Proceedings of the International Gas Union Research Conference (IGRC)

September 17-19, 2014, Copenhagen, Denmark

A CHALLENGING EXPERIMENTAL SETUP FOR TESTING THE IMPACT OF SUSTAINABLE GASES ON EXISTING PIPING SYSTEMS

Johannes de Bruin
Kiwa Technology
Apeldoorn, The Netherlands
Johannes.de.Bruin@kiwa.nl

René Hermkens
Kiwa Technology
Apeldoorn, The Netherlands

ABSTRACT

The use of new sustainable gases (e.g. biomethane, Biogas, SNG) is increasing worldwide, in particular because their use can lead to a reduction in the emission of greenhouse gases[1]*. Since their introduction, gas Distribution and Transmission System Operators (DSOs and TSOs) have nevertheless raised questions about the impact of these gases on their grids. In this context, Kiwa Technology has participated in the research programme Energy Delta Gas Research (EDGaR), funded by the Dutch Ministry of Economic Affairs and the Province of Groningen, in order to evaluate the effects of different types of new gases (those originating from digestive or synthetic production or from other processes) on the materials present in existing gas networks.*

A literature survey was first carried out in order to establish which materials are present in Dutch gas distribution grids, which chemical components occur in sustainable gases, at which concentration levels they occur and the effect of these sustainable gases on the materials used in the grids. The most important polymeric materials in the Dutch gas distribution grids are polyethylene (PE), polyvinyl chloride (PVC), rubber and polyoxymethylene (POM). The most important metallic materials are steel, copper, aluminium and brass[2][3][4]*.*

The literature survey demonstrated that the knowledge available at present is sometimes inconclusive. For polymeric materials in particular, little is known about the impact of chemical components containing sulphur or chlorine, CO_2*, ammonia and* H_2*. The effect at different concentration levels of* H_2S*,* O_2 *and* CO_2 *on metallic materials in an aqueous environment is also unknown. Lab and field experiments based on these so-called "white spots" have therefore been initiated.*

Two types of lab experiments are currently taking place:

1. *Experiment type 1: to determine whether a chemical component has any effect on a given material at the maximum occurring concentration levels*
2. *Experiment type 2: to determine the extent to which the material is affected by a given chemical component at different concentration levels*

Almost all the experiments performed on the polymeric materials are of type 1, since nothing at all is known about the effect of the chemical components on these materials. In order to determine the effect on the polymeric materials at such a large scale, specially designed environmental stress cracking (ESC) experiments have been set up. The experiments performed on the metallic materials are mainly type 2 experiments. While it is known that the chemical components under consideration affect these metals, the extent to which they affect the corrosion speed at the concentration levels found in sustainable gases is not yet known. The concentration levels at which corrosion problems arise in an aqueous environment[5] *is therefore being determined by means of specially designed corrosion experiments.*

For the field experiments, test rigs have been installed in both a natural gas and in a biomethane piping system. The same materials are being tested as in the laboratory experiments, where applicable under the same applied stresses. The purpose of these field experiments is to determine whether sustainable gases have any unforeseen adverse effects.

Materials taken from actual gas distribution systems (e.g. pipes, fittings, regulators) are used for both the lab and field experiments.

These experiments are currently in progress as designed and will run for at least two years. After exposure, the polymeric materials will be tested both non-destructively and destructively for any degradation in their mechanical quality. These tests will examine the impact of ESC. The corrosion rate and corrosion products of the metallic materials will also be evaluated. The first results of the experimental survey component of the research programme are expected at the beginning of 2015.

INTRODUCTION

The exploration and exploitation of natural gas in the Netherlands began in the province of Groningen following the discovery of the natural gas field at Slochteren[6]. Since then, 98% of Dutch households and small-scale consumers have been connected to the natural gas grid. A total of approximately 124,000 km of distribution mains and 70,000 km of service lines have been installed to date[2][3][4].

In order to maintain a strong position in natural gas, the Dutch gas Distribution and Transmission System Operators (DSOs and TSOs) must anticipate future technological and economic developments. One of these is the use of new sustainable gases (e.g. biomethane, Biogas, SNG). The use of such sustainable gases is increasing worldwide, particularly as their use can lead to a reduction in greenhouse gas emissions. Since the introduction of these new sustainable gases, DSOs have nevertheless raised questions about the impact of these gases on their assets.

It is within this context that the Energy Delta Gas Research (EDGaR) programme[7] was launched by the Ministry of Economic Affairs and the Province of Groningen. The EDGaR programme coordinates the realisation of scientific, applied and technological research into gas and sustainability. The programme aims to map out a case for the energy future of the Netherlands through the sustainable use of energy resources. The research programme is focused on three themes: from monogas to multigas, the future of energy systems and changing gas markets.

As regards the research theme “from monogas to multigas”, one of the aims is to determine the effects of the introduction of new sustainable gases on the gas infrastructure. It should also pave the way for the implementation of a gas distribution system that can carry gas of various qualities.

AVAILABLE KNOWLEDGE OF GAS COMPONENTS AND MATERIALS

As a first step, several literature surveys were carried out[2][3][4]. An inventory was prepared of the most important materials (including joints) used in Dutch gas distribution systems. This very long list was divided up on the basis of importance and vulnerability by examining the quantities employed and the potential safety impact.
In plastic piping systems, the most important pipe materials are PE and PVC. The main jointing techniques in these systems are:

- Fused PE joints (electro-fusion and butt fusion)
- POM couplers with rubber sealing (mechanical fitting, full-end-load resistant)
- PVC couplers with rubber sealing (mechanical fitting, non-end-load resistant)

In metal piping systems, the principle materials are steel and copper. Aluminium is also widely used as a shell material for regulators, and as such is also important. Two main joint types are employed in metal piping systems:

- Welded steel joints (made by gas metal arc welding (GMAW) or shielded metal arc welding (SMAW))
- Brass mechanical fittings used in copper piping systems

In the second step, the chemical compositions of the different types of sustainable and new gases were examined. The result was an extensive list of different chemicals, which were subsequently categorised into groups based on their chemical composition. The first column of Table 1 shows the categorised chemical compositions. A distinction was made between G-gas, narrow band gas and wide band gas. G-gas, or so-called Groningen gas, is natural gas from the large gas field near Slochteren. This gas contains

a relatively large amount of nitrogen in comparison to other gas fields. Narrow band gas has been defined as upgraded or downgraded gas that has the same physical properties (e.g. Wobbe index, Calorific value) as G-gas. The concentration limits for the composition of narrow band gases are based on the additional terms and conditions applicable to Dutch biomethane producers[9]. Differences in chemical composition between G-gas and narrow band gas are mainly to be found in the levels of CO_2 and H_2S. Differences also exist in the concentrations of trace components such as those containing halogens.
Wide band gas has been defined as all sustainable gases including raw gases and partially upgraded sustainable gases. This means that the physical properties and the chemical composition of wide band gas may be completely different to those of G-gas or narrow band gas and that the concentrations of chemical compositions may lie within a very broad range. Table 1 shows a comparison between the chemical composition of average G-gas, the limiting values of narrow band gases and the maximum concentration values found in wide band gases.

Table 1 – Chemical limitations for narrow band gases, maximum concentrations found in wide band gases and average values for G-gas.

Chemical compound/mix	**G-gas Average[8]**	**Narrow band gas limiting values[9]**	**Wide band gas Max. found concentration[3]**	**Unit**
Sulphur (total)	6.7	45	-	mg/m^3 (n)
Inorganically bound sulphur (H_2S)	0.4 ppm	5 ppm	4 300 mg/m^3 (n)	
Mercaptane	< 1.0	10	-	mg/m^3 (n)
Odorant value (*THT*)	17.7	> 10; nom 18; < 40	-	mg/m^3 (n)
Chlorine-containing compounds	< 0.1	50	735	mg/m^3 (n)
Fluorine-containing compounds	< 0.1	25	256	mg/m^3 (n)
Ammonia	< 0.1	4	100	ppm
Hydrogen chloride (HCl)	< 1.0	1	Traces (ppb)	ppm
Hydrogen cyanide (HCN)	< 1.0	10	Traces (ppb)	ppm
Carbon monoxide (CO)	< 100	10 000	700 000	ppm
Carbon dioxide (CO_2) in dry gas	0.9	10,3	59,0	vol %
Aromatic hydrocarbons	500	10 000	Traces	ppm
Benzene	-	500	1.4	ppm
Toluene	-	-	76.2	ppm
Oxygen (O_2) in dry gas	< 100 ppm	0.5	3	vol%
Hydrogen (H_2)	< 0.01	12	62	vol %
Methane (CH_4)	81.29	No limit	99.8	mol%
Nitrogen (N_2)	14.32	No limit	50.9	mol%
Ethane (C_2H_6)	2.87	-	2	mol%
C_2H_y (except C_2H_6)	-	-	25	mol%
C_3H_y	0.38	-	10	mol%
C_4H_y	0.15	-	3.5	mol%
$C_{5+}H_y$	0.09	-	0.6	mol%
C_xH_y	-	-	0.3	mol%
Phosphine	Technically free	Technically free	0.7	mg/m^3 (n)
Organosilicons	< 0.1	5	20	mg/m^3 (n)
Volatile Organic Compounds (VOC)	Traces	Technically free	Traces	ppm

Metals (copper, mercury)	Traces	Technically free	Traces	ppm

A literature review was carried out based on the differences between G-gas, narrow and wide band gas in order to determine whether deteriorating influences at these concentration levels on the materials present in the gas distribution network could be expected. As regards polymeric materials (PE, PVC, rubber and POM), the survey focused on the effect on environmental stress cracking (ESC). For metallic materials (steel, copper and aluminium), it focused on the effect on corrosion rate. ESC in polymeric materials and the corrosion of metallic materials are considered to be the most important failure mechanisms where these materials are exposed to sustainable gases.

The results of the literature study are summarised in the matrix below. The colours indicate what is known about the impact of the gas components on the various materials and on both existing and new joints in existing networks. New joints in existing networks must be considered with regard to maintenance, repair or extension of the gas network where the existing pipe material has been exposed to sustainable gases. The meaning of the colour coding in the matrices is summarised in Table 2.

Table 2 – Meaning of the colour coding in the matrices

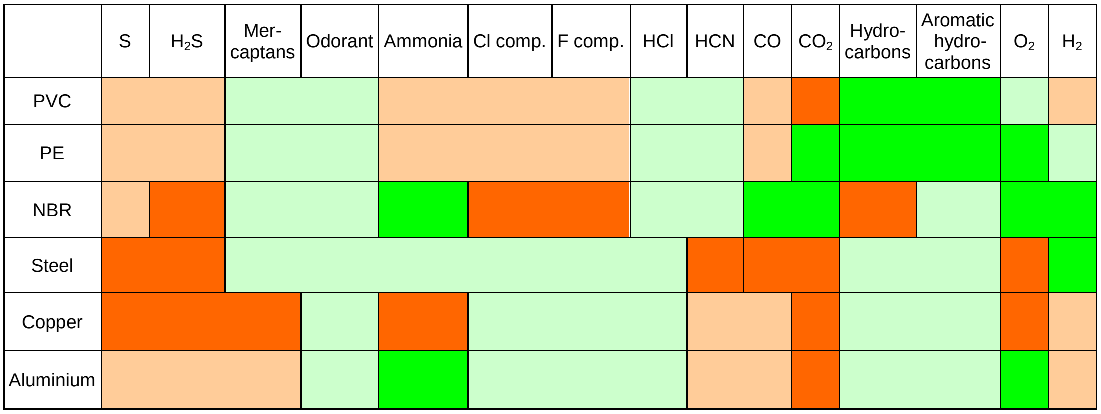
Colour		**Result of the literature research**
🟢	=	The effect is unknown, but is expected to be very minor or non-existent.
🟩	=	This component has no effect on the material at the concentrations found in narrow or wide band gas
🟠	=	The effect is unknown
🟧	=	Deleterious effects are to be expected under some conditions.

Table 3 shows the results of the literature study with regard to the impact of wide band gases on the most important gas distribution materials. The effect specified applies to the maximum concentrations found for wide band gases in the literature examined.

Table 4 shows the results of the literature study with regard to the impact of new sustainable gases on new joints. The impact specified applies to the maximum concentrations found for wide band gases in the literature examined.

Note: These matrixes are shown as an example. For complete results, please see the full reports[2][3][4].

Table 3 – The impact of wide band gases on the most important gas distribution materials [3].



	S	H_2S	Mer-captans	Odorant	Ammonia	Cl comp.	F comp.	HCl	HCN	CO	CO_2	Hydro-carbons	Aromatic hydro-carbons	O_2	H_2
PVC	🟠	🟠	🟢	🟢	🟠	🟠	🟠	🟢	🟢	🟠	🟧	🟩	🟩	🟢	🟠
PE	🟠	🟠	🟢	🟢	🟠	🟠	🟠	🟢	🟢	🟠	🟩	🟩	🟩	🟩	🟢
NBR	🟠	🟧	🟢	🟢	🟩	🟧	🟧	🟢	🟢	🟩	🟩	🟧	🟢	🟩	🟩
Steel	🟧	🟧	🟢	🟢	🟢	🟢	🟢	🟢	🟧	🟧	🟧	🟢	🟢	🟧	🟩
Copper	🟧	🟧	🟧	🟢	🟧	🟢	🟢	🟢	🟠	🟠	🟧	🟢	🟢	🟧	🟠
Aluminium	🟠	🟠	🟠	🟢	🟩	🟢	🟢	🟢	🟠	🟠	🟧	🟢	🟢	🟩	🟠

Table 4 – The impact of sustainable gases on new joints in existing gas distribution networks[4].

Joint	Material	S	H_2S	Mer-captans	Odorant	Ammonia	Cl comp.	F comp.	HCl	HCN	CO	CO_2	Hydro-carbons	Aromatic hydro-carbons	O_2	H_2
Coupler and pipe	PVC/SBR PVC/NBR POM/NBR	🟧	🟧	🟢	🟢	🟧	🟥	🟥	🟢	🟢	🟧	🟥	🟩	🟩	🟧	🟧
Electro-fusion and butt fusion	PE	🟧	🟧	🟢	🟢	🟧	🟧	🟧	🟢	🟢	🟥	🟥	🟩	🟩	🟩	🟧
Welded	Steel	🟥	🟥	🟢	🟢	🟢	🟧	🟧	🟧	🟧	🟥	🟥	🟢	🟢	🟥	🟢
Compres-sion	Copper /Brass	🟥	🟥	🟥	🟢	🟥	🟢	🟢	🟢	🟧	🟧	🟥	🟢	🟢	🟥	🟧

The literature survey was in some cases inconclusive. This leads to so-called "white spots". As regards the polymeric materials, these "white spots" are to be found in particular in the light orange blocks. For the metallic materials, they can be found in the dark orange blocks. These "white spots" form the starting point for the experiments.

FILLING IN THE WHITE SPOTS THROUGH EXPERIMENTS

The information gained in the literature survey was used to design a set of experiments with the objective of filling in these "white spots". Two types of experiments were identified:

- TYPE 1 TEST: To determine if there is any effect at all.
  These tests are typically performed with relatively high concentrations in order to determine if there is any effect at all.

- TYPE 2 TEST: To determine at which concentrations any problems arise.
  Testing is performed at different concentration levels in order to determine the effect at each concentration level.

For the polymeric materials, type 1 tests are generally required. These determine whether there is any effect at all. These tests focus on Environmental Stress Cracking (ESC). For joints in plastic piping systems, the fusibility of PE after possible absorption of certain gaseous components in PE pipe requires particular attention.

For metal piping systems, the experiments mainly focus on determining the concentration levels at which corrosion problems arise (Type 2). The corrosion rate is the benchmark for determining the effect of new sustainable gases on metals. The same applies to welded joints in steel piping systems. As regards brass fittings in copper piping systems, stress corrosion is the most important effect considered.

TESTING THE IMPACT ON PLASTIC PIPING SYSTEMS

ENVIRONMENTAL STRESS CRACKING TESTS FOR POLYMERIC MATERIALS

The impact of sustainable gases on polymeric materials is currently being tested by means of environmental stress cracking (ESC) experiments. Many different ESC methods have been described in literature and have been standardised[10]. All methods are based on the same principle: a stress is applied to the material well below its yield strength while the material is exposed to the chemical component under consideration. Specially designed environmental stress cracking methods, in which samples are taken from pipes and fittings, have been devised for this investigation: dogbones under constant load (Figure 1), rings in a U-clamp (Figure 2), dogbones in a Marbone clamp (Figure 3) and rubber rings over oversized pipes (Figure 4). In designing the experiments, special attention has been paid to obtaining reproducible and reliable results.

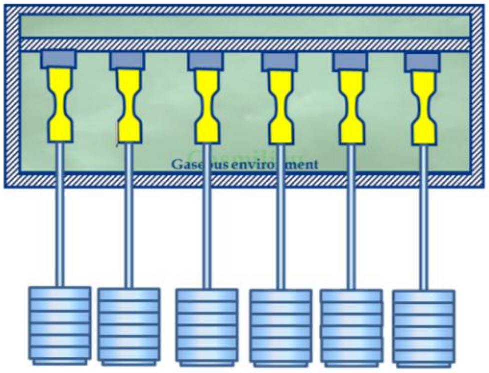


Figure 1 – Schematic view of the constant load equipment for testing PE and PVC samples.

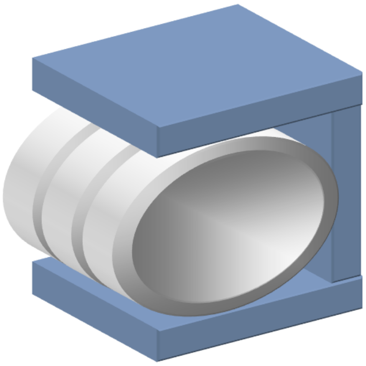


Figure 2 – Principle of a U-clamp test on a PE and POM ring

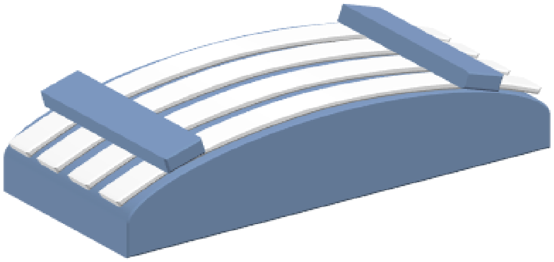


Figure 3 – Principle of a Marbone clamp test on POM tensile test bars.

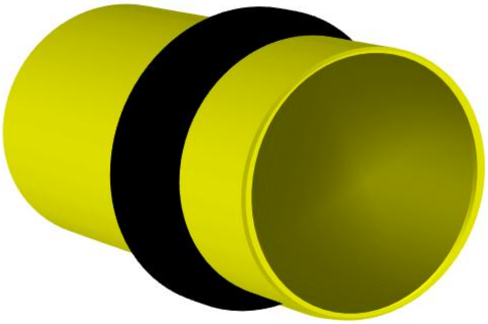


Figure 4 – Setup to expose stressed rubber rings to a particular gaseous environment

Table 5 gives an overview of all the applicable types of polymeric materials and the applied ESC method. The PE and PVC samples were taken directly from pipes. For old materials (e.g. first generation PE and PVC-U), this necessitated the excavation of such pipes from the Dutch gas distribution network. For other PE and PVC materials, newly fabricated materials were used. The rubber materials were taken from sealing rings of new PVC couplers. The POM rings used in the U-clamps were milled from new POM couplers. The POM dogbones for the Marbone clamp were not taken from couplers but instead punched out of sheets of virgin POM material.

Table 5 – Investigated types of materials, their condition and the ESC methods employed.

Polymeric materials		**Condition of material**	**ESC methods**
PE	First generation PE50	Old and used	Constant load & U-clamp
	Second generation PE80	New	Constant load & U-clamp
	Third generation PE100	New	Constant load & U-clamp
PVC	PVC-U – type 1	Old and used	Constant load
	PVC-U – type 2	Old and used	Constant load
	PVC-HI – type 1	New	Constant load
	PVC-HI – type 2	New	Constant load
Rubber	SBR	New	Ring over pipe
	NBR	New	Ring over pipe
POM	Homopolymer	New	U-clamp & Marbone clamp
	Copolymer	New	Marbone Clamp

Table 6 shows the polymeric materials and the investigated gaseous environments. The chemical compositions of the gaseous environments are based on the "white spots" determined in the literature survey. The concentration levels of these gaseous environments are based on the values given for the limiting concentration values of narrow band gases and on the maximum concentrations found in wide band gases. An explanation of the concentration levels is also given in Table 6.

Of all the chlorine and fluorine containing components that may occur in the different gases, it is known that dichloromethane (DCM) is one of the most aggressive halogenated organics as regards its effect on PVC and PE. It was therefore decided to use DCM as model gas for all halogen-containing materials. Sulphur-containing components may also be present in a wide variety of gases. H_2S is considered to be the most aggressive of these components and has the highest risk of adverse effects on polymeric materials. It was therefore decided to use H_2S as a model gas for sulphur-containing components and to investigate the effects of this gas only.

Table 6 – Polymeric materials versus the investigated gaseous environments and explanation of these concentration levels

Polymeric materials	**Gaseous environments**	**Explanation of the concentration levels (see also Table 1)**
PE, PVC, rubber, POM	100 vol% N_2	Nitrogen is chosen as matrix gas and 100 vol% N_2 is therefore needed for reference purposes.
Rubber*	5 ppm H_2S	The maximum allowed concentration of H_2S in narrow band gas is 5 ppm.
PE, PVC, Rubber, POM	160 ppm H_2S	This concentration of 160 ppm H_2S for wide band gas was chosen by the Dutch DSOs as acceptable (= five times the MAC value for eight hours). The Dutch DSOs have decided that it is not safe to operate the grid above these concentrations at any time.
Rubber*	80 ppm H_2S	This concentration lies between that of the wide and narrow band gases.
PE, PVC, Rubber, POM	75 mg/m^3 DCM	The maximum allowed concentration of halogen-containing compounds in narrow band gas is 75 mg/m^3.
PE, PVC, Rubber, POM	1000 mg/m^3 DCM	The maximum concentration of halogen-containing chemicals found in wide band gas is 1000 mg/m^3.
Rubber*	550 mg/m^3 DCM	This concentration lies between that of wide and narrow band gases.
PE, PVC, Rubber, POM	100 ppm NH_3	The maximum concentration of NH_3 found in wide band gas is 100 ppm.
PVC, Rubber, POM	59 vol% CO_2	The maximum concentration of CO_2 found in wide band gas is 59 vol%.
POM	3 ppm HCl	The maximum allowed concentration of HCl in narrow band gas is 1 ppm **.
POM	62 vol% H_2	The maximum concentration of H_2 found in wide band gas is 62 vol%.
Rubber	Natural gas	G-gas is needed for reference purposes.
Rubber	2 vol% propene	The maximum concentration of propene found in wide band gas is 2 vol%.

* *A type 2 test is underway in order to determine the impact of H_2S and DCM on rubber.*

** *Several gas mixture producers have stated that it is impossible (with current techniques) to produce a constant gas mixture of 1 ppm HCl. A concentration of 3 ppm was therefore used.*

The gas pressures used in the Dutch gas distribution grid lie predominantly between 30 and 100 mbar(g) and between 4 and 8 bar(g). It was therefore decided to perform the experiments at gas pressures of 30 mbar(g) and 8 bar(g). After the period of exposure the environmental stress cracking samples will be subjected to non-destructive (visual and dimensional changes) and destructive testing. Table 7 provides an overview of the destructive tests to be performed on the polymeric samples.

Table 7 – Destructive tests performed on the Polymeric materials after exposure to components of sustainable gases for a period of two years.

Material	Samples	Destructive testing
PE	Dogbone samples	Tensile testing in accordance with ISO 6259-3[11]
	Ring samples	Ring tensile testing in accordance with ISO 8496[12]
PVC	Dogbone samples	Impact testing in accordance with ISO 8256[13]
Rubber	Ring samples	Tensile test
POM	Ring samples	Ring tensile testing in accordance with ISO 8496[12]
	Dogbone samples	Tensile test in accordance with ISO 527[13]

FUSIBILITY OF PE AFTER EXPOSURE

The fusibility after possible absorption of certain gaseous components of PE materials is currently being tested. The literature survey prompted the conclusion that two main gas components should be investigated. These are:

- A mixture of 59 vol% CO_2 in a matrix of N_2
  PE can absorb large amounts of CO_2. This can have a negative impact during welding.
- A mixture of different siloxanes (L1, D4 and D5)
  PE does not absorb siloxanes well. However, the siloxanes can form a layer on the pipe wall. It is known that these siloxanes are hard to remove from the welding zone and that they can have a negative impact during welding[15].

The effects of CO_2 absorption are being tested by exposing the PE pipes to the CO_2 and N_2 mixtures at a slight overpressure at room temperature for a period of two years. After two years of exposure, the PE pipes will be welded. The quality of the welds will be tested destructively. In order to investigate the formation of siloxane layers and the effect that this has on the fusibility of PE pipes, the pipes are being exposed to a mixture of pure siloxanes. The ends of the PE pipes will be submerged in this siloxane mixture. After a period the pipes will be taken out and welded together. The quality of the joints will be tested destructively.

TESTING IMPACT ON METAL PIPING SYSTEMS

CORROSION TESTS ON METAL MATERIALS

The testing of metallic materials focuses mainly on corrosion. The effects on the corrosion rate are determined at different concentration levels of the tested components (Type 2 test). The steel and copper samples used in the experiments are derived from strips taken from plates that have the same metallic structure as pipes. The aluminium samples are parts from a pressure regulator.

Water must be present before corrosion of metallic materials can occur. The samples have therefore been partially submerged in water while gas is flushed through an autoclave. The temperature around the autoclave is kept constant at 30° Celsius by means of a surrounding water bath. Figure 5 shows an illustration of the experimental setup.

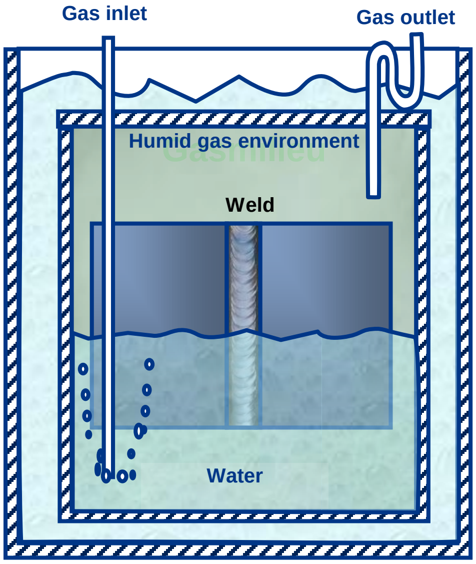


Figure 5 – Experimental setup (autoclave) for corrosion testing of metals.

Table 8 gives an overview of the metallic materials, the investigated gaseous environments and the test pressures. The concentration levels are based on the "white spots" and the narrow and wide band limits derived from the literature survey. It is known that most of the chemical components listed may have an effect on the metallic materials. However, the concentration levels that must be present before negative effects arise and in particular the interactions between the various gas components (especially the effects of O_2) that may increase or decrease the corrosion rate are still unknown. The gas conditions and quantities were determined using Design of Experience (DOE). Table 8 also includes an explanation of the specified concentration levels.

Table 8 – Metallic materials, investigated gaseous environments and test pressures

Material	**Gas conditions**				**Pressure (bar(g))**	**Explanation of the concentration levels (see also Table 1)**
	Relative Humidity (%)	**CO_2 (vol%)**	**O_2 (vol%)**	**H_2S (ppm)**		
Steel, Copper & Aluminium	100	10	0.5	34	0.03	CO_2, O_2 en H_2S inside narrow band gas limits
	100	0	0.5	34		O_2 en H_2S inside narrow band gas limits
	100	10	0.1	34		Effects of low O_2 levels are unknown, therefore this concentration was chosen
	100	10	0.01	34		Effects of low O_2 levels are unknown, therefore this extremely low concentration was chosen
	100	50	0.01	160		Worst case wide band gas with low O_2 level, low pressure
	100	50	0.01	160	8.0	Worst case wide band gas with low O_2 level, high pressure
	50	50	0.01	160	0.03	Worst case wide band gas with low O_2 level and 50% R.H.
	100	50	3	160		Worst case biogas with normal O_2 level
	100	0	3	160		H_2S worst case wide band gas without CO_2
	100	50	3	0		CO_2 worst case wide band gas without H_2S

The experiments have a total duration of two years. As the experiments progress, the corrosion rate is being followed by measuring the material thicknesses at set intervals. The effect of each component on the corrosion rate is calculated on the basis of the concentration levels.

CORROSION TESTS ON WELDS AND FITTINGS

The microstructure of steel is altered locally when the material is welded (heat affected zone). The heat-affected zone is particularly susceptible to corrosion. This has been taken account of in the experimental setup for corrosion testing of metals by adding a welded joint to the steel strips.

In contrast to plastic pipe systems, the welding of exposed metal pipe material will not be tested. This is because it is not expected to have any effect. Corrosion is removed before welding and any gases trapped in the metal structure will evaporate due to the high temperatures that arise during welding.

The effect of ammonium on brass mechanical fittings as used in copper pipelines (generally inside buildings) is also being tested. It is known that ammonium may affect both brass and copper under certain circumstances[2][3] through stress corrosion. During the test, assemblies of copper pipes with brass mechanical fittings with different torques are exposed to the highest known concentration of ammonium in wide band gases. The literature states that this concentration is 100 ppm NH_3. The joints will subsequently be inspected for corrosion.

BUILDING TEST RIGS FOR DIFFICULT LARGE SCALE TESTS

The tests described above require specially designed test rigs. This was a challenging operation. The test rigs needed to be able to hold a large number of samples and required special safety measures due to the severe toxicity of some of the gases and the elevated pressures of up to 8 bar. The concentration levels of the chemical components must be maintained at very constant levels throughout the test period of two years. This is in itself challenging. Figure 6 shows a detail of the test rig for the polymeric samples under constant load, while Figure 7 shows the complete installation used for testing. Figure 8 shows the metallic materials in a special PTFE holder used to place them in the test rig, while Figure 9 shows the entire test installation for the corrosion experiments.

Figure 6 – Constant load experiments on PVC samples

Figure 7 – Full-scale setup used to determine the effects of sustainable gases on polymeric materials

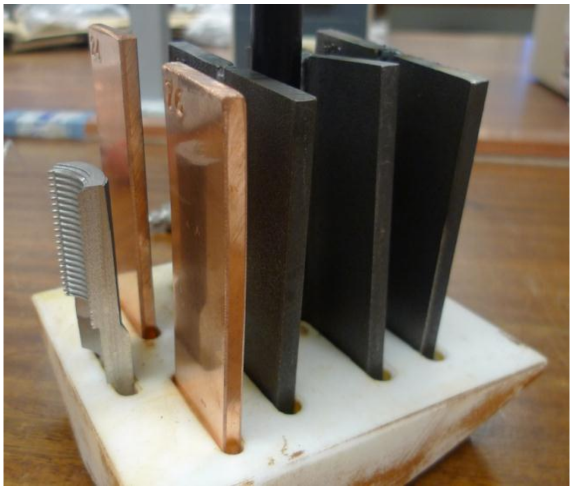


Figure 8 – Metallic samples in a special PTFE holder for the corrosion test

Figure 9 – Complete setup of the corrosion tests

FIELD EXPERIMENTS

In addition to the laboratory tests, field experiments are also being performed. The purpose of these tests is to determine whether narrow band gases have any adverse effects that have not been foreseen. For the field experiments, two rigs were inserted into the Dutch distribution grid; one was installed directly after a biomethane feed (meaning narrow band quality, see Figure 10), whereas the other was installed in a pipeline carrying G-gas quality only (Figure 11). The G-gas test rig was installed for reference purposes. The test rigs have been filled with the same materials as used in the laboratory experiments, where applicable under the same applied stresses. After an exposure period of two years the materials that have been exposed to G-gas and narrow band gas will be tested in a similar manner to the lab samples for any degradation in quality.

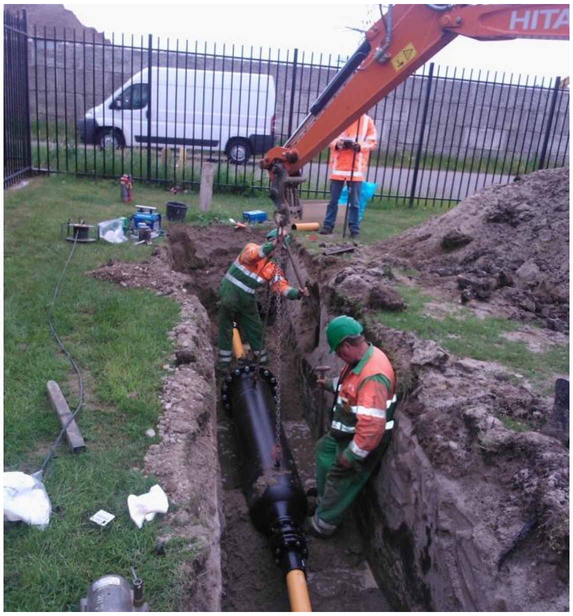


Figure 10 – Test rig under biomethane conditions (narrow band)

Figure 11 – Test rig under G-gas conditions.

ACKNOWLEDGMENTS

This research has been financed by a grant from the Energy Delta Gas Research (EDGaR) programme. EDGaR is co-financed by the Northern Netherlands Provinces, the European Fund for Regional Development, the Dutch Ministry of Economic Affairs and the Province of Groningen. The authors would also like to thank Netbeheer Nederland (the Netherlands) for their financial support for the project.

REFERENCES

[1] IPCC, *2007: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

[2] Kiwa Technology, *Effects of Narrow Band Gases on Materials used in Gas Distribution Networks (A6a)* - Literature Review, GT-110204, (April 2012).

[3] Kiwa Technology, *Effects of Wide Band Gases on Materials used in Gas Distribution Networks (A5a)* – Literature Review, GT-110205, (June 2012).

[4] Kiwa Technology, *Impact of Sustainable Gases on Joints used in Gas Distribution Systems (B9) - Literature Review*, GT-110207, (October 2012).

[5] Kiwa Technology, *Kiwa Experimental Setup of projects A6a, A5a & B9,* GT-120085, (November 2012).

[6] Kielich, Wolf, *Subterranean Commonwealth, 25 years of Gasunie and Natural Gas*, Amsterdam, Uniepers, 1988.

[7] http://www.edgar-program.com/ last visited on 25 July 2014

[8] NV Nederlandse Gasunie, *Basisgegevens Aardgassen,* (1980), 39 (Table A9)

[9] Schoemaker I., *Aanvullende voorwaarden RNB Groen gas invoeders*, (Dutch), versie D14.0, 15 January 2009.

[10] Several methods for determining the influence of Environmental Stress Cracking (ESC) have been standardised. The following list gives a brief overview:

- *ISO 16242, Notch tensile test to measure the resistance to slow crack growth of polyethylene materials for pipe and fitting products (PENT)*
- *ISO 16770, Plastics -- Determination of environmental stress cracking (ESC) of polyethylene -- Full-notch creep test (FNCT)*
- *ISO 22088, Plastics -- Determination of resistance to environmental stress cracking (ESC) -- Part 2: Constant tensile load method*

[11] ISO 6259, *Thermoplastics pipes -- Determination of tensile properties -- Part 3: Polyolefin pipes*

[12] ISO 8496, *Metallic materials -- Tube -- Ring tensile test*

[13] ISO 8256, *Plastics -- Determination of tensile-impact strength*

[14] ISO 527, *Plastics -- Determination of tensile properties -- Part 3: Test conditions for films and sheets*

[15] Scholten F.L. and Wolters M, *Securing Good Electro Fused Joints in PE Pipelines*, Plastic Pressure Pipes, Düsseldorf, 21-24 February 2011, org: AMI, UK.