International Gas Union Research Conference 2014 – WP3-28

Assessing the Fitness of Stop-off Bags for Use in Gas Distribution Systems up to an Operating Pressure of 5 bar

Main author: Andreas Bilsing[(a)]
Co-authors: Klaus Hilbich[(a)], Gert Müller-Syring[(a)], Werner Weßing[(b)], Olivier Rebibo[(c)], Michel Hardy[(c)]

(a) DBI Gas- und Umwelttechnik GmbH, Germany; (b) E.ON New Build & Technology GmbH, Germany; (c) GDF SUEZ, France

ABSTRACT

An isolation technology for a temporary gas supply interruption that is safe, cost-effective, and proved by a huge amount of sites were it was successfully applied: Stop off-Bags-Technology. According to the DVGW Codes this technology can be applied up to operating pressures of 1 bar. Regulations in other European member states allow the application for higher pressures as well. Based on a literature inventory and an expert discussion it was not possible to identify profound testing results that support the recommendation of this technology for higher pressures. Therefore, a R&D project was set up aiming to investigate whether it would also be feasible to use this method in pressure ranges up to 5 bar. These investigations were performed in close cooperation with GDF SUEZ in the frame of a GERG project [GERG 2014].

For this purpose 10 construction sites where this method was used in the pressure range up to 4 bar (based on the current regulations of the DVGW this is the highest pressure that usually can be found in gas distribution grids) were assessed. Furthermore, the equipment available was approved up to 4 bar. In addition, the DVGW itself carried out a survey with companies that had already used this method at pressures of more than 1 bar in order to receive valuable information from “standard applications”.

In order to investigate the performance of the technology in polyethylene and steel pipes, also under unfavourable conditions, a test rig was set up at DBI. More than 20 tests were conducted to investigate leakage gas volumes in clean and fouled pipes with impurities. Typical impurities as gas dust, steel cuttings, polyethylene cuttings and moisture have been simulated as these substances may occur in gas pipelines. The behaviour of the remaining gas bag in case of failure of the pressure-side bag was also investigated under these conditions. This test, which simulated pressure-side bag failure with a severe pressure surge, was always completed satisfactorily.

In eight out of ten tests the leakage gas volumes measured were within the range specified/given in DVGW Codes (30 dm^3/min at 1 bar) even though the operation pressure of 1 bar for which the DVGW-threshold has been developed was significantly override (4 bar in the tests). The gas leakage between the stop-off bags was only exceeded with severe fouling. In practice, the leakage gas is safely vented via vent lines.

Based on the information obtained from the pilot construction sites that were surveyed, the laboratory tests carried out and an assessment of the results, the technology of stop off bag insertion is found to be fit for the purpose with the systems used in this DVGW R&D project. The system should however only be used by experienced staff who have been trained in using such systems. Irrespective of the positive assessment of this technology up to an operating pressure of 5 bar, further development efforts should be made to identify unfavourable pipeline conditions (severe dust deposits, cuttings and moisture) or to avoid these conditions (e.g. cuttings) more effectively in the future. This would further improve the safety level of this technology.

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1 INTRODUCTION

Over the past few years many regional gas transmission and distribution systems have been constructed with a maximum operating pressure (MOP) of 5 bar. In order to be able to operate these pipelines it is necessary to have repair and isolation technologies which are both suitable and approved for this pressure range. An isolation technology which is safe, cost-effective and proved by many field applications is the use of stop-off bags. Requirements for this method in the pressure range up to 1 bar are stated in the DVGW Codes of Preliminary Test Specifications VP 620-1 and VP 621-1/2. The objective of this research project was to investigate whether it would also be feasible to use this method in the pressure range up to 5 bar. These investigations were carried out in the frame of DVGW-project in cooperation with a GERG project.

For this purpose 10 construction sites where this method was used in the pressure range up to 5 bar were observed and a comprehensive programme of tests and practical conditions was conducted. In addition, DVGW carried out a survey of companies who had already used this method at pressures in excess of 1 bar.

In order to investigate the technology in polyethylene and steel pipes, also under unfavourable conditions, a test rig was set up at DBI. More than 20 tests were carried out to investigate gas leakage volumes in clean and fouled polyethylene and steel pipes. The foreign matter used for these tests included gas dust, steel cuttings, polyethylene cuttings and moisture. The behaviour (firm seating and gas-tightness) of the vapour bag in the event of the failure of the pressure-side bag was also investigated under these conditions.

Thanks to the scientific observation of the pilot construction sites in combination with the laboratory tests conducted, it was possible to obtain a comprehensive view of the technology of gas bag insertion.

Note 1: As indicated by the title of the project, gas bags up to an operating pressure of 5 bar (MOP 5 bar) are investigated. However, as the isolation technology (bag insertion tool and gas bag) is only approved by the manufacturer up to an isolating pressure of 4 bar, work on the pilot construction sites was only carried out up to this pressure. Most of the tests were also carried out at 4 bar. This pressure was only intentionally exceeded during the additional tests mentioned above.

Note 2: this report uses the terminology of the Provisional Test Specification VP 621 1. “Isolating pressure” is the pressure in the isolated pipeline. “Working pressure” is the pressure in the gas bag (internal pressure in bag) during the isolating procedure.

2 GAS BAGS

MDS (multi-dimensional) gas bags are used for pipeline isolation in 4 bar systems. The MDS bag used for the laboratory tests and on the construction sites (see Fig. 1) consists of natural rubber with aramid fibre reinforcement. This reinforcement which has a cross-ply configuration is located between two layers of rubber. In order to increase adhesion to the pipe wall caused by friction, corundum crystals are applied to the surface of the bag.

A telescopic rod is located inside the bag. This rod is shortened as the bag is inflated and extends as the bag is deflated. This ensures that the gas bag maintains a straight position at all times.

An additional hose is installed inside the telescopic rod. This allows the measurement of the upstream pressure (pressure in the isolated pipeline upstream from the gas bag) via an opening at the end of the bag.

The gas bags may be reused several times. The bag must be visually inspected to identify any damage each time before it is reused.

Figure 1: Gas bag (MDS bag; manufacturer KLEISS; diameter 160 – 215)

Test results obtained by the bag manufacturer indicate that the burst pressure of the bag is higher than 24 bar, i.e. at least three times as high as the working pressure, depending on the bag diameter. The operating instructions clearly state that the gas bags must be cleaned using appropriate materials before and after use. The bags must also be stored in accordance with the manufacturer’s instructions. Before the bag is inserted, it must be inspected for any leaks using a leak detection spray at a pressure of 300 mbar.

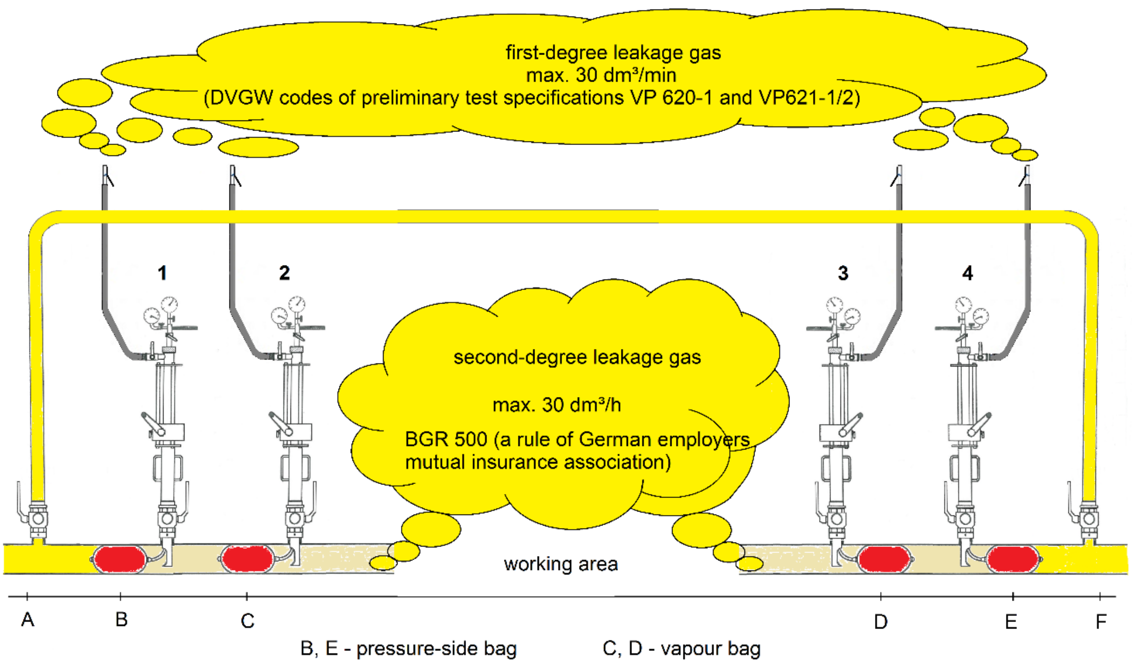
3 GAS LEAKAGE

The pipeline section is isolated by positioning two gas bags, the “pressure-side bag” and the “vapour bag”. The two bags are of identical design.

The pipeline section between the two bags is depressurized. On the construction site, the gas leaking into this section as a result of leaks via the pressure-side bag is vented to atmosphere via a hose. This gas is referred to as “first-degree leakage gas”. As this leakage gas is vented to atmosphere, there is no pressure build-up in the space between the two bags. The work area is located downstream from the vapour bag. After the work area has been depressurized using the positioning tool of the vapour bag the pipeline is normally cut. In this case the vapour bag provides protection in the event of a failure of the pressure-side bag and prevents the gas leaking via the pressure-side bag from reaching the work area. Gas escaping into the work area is referred to as “second-degree leakage gas”. In normal operation there is no second-degree leakage gas. Downstream from the pressure-side bag the maximum leakage rate which is allowed is 30 dm³/minute as against only 30 dm³/hour in the work area (Figure 2).

In the laboratory tests, the gas leakage rate via a gas bag used as a pressure-side bag (first-degree leakage gas volume) was measured.

Figure 2: **Leakage gas volumes allowed by standards at construction sites**



4 PILOT CONSTRUCTION SITES

In Germany, Hütz+Baumgarten GmbH (H+B) has been carrying out pipeline isolation work with its own technology (4 bar bag positioning system) and gas bags manufactured by KLEISS since 2009. As part of this project DBI GUT personnel provided scientific support for H+B at a total of 10 pilot construction sites. The pipelines concerned were all natural gas pipelines at pressures ranging from 1.3 to 3.4 bar. Seven isolation operations on polyethylene pipelines and three on steel pipelines were documented and assessed. Furthermore, a comprehensive reference list of the construction contractor Hütz+Baumgarten is available. This company has completed more than 50 isolating operations in the pressure range from 1 to 4 bar with its 4 bar system.

5 USER SURVEY

In order to verify practical experience on site and to obtain some price indications, DVGW carried out a survey of companies concerning experience with the use of gas bags for pipeline isolation up to 4 bar. The companies surveyed included specialist contractors and network operators who had used the gas bag procedure for pipeline isolation at least once. Of the companies contacted, 16 took part in the survey. These 16 companies had completed a total of 36 pipeline isolation operations. The main result is an estimation of cost reduction by isolation operations shown in Table 1. Companies who had already completed several isolation operations indicated a saving of the order of 50% or higher.

Table 1: Cost saving because of the use of gas bags (survey)

Cost saving	Number of isolation operations
Same cost	1
approx. 20%	2
20 – 50 %	4
50 %	11
50 – 70 %	12

6 LABORATORY TESTS

Laboratory tests were carried out by DBI GUT in Germany and GDF SUEZ at CRIGEN in France.

6.1 LABORATORY TESTS OF DBI GUT

During the laboratory tests at DBI GUT the leakage gas volumes were measured and the behaviour of the vapour bag in the event of a failure of the pressure-side bag was investigated. For this purpose, a test rig largely in accordance with the configuration laid down in VP 620-1, Appendix 2, was developed.

On the test rig a gas bag was investigated in its function as pressure-side bag and the leakage gas volume is measured. In addition, the behaviour of this bag as a vapour bag exposed to a pressure surge (simulating the failure of the pressure-side bag) was investigated.

The test rig consists of two parts:

- a steel pipe section (DN 200), which can also be replaced by a polyethylene pipe section,
- a pressure vessel to simulate the failure of the pressure-side bag by providing a sufficient pressure buffer.

Compressed air (available in the laboratory at a maximum pressure of 6.7 bar) was used as test gas. The gas bag was filled with nitrogen. The tests were carried out using a steel pipe and a PE100 pipe (DN 225). The test plan which was drawn up intended to cover possible conditions in the isolated pipeline section. It was assumed that the pipeline section to be isolated could contain gas dust, moisture and drilling cuttings, also in various combinations. Following comprehensive adaptations this test rig would also be suitable for demonstrating the use of this technology during training courses. The gas dust used was a surrogate mixture with fractions and a particle size distribution based on a laboratory analysis. Steel cuttings were also simulated. In the case of polyethylene cuttings original material from a construction site was used. Initially, the piping system was filled with compressed air at an operating pressure of 4 bar. The bag positioning equipment was installed in accordance with the operating instructions of the manufacturer and the gas bag was inserted into the pipe. The gas bag was then inflated to a pressure of 8 bar using nitrogen. Following inflation, the pressure downstream from the gas bag was relieved and a gas flow meter (laboratory meter) was installed. This meter was used to measure any possible leakage between the pipe wall and the vapour bag at several defined time intervals. The results are given in Table 2.

Following the completion of the leakage-measurements, each test ended with the simulation of the failure of the pressure-side bag. These tests never failed.

Table 2: Results of leakage gas volume and pressure surge tests

Test conditions Isolating pressure 4 bar Working pressure 8 bar	Leakage gas volume	Pressure surge test
Steel (clean)	$\dot{v} = 0 \ldots 0.5\ dm^3/min$	passed
Steel (gas dust)	$\dot{v} = 19 \ldots \mathbf{36}\ dm^3/min$	passed
Steel (steel cuttings)	$\dot{v} = 2 \ldots 3\ dm^3/min$	passed
Steel (dust + cuttings)	$\dot{v} = 24 \ldots \mathbf{37}\ dm^3/min$	passed
Steel (dust + cuttings + moisture)	$\dot{v} = 10 \ldots 21\ dm^3/min$	passed
Polyethylene (clean)	$\dot{v} = 0.2\ dm^3/min$	passed
Polyethylene (one long PE cutting)	$\dot{v} = 0\ dm^3/min$	passed
Polyethylene (dust)	$\dot{v} = 6 \ldots 12\ dm^3/min$	passed
Polyethylene (cutting + dust + moisture)	$\dot{v} = 24 \ldots 27\ dm^3/min$	passed
Polyethylene (cutting + moisture)	$\dot{v} = 0\ dm^3/min$	passed

6.2 Laboratory tests of CRIGEN (GDF SUEZ)

Resistance tests

During the laboratory test at GDF SUEZ resistance tests were performed. These tests were made to investigate adhesion and seating of the gas bag in the pipe. The resistance tests showed that the gas bags were in a position to reliably withstand a pressure of 5 bar for 12 hours (normal duration of operation on site). It was observed that a difference of 2 bar between the isolating pressure on the working pressure was adequate to maintain a satisfactory adhesion between the gas bag and the pipe wall.

Tightness test and cycling

Using the same test rig as for the resistance test, the pressure and temperature over the course of time were measured. It was possible to calculate the leakage rate from the pressure loss. The values confirm that a safe working area can be achieved in the pressure range up to MOP 5 bar with two gas bags and depressurization of the enclosed space between them.

Effects of bag positioning on the pipeline

Tests were carried out to investigate the question of whether a gas bag pressed against a pipe wall (approved for the pressure range up to MOP 5 bar) at 6 to 10 bar can damage the pipe. For this purpose, used polyethylene pipe (produced in 1977) was tested at a working pressure of 8 bar over a period of 24 hours at 80°C (corresponding to 1000 hours). In the course of this test the outside diameter of the pipe was increased by 0.1 mm. After the pressure had been removed the outside diameter returned to its original value. It is therefore scarcely to be expected that the service life of the material will be impaired.

The Executive Summary drawn up by CRIGEN continues to assume that there will be certain risks in connection with bag insertion equipment.

7 SUMMARY

Over the past few years, many regional gas transmission and distribution systems have been constructed with a maximum operating pressure (MOP) of 5 bar. In order to be able to operate these pipelines it is necessary to have repair and isolation technologies in place, which are both suitable and approved for this pressure range. An isolation technology which is safe, cost-effective,tried and tested is the use of gas bags. Requirements for this method in the pressure range up to 1 bar are stated in the DVGW Codes of Practice/Preliminary Test Specifications VP 620-1, VP 621-1, VP 621-2 and G465-22. The objective of this research project was to investigate whether it would also be feasible to use this method in the pressure range up to 5 bar. These investigations were carried out in cooperation with a GERG project.

On the basis of the information obtained from the pilot construction sites, the laboratory tests carried out in Germany and France as well as an assessment of the results, the technology of gas bag insertion has been found to be appropriate for the purpose in systems up to 4 bar (respectively 5 bar) as used in this DVGW R&D project. The system should however only be used by experienced personnel who have been trained in the use of such systems. Irrespective of the positive assessment of this technology for the isolation of gas distribution systems up to an operating pressure of 5 bar, further development efforts should be made to identify unfavourable pipeline conditions (severe dust deposits, cuttings and moisture) or to avoid these conditions (e.g. cuttings) more effectively in the future. This would further improve the safety level of this technology.

The project team supports the approval of stop-off bags insertion technology by the DVGW Codes of Practice, initially up to a maximum isolation pressure of 4 bar, provided that the work is carried out by qualified, certified personnel. Adequate operating experience is already available up to this isolating pressure level. When more experience is available up to an isolating pressure of 5 bar this extended pressure range should be covered by a second revision of the Code of Practice.

The authors kindly thank the DVGW and the project tutors for the constructive cooperation. A special thank you goes to Mr. Günther Koch from the company Hütz + Baumgarten GmbH, who made the involvement of the pilot construction sites possible and supported the laboratory tests by provision of equipment. Furthermore, we want to thank all colleagues who have contributed to the success of the project.

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Contact

Andreas Bilsing

DBI Gas- und Umwelttechnik GmbH
Karl-Heine-Str. 109/111
D-04229 Leipzig
Germany

phone: +49 (0) 341-24571-13
fax: +49 (0) 341-24571-36

web: www.dbi-gut.de
e-mail: andreas.bilsing@dbi-gut.de