project [6], in addition to numerous possibilities for reducing methane emissions from gas pipelines, several measures were also presented with which methane emissions can be reduced at installations and measuring points in the gas distribution network. Another possibility is to use the PLEXOR inspection system from Wigersma & Sikkema (W&S) to carry out functional inspections on gas pressure regulating stations.

In this project, the reduction of methane emissions when using the PLEXOR inspection system will be investigated. For this purpose, the emissions are measured during the functional inspection at a HanseGas facility. The emissions are measured for three different procedures during the test. The aim of this project is to determine the methane emissions of a functional inspection at a GPRS with and without the use of the PLEXOR system, as well as with an optimised procedure for the functional test. Theoretical and practical verification is to be carried out. In the case of functional testing with PLEXOR, only a metrological verification is carried out.

HanseGas has been using the PLEXOR inspection system for Condition-Based Maintenance (CBM) since 2001. The results of this project are to be used to inform other network operators about the possibilities of reducing emissions at gas pressure regulating stations and thus to make existing knowledge and developments available to the public.

2 Basics

2.1 Maintenance of gas pressure regulating stations: functional testing

The specifications for the functional testing of gas pressure regulating stations (GPRS) are described in DVGW Code of Practice G 495 "Gas systems - operation and maintenance" [7, p. 22f]. This serves as the basis for the operation and maintenance (OM) of gas systems. The functional test is part of the monitoring of the system, which is part of maintenance. The purpose of the functional test is to check the operability and the existing deviations of the gas installation or its components and assemblies. This requires functional interventions in the system, components, or assemblies [7, p. 14f].

In G 495, Table 3 [7, p. 35ff] lists the work of the maintenance measures. The methane-emitting steps in the functional test are the tests of the tripping pressures and tightness of the SSV and SRV, as well as of the operating pressure, closing pressure and tightness of the gas pressure regulators.

In Germany, the functional testing of gas systems is carried out either as predetermined maintenance according to static, time-oriented cycles, or as condition-based maintenance (CBM), in which the maximum maintenance intervals can be extended depending on the condition of the components. Condition-based functional testing requires the implementation and ongoing maintenance of an assessment system of the asset inventory of a gas network operator. The applicable maximum periods of the functional test according to predetermined maintenance as well as CBM are shown in Table 1. The determination of the assessment factor (AF) is described informatively in G 495 [7] in Appendix C. The AF can be a maximum of 2, so that the intervals of the functional test can be a maximum of twice as long as specified in the table. The extension of the intervals between functional tests is also a possibility to reduce methane emissions by means of maintenance measures on GPRS's.

Table 1: Applicable maximum periods for the functional test according to G 495 [7, p. 25-26].

Maximum inlet pressure (bar)	Maximum standard flow (m3/h)	Periods between functional inspections (time based)	Periods between functional inspections (Condition Based)
<= 0,1	1	according to need	according to need
> 0,1 to 1	<= 200	12-yearly	12-yearly x AF
	> 200	4-yearly	4-yearly x AF
> 1-5	<= 200	6-yearly	6-yearly x AF
	> 200	2-yearly	2-yearly x AF
> 5 to 16		1-yearly	1-yearly x AF
> 16-100		1/2-yearly	1/2-yearly x AF

2.2 PLEXOR inspection system

The PLEXOR inspection system from the Dutch company Wigersma & Sikkema (W&S) is used to test components in gas pressure control systems. The portable test device essentially consists of two precise electronic pressure gauges and external software which controls the sequence of the functional test automatically. The inspection system is connected to the system via hoses and permanently installed system couplings.

In addition to the couplings for different pressure ranges, a special 3-way coupling has been designed which is mounted directly in the sensing line of the SSV. This coupling enables direct pressurisation of the SSV via the sensing line. This eliminates the time-consuming and emission-intensive filling and depressurising of the outlet volume. Figure 1 shows the connection of the PLEXOR system via hoses to the gas control line (GCL).

The pressure and volume for checking the response values of the safety devices (SSV and SRV) is determined from the input pressure of the gas control line.

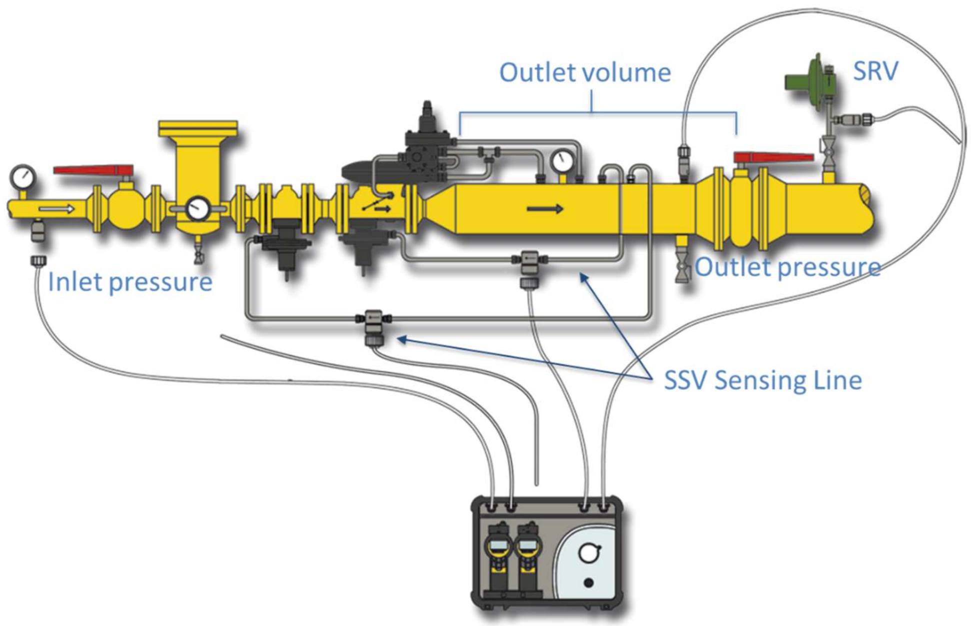

Figure 1: PLEXOR test device and connection to the gas control line

The test procedure follows valid standards and regulations. In addition to the set values and closing pressures, PLEXOR also tests the internal tightness of the SSV and closing valves and can quantify leaks. Once defined, the test steps are always carried out with the same procedure and time intervals. This makes it possible to obtain operator-independent measurement data, which can then be compared with measurement data from earlier functional tests to analyse the condition of the components.

The PN16 PLEXOR inspection system can standard be used for GPRSs with up to 16 bar inlet pressure. With an upstream external pressure regulator EVDR 16, it is possible to use the system for inlet pressures of up to 100 bar. The maximum possible outlet pressure is approx. 13 bar. There is also a PN100 version of the PLEXOR inspection system available, which can be used without an upstream external pressure regulator EVDR 16.

In this project, the PN16 version of the PLEXOR inspection system was used.

The use of the PLEXOR system results in a reduction of methane emissions, as only the most necessary methane emissions occur due to the automated testing procedure and no operator-dependent emissions occur. The discharge volumes are also lower: since the pressure is applied directly to the sensing line of the SSV, smaller volumes must be released.

A standardised analysis of the functional tests over several cycles is possible, which also enables CBM.

2.3 Procedure of the functional inspection for the measurement

For the measurement of the methane emissions during the functional inspection, the test was carried out in three different sequences on the measurement day.

1.) Traditional functional inspection with needle valve, without using the PLEXOR system ("needle valve")

2.) Functional inspection with PLEXOR system, with standard procedure ("PLEXOR 2005")

3.) Functional inspection with PLEXOR system, with optimised flow chart ("PLEXOR 2005+Optimisation")

The steps performed in each flow chart are listed below and the steps causing methane emission are identified. The activation pressure of the SBV is not checked, as it is no longer installed in the test plant. HanseGas has removed almost all leakage gas SBVs in its network, among other things to avoid unnecessary methane emissions from blowing off SBVs as well as continuous emissions from leaks.

2.3.1 Traditional functional inspection: "Needle valve" scheme

The "needle valve" procedure corresponds to the procedure that was used at HanseGas prior to the widespread use of the PLEXOR system. It corresponds (slightly modified) to the sequence of the German network operators. Table 2 describes the procedure and identifies the which cause methane emissions are identified.

Table 2: Flow chart of a traditional functional inspection ("needle valve" scheme)

Step nr.	Description	Emission
1.	Closing of the outlet valve in the outlet volume	none
2.	Measuring the setpoint pressure (SP): Opening of the ventilation valve in the outlet volume for 1 minute → regulator adjusts to SP	Free outflow at SP
3.	Checking the closing pressure (CP): closing the ventilation valve. Measuring the CP	none
4.	Opening and closing of the ventilation valve → 2nd measurement of the CP	Due to short relieve from SD to FD
5.	Measuring the tightness of the gas pressure regulator: checking the pressure increase at CP	none
6./7./8.	Measuring the maximum tripping pressure (Psmax) of the SSV: pressure increase → tripping of SSV and measuring Psm → relieve to SSV re-set pressure →twice repeated	3 x relieve of the outlet volume from Psmax to CP
9./10.	Measuring the minimum tripping pressure (Psmin) of the SSV: pressure relieve until minimum pressure tripping point → tripping of SSV and measuring Psmin → relieve to SSV re-set pressure →once repeated	2 x relieve of the outlet volume from CP to Psmin
11.	Measuring the closing pressure of the SSV; included in step 10	Included in step 10

2.3.2 Functional inspection with established PLEXOR procedure: "PLEXOR 2005" procedure

The "PLEXOR 2005" procedure corresponds to the FI procedure that has been used at HanseGas since approx. 2005. It corresponds (slightly modified) to the procedure of the German network operators who already use the PLEXOR inspection system for FI. Table 3 describes the procedure and identifies the steps that cause methane emissions.

Steps 1-5 correspond to the "needle valve" scheme. When testing the tripping pressure of the SSV (steps 6-8), there is no need to equalise the pressure by releasing natural gas to atmosphere from the outlet volume to re-engage the SSV, as the tripping pressure has been applied directly to the SSV's sensing line and is fed into the outlet volume which is at CP. Once the SSV is triggered, the CP is restored and the SSV can be re-engaged without pressure compensation. The same applies to the check of the lower SSV tripping pressure (steps 9-10). Here, the pressure reduction in the SSV measuring line takes place via the PLEXOR vent hose. As soon as the SSV has tripped, the CP is restored and the SSV can be re-engaged without pressure compensation. At the end of a functional test with the PLEXOR system, the pressure inside the PLEXOR inspection system must, for safety reasons, be vented to the atmosphere. This is done when the inspection system is switched off at the end of the measurement day.

Table 3: Flow chart of a functional inspection with the PLEXOR system (scheme "PLEXOR 2005"). Note: The steps in which emissions are saved compared to the "needle valve" scheme are printed in **bold.**

Step nr.	Description	Emission
1.	Closing of the outlet valve in the outlet volume	none
2.	Measuring the setpoint pressure (SP): Opening of the ventilation valve in the outlet volume for 1 minute → regulator adjusts to SP	Free outflow at SP
3.	Checking the closing pressure (CP): closing the ventilation valve. Measuring the CP	none
4.	Opening and closing of the ventilation valve → 2nd measurement of the CP	Due to short relieve from SD to FD
5.	Measuring the tightness of the gas pressure regulator: checking the pressure increase at CP	none
6./7./8.	Measuring the maximum tripping pressure (Psmax) of the SSV: **pressure increase over direct connection of the PLEXOR test device with the SSV sensing line** →twice repeated	**none**
9./10.	Measuring the minimum tripping pressure (Psmin) of the SSV: pressure relieve of the sensing line until minimum pressure tripping point → tripping of SSV and measuring Psmin → relieve to SSV re-set pressure →once repeated	**2 x relieve of the sensing line volume from SP to Psmin (smallest amounts)**
11.	Measuring the tightness of the SSV; included in step 10	**Relieve of the outlet volume from CP to 0,9 x SP**

2.3.3 Functional inspection with optimised PLEXOR procedure: PLEXOR 2005+Optimisation" scheme

The "PLEXOR 2005+Optimisation" procedure corresponds to the procedure developed by HanseGas in 2021 with the aim of reducing methane emissions even further. Table 4 describes the process and identifies the steps that cause methane emissions. The main adjustment is made by the connection between the Working Gas Control Line (GCL) and the Standby GCL. This allows for the set-point of the regulator to be checked by venting the working GCL into the standby GCL, instead of into the atmosphere. It should be mentioned that this test procedure only works if natural gas can be fed into the grid. The FI according to this procedure must therefore be carried out in a period of the year in which natural gas can be fed into the grid.

Furthermore, the test time for the set point has been shortened, so that this relaxation now causes emissions in half as long a period. In addition, there is no longer a check of the lower tripping pressure of the SSV, as the comprehensive equipment of the house pressure regulators with a gas shortage protection, as no unobserved gas leakage can take place due to the set-up of the house pressure regulators with a minimum gas protection. Moreover, not all gas pressure regulators in the GCLs had a lower shut-off protection due to their design. Therefore, this test is not carried out.

Table 4: Flow chart of a functional inspection with the optimised PLEXOR system (scheme "PLEXOR 2005+Optimisation" scheme). Note: The steps in which emissions are saved compared to the "PLEXOR 2005" scheme are printed in **bold**.

Step nr.	Description	Emission
1.	Closing of the outlet valve in the outlet volume	none
2.	Measuring the setpoint pressure (SP): Opening of the ventilation valve in the outlet volume for 30 s → regulator adjusts to SP Working line: relieve in the standby line Standby line: relieve to atmosphere	Standby line: free outflow at SP, **30 s i.s.o. 60 seconds** **Working line: none**
3.	Checking the closing pressure (CP): closing the ventilation valve. Measuring the CP	none
4.	Opening and closing of the ventilation valve → 2nd measurement of the CP	Due to short relieve from SD to FD
5.	Measuring the tightness of the gas pressure regulator: checking the pressure increase at CP	none
6./7./8.	Measuring the maximum tripping pressure (Psmax) of the SSV: pressure increase over direct connection of the PLEXOR test device with the SSV sensing line →twice repeated	none
9./10.	Not applicable: Measurement of the Psmin of the SSV	**none**
11.	Measuring the tightness of the SSV; measuring the pressure increase in th eoutlet volume at 10% under the closing pressure	Standby line: relieve of outlet volume from CP to 0,9 x SP **Working line: none**

2.4 Measurement procedure

The measurement took place on 28.09.2021 from 8:30 a.m. to 4:00 p.m. at a gas pressure regulator station in Bad Sülze, Mecklenburg-Western Pomerania. The DP16 bar station consists of two gas control lines (working and stand-by line) DN50/150, which feed into the LP network, and two gas control lines in the with MP station. The photos in Figure 2 and Figure 3 show the layout of the GCLs on which the measurements were carried out.

Figure 2: LP gas control lines

Figure 3: MP gas control lines

Table 5: Setpoint values of the gas pressure regulator and SSV

		LP working line	LP standby line	MP working line	MP standby line
SSV max	Psmax (mbar)	90	110	900	1000
Gas Pressure Regulator	Psp (mbar)	50	40	700	600
SSV min	Psmin (mbar)	10	10	20	20

The emissions were measured using an Elster BK-G4 M diaphragm gas meter. One diaphragm gas meter each was installed in the expansion line of the regulator outlet section and in the vent hose of the PLEXOR test device. The measuring range of the meter is: 0.04-6 m³/h (0.7-100 l/min) and the reading accuracy is 0.2 l. Although emissions are technically present in some sub-steps, they were not registered by the gas meter due to the low volume flow. To simplify matters, the reading accuracy was used as the determination limit for these measured values and conservatively included in full in the summation.

To be able to estimate the accuracy of the measured values, the measurements were carried out as double determinations, i.e., two values were obtained for each test and the mean value was calculated.

The measured volumes in the operating conditions were converted to standard conditions (0 °C, 1.013 mbar). For the determination of the methane emissions from the natural gas emissions, a methane content of 93% by volume was used.

Venting of the PLEXOR inspection system (see section 2.3.2) was carried out at the end of the measurement day and the emissions were measured as described. On the measurement day, the system was vented only once for twelve FIs with the PLEXOR system. However, since it is assumed that in practice the functional inspection is only carried out once for the standby and working line, the emissions of the PLEXOR venting are added to each complete FI for working GCL and standby GCL.

3. Theoretical estimation of methane emissions

In addition to the measurements, the emissions from the FI of the GPRS are to be theoretically estimated, with the aim of verifying the applicability of various calculation approaches and measured values. For this purpose, the emissions are determined based on exemplary emission factors (EF) determined in the MEEM project [8]. The EFs calculated in the project in 2018 were used in 2020 in an unpublished project using the same calculation method for other station sizes to represent other pressure and nominal diameters. Table 5 shows the EF of eight exemplary gas pressure regulating stations in Germany in various nominal diameters and pressures. The EFs were calculated for each emptied gas line based on the internal pipe volumes and overpressures in the pipelines, assuming that there is no pressure reduction before venting and thus a conservative value was determined.

Table 6: Exemplary emission factors (EF) for blowing out GDR(M)A, per emptied line

Criterium	**Small GPRS**	**Medium GPRS**	**Medium GPRS**	**Large GPRS**	**Large GPRS with heating**	**Large GPRS with heating**	**Large GPRS with heating**	**Large GPRS with heating**	**Filter incl. cartridge**
Inlet pressue class (bar)	DP2,5	DP4	DP10	DP16	DP25	DP25	DP70	DP70	DP25r
Nominal size inlet/outlet	DN25/ DN50	DN50/ DN100	DN80/ DN150	DN80/ DN150	DN80/ DN150	DN250/ DN300	DN200/ DN250	DN250/ DN300	DN250
EF for relief of a gas control line (Nm3/run)	0,004	0,075	0,242	0,318	1,22	15,6	18,8	46,6	33,1

The station to be tested is a GPRS of pressure stage DP16 bar with nominal inlet diameter DN50. The LP gas GCLs are dimensioned with DN150 at the outlet, the MP gas control lines with DN100.

The EF for "Medium GDR(M)A" with nominal diameters DN80/150 is used for the LP gas control lines, since it is formally a DP16 bar system, but the inlet pressure is only 7 bar. For the emission of the two LP gas control lines, methane emissions of 450 l (standardised) are calculated.

The MP gas control lines are categorised as "large GDR(M)A" DP16 bar. This results in emissions of 591 l (normalised) for both gas control lines.

Another possibility for the calculated estimation of emissions is the individual consideration of the discharged volumes for the GPRS under consideration. For this purpose, the approaches listed in Table 6 are used for the functional inspection steps described in Section 2.3.1.

Table 7: Approaches for calculating the discharge volumes of the emission-relevant steps of the FI.

Step nr.	Description	Calculated estimate of the emissions
1.	Closing of the outlet valve in the outlet volume	none
2.	Measuring the setpoint pressure (SP)	Standby line: free outflow at SP, with oulet valve open
3.	Measuring the closing pressure (CP)	none
4.	2.measurement of the closing pressure (CP)	negligible
5.	Measuring the tightness of the gas pressure regulator	none
6./7./8.	Measurement of the maximum tripping pressure (Psmax) of the SSV	3 x relieve of the volume in the outletsection from Psmax to CP
9./10.	Measurement of the minimum tripping pressure (Psmin) of the SSV	2 x relieve of the volume of the outletsection from CP to Psmin
11.	Measuring the tightness of the SSV	Included in step 10

For the functional inspection with the "needle valve" procedure, with the above-mentioned approaches methane emissions of 651 l (standardised) for the LP gas control lines and 780 l (standardised) for the MP gas control lines are calculated. The theoretically determined emissions are compared in Table 7. These values are compared and evaluated with the measured values.

Table 8: Theoretically determined methane emissions for the GPRS considered in this project in [l CH_4 (normalised)].

	Emission factors	Calculated determination of the discharge volumes
LP standby + working line	450	422
MP standby + working line	591	780

4 Measurement results and interpretation

4.1 Measurement data

Table 9 and Table 10 present the results of the methane emissions in the low- and medium-pressure GPRSs.

The emissions during venting of the PLEXOR inspection system amounts to 4 l in operating conditions. Since the pressure is not known, an average overpressure of 500 mbar was used to convert the vented volume to standard conditions. The methane emissions in the standard condition thus amount to approx. 5 l per venting and as described in section 2.4, are added up to a complete functional inspection (working line and standby line).

Table 9: Table of measured values of the methane emission quantities in the LP GPRS in [l (normalised)].

LP, standby line									
	Needle valve			PLEXOR 2005			PLEXOR 2005 + optimisation		
Step	**1**	**2**	**ø**	**1**	**2**	**ø**	**1**	**2**	**ø**
2, SP	23,7	21,8	**22,8**	58,2	40	**49,1**	3,6	4,6	**4,1**
4, CP	0,9	0,9	**0,9**	0,9	0,9	**0,9**	0,5	0,2	**0,3**
6, SSV max	1,0	1,0	**1,0**	–	–	**–**	–	–	**–**
7, SSV max	1,0	1,0	**1,0**	–	–	**–**	–	–	**–**
8, SSV max	1,0	1,0	**1,0**	–	–	**–**	–	–	**–**
9, SSV min	6,4	5,5	**5,9**	< 0,2	< 0,2	**< 0,2**	–	–	**–**
10, SSV min	4,6	5,5	**5,0**	< 0,2	< 0,2	**< 0,2**	–	–	**–**
11, Δp SSV	–	–	**–**	1,8	0,9	**1,4**	1,4	1,6	**1,5**
Total	38,4	36,6	**37,5**	61,4	42,3	**51,8**	5,5	6,4	**5,9**
LP, working line									
	Needle valve			PLEXOR 2005			PLEXOR 2005 + optimisation		
Step	**1**	**2**	**ø**	**1**	**2**	**ø**	**1**	**2**	**ø**
2, SP	54,1	64,2	**59,1**	53,2	72,4	**62,8**	–	–	**–**
4, CP	0,9	0,9	**0,9**	1,8	1,8	**1,8**	–	–	**–**
6, SSV max	1,0	1,0	**1,0**	–	–	**–**	–	–	**–**
7, SSV max	1,0	< 0,2	**0,6**	–	–	**–**	–	–	**–**
8, SSV max	< 0,2	1,0	**0,6**	–	–	**–**	–	–	**–**
9, SSV min	11,9	11	**11,5**	< 0,2	< 0,2	**< 0,2**	–	–	**–**
10, SSV min	11,0	11,9	**11,5**	< 0,2	< 0,2	**< 0,2**	–	–	**–**
11, Δp SSV	–	–	**–**	1,8	0,9	**1,4**	–	–	**–**
Total	80,0	90,1	**85,1**	57,3	75,6	**66,4**	0	0	**0**
Venting of the PLEXOR system			–			5			5
Total FI			**122,6**			**123,2**			**10,9**

Table 10: Table of measured values of methane emission quantities in the MP GPRS in [l (normalised)].

MP, standby line									
	Needle valve			PLEXOR 2005			PLEXOR 2005 + optimisation		
Step	**1**	**2**	**Ø**	**1**	**2**	**Ø**	**1**	**2**	**Ø**
2, SP	83,2	76,3	**79,8**	12,5	101,3	**56,9**	31,9	29,1	**30,5**
4, CP	1,4	2,9	**2,2**	1,4	4,3	**2,9**	2,9	1,4	**2,2**
6, SSV max	8,6	5,2	**6,9**	–	–	–	–	–	–
7, SSV max	6,9	6,9	**6,9**	–	–	–	–	–	–
8, SSV max	6,9	6,9	**6,9**	–	–	–	–	–	–
9, SSV min	15,3	16,6	**16,0**	1,4	1,4	**1,4**	–	–	–
10, SSV min	15,3	13,9	**14,6**	1,4	1,4	**1,4**	–	–	–
11, Δp SSV	–	–	**–**	5,5	1,4	**3,5**	5,5	4,2	**4,9**
Total	137,7	128,7	**133,2**	22,2	109,8	**66,0**	40,3	34,7	**37,5**
MP, working line									
	Needle valve			PLEXOR 2005			PLEXOR 2005 + optimisation		
Step	**1**	**2**	**Ø**	**1**	**2**	**Ø**	**1**	**2**	**Ø**
2, SP	67,7	28,0	**47,9**	179,7	232,7	**206,2**	–	–	**–**
4, CP	1,5	1,5	**1,5**	4,6	3,1	**3,8**	–	–	**–**
6, SSV max	4,9	3,3	**4,1**	–	–	–	–	–	**–**
7, SSV max	3,3	1,6	**2,5**	–	–	–	–	–	**–**
8, SSV max	4,9	3,3	**4,1**	–	–	–	–	–	**–**
9, SSV min	17,7	19,1	**18,4**	1,5	1,5	**1,5**	–	–	**–**
10, SSV min	19,1	19,1	**19,1**	1,5	1,5	**1,5**	–	–	**–**
11, Δp SSV				2,9	5,9	**4,4**	–	–	**–**
Total	119,3	76,0	**97,6**	190,2	244,6	**217,4**	0	0	**0**
Venting of the PLEXOR system			–			5			5
Total FI			**230,8**			**288,4**			**42,5**

When measuring the setpoint (step 2), the vent is opened a little manually. How far and the exact duration is highly dependent on the operator. The measured values show that, although the same procedures are carried out in all three schemes, the measured values of the exhaust emissions differ greatly from one another.

For a better comparison of the three schemes, the further evaluation will therefore be based on the mean values from the emissions produced during the FI in the "needle valve" scheme as well as "PLEXOR 2005". In the "PLEXOR 2005+Optimisation" scheme, the measuring time was shortened (see section 2.3.3), so the measured value in this scheme is not included in the averaging.

Table 11 shows the emissions of the FI added up over the reserve and working GCL according to the three flow diagrams. The mean values of the measured values for the setpoint test were taken for the schemes "needle valve" and "PLEXOR 2005" and were used to provide better comparability.

Table 11: Summary of methane emissions during FI according to the three discharge schemes in the low-pressure and medium-pressure gas control lines (emissions of the FD test are averaged over all measured values of the "needle valve" and "PLEXOR 2005" test schemes)

	Low pressure			Medium pressure		
	Needle valve	**PLEXOR 2005**	**PLEXOR 2005 with optimisation**	**Needle valve**	**PLEXOR 2005**	**PLEXOR 2005 with optimisation**
SP	96,9	96,9	4,1	195,4	195,4	30,5
SSV max	5,0	0	0	31,4	0	0
SSV min	33,8	0,8	0	68,1	5,7	0
Rest	1,8	10,5	6,8	3,7	19,6	12,0
Total	**137,5**	**108,2**	**10,9**	**298,6**	**220,7**	**42,5**
Reduction compared to Needle valve		**21%**	**92%**		**26%**	**86%**

Figure 4 shows the results graphically. The methane emissions of the functional inspection in the MP GPRS are, as can be expected, higher than in the LP GPRS. The methane emissions in the medium pressure range were about twice as high as in the low-pressure range. The set-point pressure check was responsible for most of the emissions in the "needle valve" and "PLEXOR 2005" schemes (between 65 % and 90 %).

The optimised test scheme "PLEXOR 2005+Optimisation" has by far the lowest methane emissions in both pressure levels (around 12 l (normalised) in LP and 43 l (normalised) in MP). The use of the PLEXOR inspection system in the "PLEXOR 2005" scheme results in 20 % (in LP) and 26 % (MP) less methane emissions compared to the traditional approach in the "needle valve" scheme. For the adapted inspection procedure in the scheme "PLEXOR 2005+Optimisation", an emission reduction of 92 % in the LP and 89 % in the MD was determined.

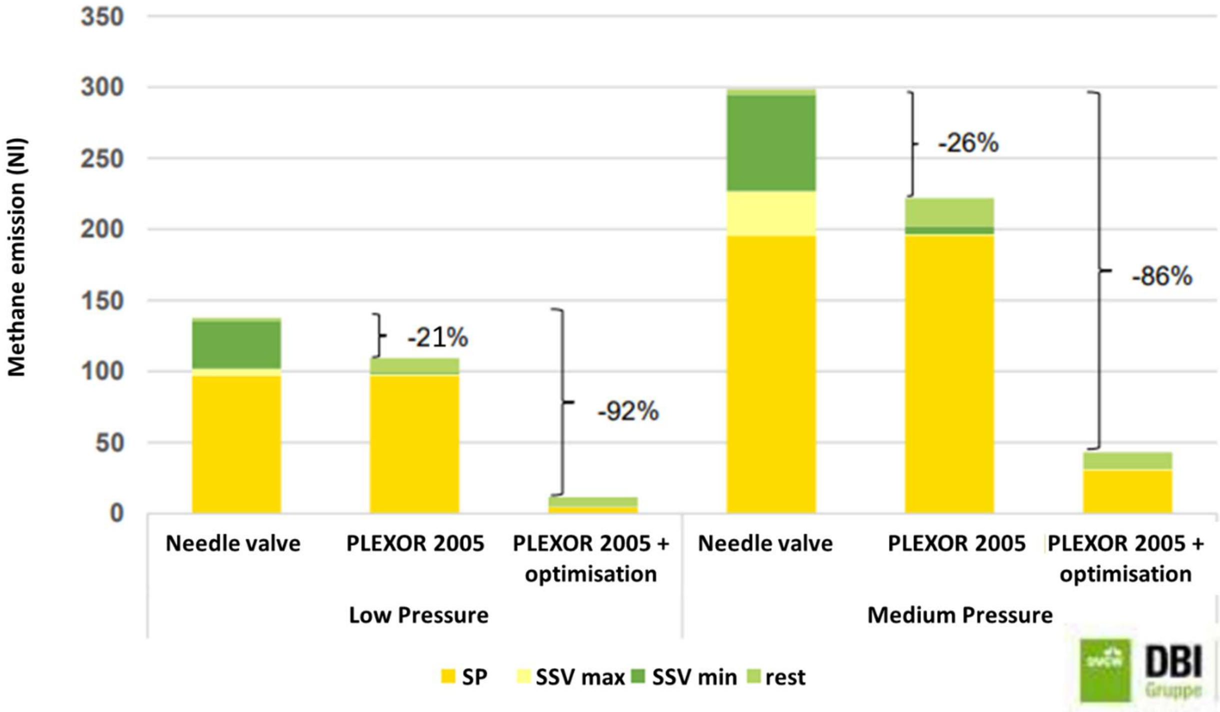

Figure 4: Methane emissions of the functional inspection with three different procedures

4.2 Error discussion

Measuring the exhaust volumes with a diaphragm gas meter is a simple and inexpensive method for measuring such emissions. However, it has limitations that need to be discussed to evaluate the measurement values in terms of their accuracy.

Like all gas volume meters, the diaphragm meter measures the volumes in the operating conditions. To be able to establish comparability of measured values among each other, a conversion to a defined gas condition must be carried out (here to standard conditions). The pressure at which the gas flows out has the greatest influence on this measurement. However, this pressure is not the same over the entire outflow period but decreases over time. Especially at higher pressures, the relative error can be 100 % and more. For further measurement projects of this kind, it would be conceivable to install a chocking valve upstream of the meter so that the gas flows through the meter at reduced pressure and a constant volume flow. An alternative to the use of a diaphragm meter for small release volumes is the recording in gas bags, which are calibrated after the functional test on a gas meter with the help of a pump or on the basis of geometric determination. When evaluating the measurement results, it should also be borne in mind that diaphragm meters are only approved for calibration up to 100 mbar (pressure-resistant up to 500 mbar). Furthermore, recording the outgoing volume as a mass flow in a mass flow meter/controller (MFC) is a more cost-intensive but more accurate alternative.

The accuracy of the measured values is influenced at least as much by the procedure during the switching operations of the FI. For instance, the measured discharge volumes when testing the setpoint and closing pressure are strongly dependent on the opening angle of the ball valve in the venting line and on the person performing the test. This becomes apparent in the strong fluctuation of the double determinations among each other (in places > 100 %), but also in the discharge emissions when determining the setpoint and closing pressure across all three test schemes (deviation also partly > 100 %). In the scheme PLEXOR 2005+optimisation, gas flows out for only half as long, but otherwise the switching operations are comparable in all schemes.

Also, in comparison with the theoretical determination of the discharge volumes based on the pipe geometries (which in turn is also associated with uncertainties and estimates), it can be concluded that a measurement error of measurement error of 100 % can be assumed and is not too conservatively estimated.

Table 12: Comparison of the theoretically determined and measured methane emissions for the plant considered in this project considered in this project in [l (normalised) CH4]

	Theoretical average		Measured average
	Emission factor	**Calculated average of the discharge volumes**	**Test scheme "needle valve"**
LP standby + main line	450	422	138
MP standby + main line	591	780	299

5 Conclusion and outlook

More and more network operators and equipment manufacturers are becoming aware of the relevance of methane emissions in terms of environmental protection. HanseGas is playing a pioneering role in this respect and has been striving for many years to implement measures to reduce its operational methane emissions, e.g. by flaring the emissions during pipeline measurements or applying condition-based maintenance with extended inspection intervals. In the search for ways to reduce emissions at GPRSs during functional inspections and maintenance, HanseGas, together with the manufacturer of the PLEXOR inspection system, Wigersma & Sikkema, has developed an optimised test procedure for its functional inspection (referred to as "PLEXOR 2005+Optimisation"). This is characterised, among other things, by the fact that the methane emissions, which occur due to the release to the atmosphere required for the setpoint test, are fed from the working GCL into the standby GCL.

In this project, the methane emission reduction was to be proven theoretically and metrologically by comparing three different inspection procedures. It was found that the procedure "PLEXOR 2005+Optimisation" significantly reduces the methane emissions generated during the functional inspection, approx. 89 - 92 % compared to the traditional FI. The measured discharge volumes with the PLEXOR inspection system are 21 - 26 % lower than with the FI according to the traditional inspection scheme without the PLEXOR system. Due to the inaccuracy in the measurement methodology and the unavoidable deviations in the repeated performance of the inspection by manual operation of (especially when testing the setpoint pressure), the measurement results can only serve as a rough qualitative qualification. For the verification of the results, each measured value was obtained as a double determination and the results were subjected to a plausibility check with the aid of theoretically determined values. A more detailed investigation with another measurement method could provide further information about the facts, as well as confirm the results quantitatively.

The project also offers a comparison of theoretical values, some of which are publicly available, or values calculated according to common approaches with real measured values. It is shown that the theoretical values for the two GPRSs considered are comparable in their order of magnitude with the values determined by measurement. This statement has already been confirmed by another distribution grid operator who also carried out measurements during maintenance measures a few years ago. However, if the accuracy requirements for these rather roughly calculated or metrologically determined values become greater, there is a need for further investigation to determine the methane emissions from maintenance measures more accurately.

There is also a need for further investigation, especially at high pressure. The determination of measured values will also become even more relevant in the future regarding the reporting of methane emissions to the "Oil and Gas Methane Partnership" (OGMP) for the required selectivity of the different assets and emission types as well as for the verification of the theoretically determined emissions.

For the reduction of methane emissions, the following aspects could be demonstrated in terms of the project objectives:

1.) The use of the PLEXOR system can reduce methane emissions due to the automated, operator-independent process, the lower discharge volumes during the SSV test, and the standardised analysis, which allows statements to be made about the wear process of the equipment.

2.) The individual operator-dependent part of the inspection procedures and the determination of times for the individual steps of the functional inspection can lead to a further reduction of methane emission.

3.) By connecting the working GCL and the standby GCL, the working GCL can be vented into the standby GCL. This avoids venting to the atmosphere and the associated emissions are avoided. However, if there is no standby GCL, this measure is not feasible.

Furthermore, methane emission reduction from GPRS’s can be achieved by:

1.) Extending the inspection intervals, in accordance with the CBM's proposal under G 495, which reduces maintenance-related emissions due to the lower frequency of the measures.

2.) The removal of SRVs that are not necessary. This avoids the discharge of unnecessary methane emissions.

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