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Review of Oxygen Specification for the below 7 bar Distribution Network

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Restricted

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Executive Summary

Scotia Gas Networks (SGN) are currently developing a project which aims to inject up to 50m^3/hour of biomethane into their gas distribution system at Didcot. Biogas produced from Anaerobic Digestion (AD) results in a gas consisting primarily of methane and carbon dioxide in an approximate 2:1 ratio. The biogas can contain some other components including nitrogen, oxygen and hydrogen sulphide. Measurements taken on the biomethane at Didcot indicate that the oxygen content can regularly approach 1%.

The quality and composition of natural gas, biomethane and biogas does have an impact on the safe, efficient and reliable utilisation of the fuel.

In the UK Gas Safety Management Regulations set a limit to oxygen concentration in distributed gas of 0.2%, but the origin of this value is not clear. This report surveys the oxygen content in gas regulations used throughout Europe and there is not a consensus of values. The values range from 0.001% to 3% depending on country and on the type of gas grid.

The oxygen content of the fuel does impact on fundamental combustion parameters, like flame temperature, ignition energy, air:fuel ratio, as well as emissions and operational performance of combustion systems. However, if the content of oxygen is only a maximum of 1% then the changes are expected to be small.

Some gas utilisation equipment is more sensitive than others and particular reference to gas turbines, engines and fuel cells is raised. In addition some industrial processes may have negative impacts if oxygen is present in the fuel.

Overall, a concentration of 1% oxygen in the fuel gas is not expected to result in significant changes to

- the risks of using the gas
- the safety aspects related to gas use
- the efficiency of using the fuel
- the pollutant emissions
- the operability of equipment, appliances and processes

Additionally, although steel corrosion rates in the presence of water are likely to increase five-fold for a corresponding increase in oxygen concentration, the ensuing rate will still be small enough not to impact on asset lifetimes.

Taking the conclusions from this work one stage further, there is unlikely to be a safety or operations impact on the distribution network up to an oxygen concentration of several percent. The limiting factors are more likely to be due to Wobbe Number falling below the lower bound of the GS(M)R limit for leaner natural gases. For an average natural gas composition corresponding to that expected for the Didcot part of the SGN network (gas currently received via Bacton), this corresponds to an oxygen concentration of 2-4% depending on CO2 concentration.

Contents

1 Introduction

Scotia Gas Networks (SGN) are currently developing a project which aims to inject up to 50m^3/hour of biomethane into their gas distribution system at Didcot. Biogas produced from Anaerobic Digestion (AD) results in a gas consisting primarily of methane and carbon dioxide in an approximate 2:1 ratio. The biogas can contain some other components including nitrogen, oxygen and hydrogen sulphide. Nitrogen and oxygen may be present at levels of around 1%. Hydrogen sulphide concentrations are variable and dependent on the feedstock used for the biogas production, but levels around 100 – 200 ppm are typical. The biogas may also contain low levels of other chemical species, which need to be considered as they may impact on the performance of gas utilisation equipment, for instance, siloxanes and chlorine-containing compounds.

Historically biogas has been used in gas engines for power production, often combining with heat recovery to improve the overall efficiency of the process.

Recent work has focused on upgrading the biogas to natural gas quality, to produce biomethane; a process that involves removal of the carbon dioxide down to a level similar to that present in natural gas. Unless the upgrading and clean-up processes remove all other contaminants as well as the carbon dioxide, the concentration of these other species will be greater in the biomethane than in the biogas.

Of particular interest for the present study is the concentration of oxygen, that is often up to about 0.6% by volume in biogas (dependent on the source of the organic material used in the digestion process and the digestion technology) but could theoretically increase to about 1% following upgrade by removal of carbon dioxide. Measurements which are being made on the biomethane being produced for injection at Didcot indicate that the oxygen content does in fact approach 1% by volume on a regular basis. Given the present oxygen specification in the GS(M)R, it will not be possible to inject biomethane into the SGN gas grid at Didcot without some form of derogation because there is no opportunity for gas blending. This report endeavours to collate information on the possible impacts of elevated oxygen content of the supplied gas.

This report provides information on:

- The current legislated gas quality requirements for the UK (from the HSE)
- The current network entry specified by National Grid
- Information on oxygen content in European natural gas supplies
- The impact of oxygen content in gas on combustion
- The impact of oxygen content in gas on emissions
- The impact of oxygen content in gas on gas supply networks, meters and services

2 Network Background

The Didcot biomethane injection plant can be assumed to produce gas for grid injection at a constant 37scmh (the remainder being used onsite within the plant for heating). This means that zones of influence within the network will change depending on overall network demand. In simple terms the biomethane will disperse further when the demand is low as less gas from the other network entry point will be required. SGN have carried out some Synergee analysis (Appendix 1) which shows that at lowest predicted nominal demand (1% domestic use, no industrial or commercial) up to 200 users on the network would receive gas with some biomethane content, albeit in many cases heavily diluted with natural gas. Where demand is normal or high, the zone of influence would be limited to a nearby industrial estate with up to 50 users, again with likely high dilution.

In terms of pipeline material 82-98% of the network construction is polyethylene, with the majority of the remainder being Spun Iron and Cast iron.

3 Gas quality requirements for gas transported and distributed in the UK

To ensure that gas supplied in the UK can be utilised safely and efficiently, a specification was developed by the UK Government Health and Safety Executive (HSE), and the then nationalised British Gas utility. This forms the Gas Safety (Management) Regulations – GS(M)R.

This specification recognises that the key factor for gas quality is Wobbe Number, which is a measure of the heat flux through an appliance, based on discharge through a burner nozzle. Gases supplied within the specified Wobbe Number range, and in accord with the Incomplete Combustion Factor (ICF) and Sooting Index (SI), should provide acceptable performance within a certified appliance designed to operate in the UK.

A summary of the GS(M)R limits is shown in the following diagram:

Property	**Range or Limit**
H_2S	≤ 5 mg/m^3
Total sulphur	≤ 50 mg/m^3
Hydrogen	≤ 0.1 mol%
Oxygen	≤ 0.2 mol%
Impurities and water and hydrocarbon dewpoints	The gas shall not contain solids or liquids that may interfere with the integrity or operation of the network or appliances
Wobbe Number	Between 47.20 and 51.41 MJ/m^3 - normal limits.
ICF (Incomplete Combustion Factor)	< 0.48 - normal conditions
SI (Sooting Index)	< 0.60
Odour	Gas below 7 bar (g) will have a stenching agent added to give a distinctive odour

Table 1: Summary table of the GS(M)R under normal and emergency conditions.

[UK standard conditions are 15 °C and 1013.25 mbar for both combustion and metering]

The GS(M)R does not provide an explanation behind the limits for both hydrogen and oxygen, and it is thought that these were derived from information on the then current levels of these components within the Noth Sea natural gas supply.

In addition to the GS(M)R, distribution network operators provide a network entry specification for suppliers of gas into their networks (both transmission and distribution). This takes GS(M)R requirements and refines the limits for certain properties to account for other operational factors. With regard to oxygen the limit is low to account for LNG peak shaver operation and other gas storage systems, which are NTS based and therefore not relevant to this report.

The details of the SGN network entry specifications are shown in the following table:

Property	Range or Limit
Hydrogen sulphide	Less than or equal to 5 mg/m^3
Total sulphur	Less than or equal to 50 mg/m^3
Hydrogen Content	Less than or equal to 0.1% (molar)
Oxygen Content	Less than or equal to 0.2% (molar)
Hydrocarbon dewpoint	Not more than -2 °C at any pressure up to the delivery pressure provided in paragraph (o)
Water content	Not more than 50 mg/m^3 nor such as would cause a water dewpoint more than -10 °C at the delivery pressure provided in paragraph (o)
Wobbe Number	Shall be between 47.35 to 51.26 MJ/m^3
Incomplete combustion factor (ICF)	Less than or equal to 0.48
Sooting index (SI)	Less than or equal to 0.60
Odour	Gas delivered to the System shall be odourised with odourant NB (80% tertiarybutyl mercaptan, 20% dimethyl sulphide) at an odourant injection rate of 7 mg/SCM and may be varied at SGN's written request between 4 mg/SCM and 8 mg/SCM.
Carbon Dioxide	Less than or equal to 2.5% (molar)
Total Inerts	Not more than 7.0% (molar)
Gross calorific value	Shall:- (i) not be lower than 36.9 MJ/m^3 or (if greater) the Target CV; and (ii) not be higher than 42.3 MJ/m^3 Provided that gas may be delivered to the system at the LDZ system entry points with a Gross Calorific Value as low as 1 MJ/m^3 below the Target CV (provided that the Gross Calorific Value of gas delivered to the System shall not be less than 36.9 MJ/m^3) where DFO is able to demonstrate to SGN's reasonable satisfaction

Table 2: SGN Gas Entry Conditions (in part from Appendix B of Network Entry Provisions [from CNG Services]).

[UK standard conditions are 15 °C and 1013.25 mbar for both combustion and metering.]

Exemption from compliance with the network entry specification has to be negotiated with SGN. At the present time, no exemptions to the limits in GS(M)R have been sanctioned, although an Emergency Operation regime has been developed to accommodate a major network failure.

4 Current specification of O_2 content of Natural Gas

The following table summarises specified O_2 limits for gases supplied in Europe, as well as some representative specifications from USA and Canada.:

Country	**O_2 concentration (vol% or mol %)**	**Comment**
Austria	< 0.5 ≤ 0.02	ŐVGW G 31 “Erdgas in Österreich”) WAG and TAG pipeline specification
Belgium	<0.5	Indicative specification by Fluxys
Bulgaria	≤ 0.1	Gas quality specification for Bulgaria as stated by the State Regulatory Commission
Czech Republic	≤0.02 mol%	*RWE Transgas Net* Gas Quality Specification
Denmark	≤ 0.1 mol%	Transmission specification for natural gas transported by *Energinet.dk*
France	≤ 0.01 mol%	For general gas specification in line with EASEE-gas proposals. However, some gas accepted with higher levels, eg. O_2 content below 1000 ppm at Dunkerque and Taisnières H “Troll”, below 5000 ppm at Taisnières H “Ekofisk” and Obergailbach. It is believed that Gaz De France is prepared to accept an oxygen spec of 0.5% at Lille for dry gas with low H_2S
Germany	< 3% in dry grids <0.5% in wet grids	DVGW G 260 Requirements for natural gas in Germany, and G 262 for biomethane
Greece	≤ 0.2 mol%	Gas networks in Greece are regulated by the *Energy Regulatory Authority*
Hungary	≤ 0.2	*E.ON Földgáz* supplies all the Hungarian gas distribution companies
Ireland	≤ 0.1 mol%	Natural gas specification for gas entering the *Gaslink* network. Irish energy market is regulated by the *Commission for Energy Regulation*, *CER*
Italy	≤ 0.6 mol%	Italian government created an independent body, the Regulatory Authority for Electricity and Gas (Autorità per l’energia elettrica e il gas) but, in practice, the Italian gas quality specification is the transmission specification of *Snam Rete Gas*
Latvia	≤ 1.0	Gas in Latvia originates from Russia, Gazprom.
Luxembourg	≤ 0.01 mol%	*EASEE-gas* specification
Netherlands	≤ 0.5 mol%	*Kwaliteitsregulering Gasdistributie Nederland* Informatie- & Consultatiedocument, 2003
Poland	≤ 0.2 mol%	Gas specification for the Polish transmission company *Gaz-System SA*
Romania	≤ 0.02 mol%	Network code from Romanian regulator
Slovakia	0	*EUStream* specification
Slovenia	0	Slovenian regulator Agen-RS
Spain	≤ 0.01 mol%	The *Comisión Nacional de Energía* (*CNE*) regulates gas quality
Sweden	<1	Source: IEA Bioenergy Task 37
Switzerland	<0.5	Source: IEA Bioenergy Task 37
United Kingdom	≤ 0.2 < 0.001	Gas quality in the UK must comply with the *Gas Safety (Management) Regulations* {GS(M)R} National Grid network code
California, US EPA	1%	
Canada	0.2-1%	Most operators 0.4% but 1% for ANR

Country	O_2 concentration (vol% or mol %)	Comment
Australia	0.2%	In line with GS(M)R

Table 3: Compilation of oxygen concentration limits in natural gas

Many countries in Europe, the USA and around the world provide gas quality specifications that limit the concentration of oxygen in the gas. The reasons for this limit are not well defined but generally link to hazard and risk; in addition to the issues regard hazard and risk there are process limitations for oxygen in some network operations, especially LNG peak shaving.

The range of oxygen limits in natural gas transportation and distribution systems around Europe is relatively wide from 0.001 to 3%.

Germany has developed the most advanced standard with regard to biomethane in gas grids (G 262) and this recognises that allowed oxygen levels are sensitive to water content, as described in Section 0.

5 Impact of oxygen content of gas in combustion systems

Oxygen is one requirement of the typical fire/combustion diagram, with fuel and heat/ignition the others. Clearly it is important to understand the impact of oxygen and on any safety implications if the oxygen and fuel are intimately mixed, as they will be in biomethane.

This section investigates the impact of oxygen levels on the Wobbe Index, CV measurement, combustion fundamentals, emissions and overall utilisation equipment operability.

5.1 Impact of oxygen content on Wobbe Number

Wobbe Number is a measure of the heat input to a combustion system based on discharge of the fuel gas through a nozzle. It is defined as the gross calorific value (CV) divided by the square root of the relative density (RD). If the methane content of a gas decreases through increase in oxygen concentration then the CV is lowered and also the RD increases. Thus, the change to the Wobbe Number for methane (or a typical natural gas) will decrease by about 1.5% if the oxygen content increases from zero to 1%. As the oxygen concentration increases further, a linear decrease in Wobbe Number will be expected. Ultimately the limit to oxygen concentration is then a function of the Wobbe Number of the natural gas relative to the lower GS(M)R limit.

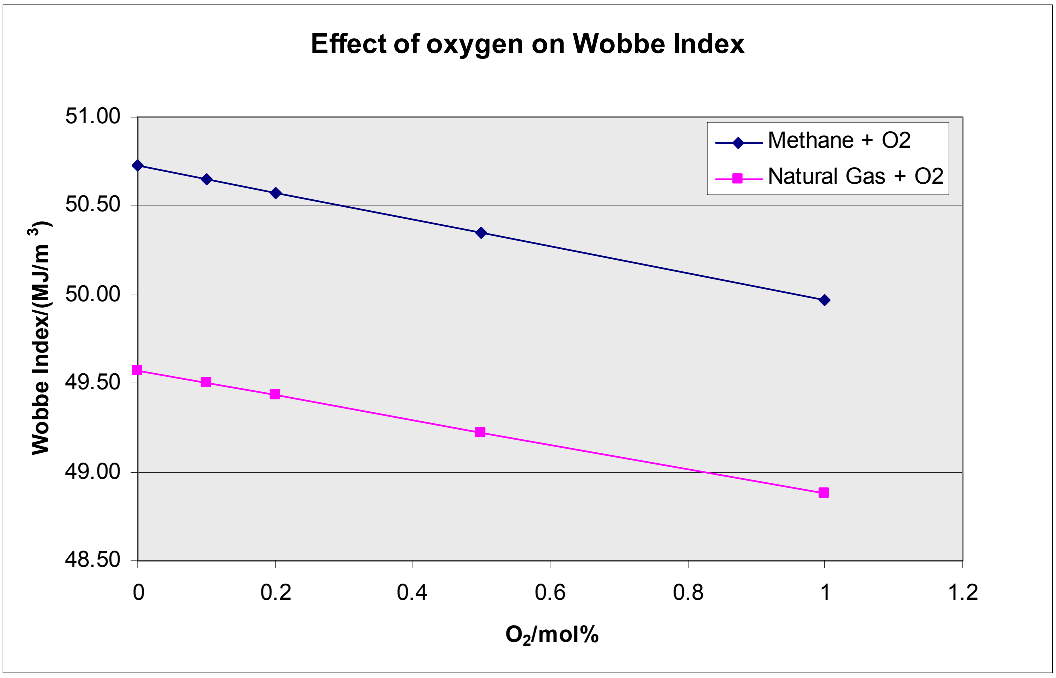


Figure 1: Impact of oxygen content on Wobbe Index

[UK standard conditions are 15 °C and 1013.25 mbar for both combustion and metering.]

The change to Wobbe Index will have a small impact on the operation of combustion equipment.

Biomethane produced from biogas by removal of carbon dioxide, and potentially enriched through addition of propane will be within the GS(M)R safe operating envelope. An example is shown in Figure 2.

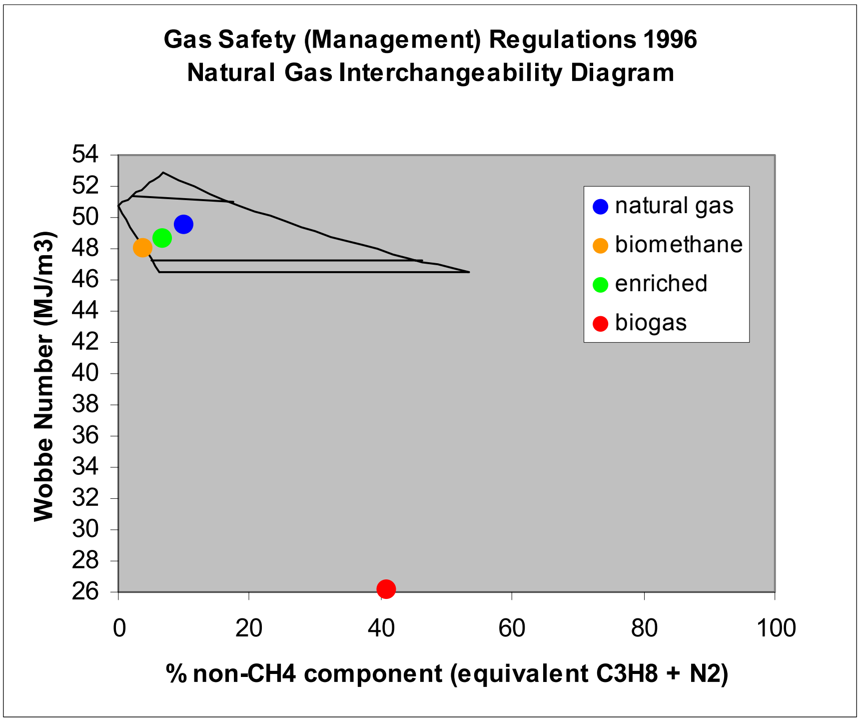


Figure 2: GS(M)R safe operating envelope

[UK standard conditions are 15 °C and 1013.25 mbar for both combustion and metering.]

The impact of increased oxygen concentration in the biomethane will be similar to increased total inerts and as such has an upper limit of 7%, according to the SGN entry specification. For GS(M)R compliance a methane – oxygen mixture can have up to 4.75% oxygen and meet the minimum Wobbe Number specification; higher oxygen concentrations would result in non-compliance. If the carbon dioxide concentration is of the order of 2% then the maximum oxygen concentration will be around 2.3%, assuming that methane is the only hydrocarbon component present.

5.2 Impact on CV Measurement

On the standard Model 500 Danalyzer, as approved for billing in the UK, any oxygen present would be co-eluted with the nitrogen. The difference in instrument response to a combined N_2 and O_2 peak would result in the nitrogen component being slightly underestimated - however since N2 does not contribute to CV the impact on CV should be negligible. O_2 and N_2 response factors have been determined for a lab based instrument (requirement under UKAS). We recommend that impact of O_2 on a correctly configured Danalyzer instrument is assessed and quantified subject to Ofgem requirement.

5.3 Impact on combustion fundamentals

If the oxygen content of the fuel increases then there will be a change to overall combustion fundamentals, including theoretical air requirement, flammability, minimum ignition energy, flame temperature and burning velocity.

Theoretical air requirement (Stoichiometric combustion)

With oxygen replacing some of the methane in the fuel, as the concentration increases from zero to 1%, there is a change in the stoichiometric combustion ratio. As the addition of oxygen is not accompanied by nitrogen (as is usually the case when considering air), air requirement decreases; in effect the fuel provides some of the required oxidant.

So for an increase in oxygen from zero to 1% there is an increase in the stoichiometric fuel amount from 9.48% to 9.61%, based on methane as the sole hydrocarbon fuel component.

Flammability

Flammability describes the range of fuel/oxidant mixtures that can support and sustain a flame. Flammability is typically defined for a set of physical conditions providing an upper and lower level within which a flame will propagate. Figure 3 provides an overview of the flammable range for a three component system – methane, oxygen and nitrogen.

Methane in air, at ambient conditions has a lower flammability limit (LFL) of 4.4% and an upper flammability limit (UFL) of 16% - as determined by recent German studies. Methane in oxygen has a much wider flammable range. The LFL of methane in oxygen remains at around 4.4% but the UFL increases to about 60%. Oxygen at low concentrations is not a problem but it can pose an explosion risk at higher concentrations (typically over 10%).

If the biomethane fuel contains only 1% oxygen (or biogas with 0.6%) then this level is not expected to give rise to any significant increase to the explosion risk, compared to systems considering natural gas alone.

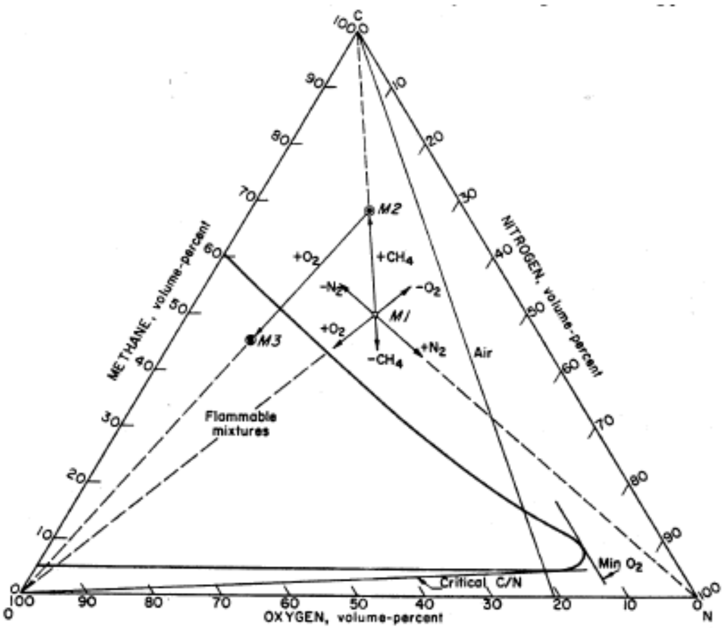


Figure 3: Flammability diagram for the methane, oxygen, nitrogen system at atmospheric pressure and 26 °C

Minimum ignition energy and autoignition

The minimum ignition energy for a fuel/oxidant mixture is dependent on the temperature pressure and composition. It relies on having an external ignition source, for example a spark. At atmospheric pressure the minimum ignition energy decreases as the oxygen content increases. A stoichiometric methane/oxygen system requires about 1/100th of the ignition energy of a stoichiometric methane/air mixture. Thus any increase in the oxygen content of the fuel, equivalent to enhanced oxy-combustion will result in a decrease to the minimum ignition energy. This may increase the risk factors for use of biomethane, although with only 1% oxygen in the biomethane the expected change is small. It is expected that the changes will be small for oxygen concentrations up to around 3% in the biomethane.

Autoignition is the self-ignition of a fuel/oxidant mixture caused by an increase in temperature or pressure rather than a result of an external ignition source. If the fuel contains an oxidant then this process can occur without any external oxidant. Autoignition can arise in gas engines and gas turbines and can lead to a negative impact on combustor performance and a degradation of system integrity, ultimately leading to failure. In addition to autoignition, if the fuel is heated then a chemical reaction can occur between the hydrocarbon and the oxygen. Systems that operate at relatively high pressure and at elevated temperature can result in chemical reaction, although without a “thermal runaway” or ignition. Some of the hydrocarbon can partially oxidise and it is possible to convert methane to methanol and methanal (formaldehyde). For biomethane and gases containing up to 3% oxygen it is unlikely that there will be a significant change to autoignition and partial oxidation behaviour.

Flame temperature

The adiabatic flame temperature for a stoichiometric methane/air flame is 2226 K. If the gas contains 1% oxygen then the flame temperature increases to 2230 K. This change is not expected to raise any significant issues. (For comparison the adiabatic flame temperature of a stoichiometric methane/oxygen flame is 3052 K.)

Burning velocity

The velocity at which a flame propagates is the burning velocity and it is an important factor of combustion systems from a flame stability and burner performance optimisation. The fuel composition has an impact on burning velocity. A stoichiometric methane/air flame has a burning velocity of 35.2 cm/s. If the methane fuel contains 1% oxygen then this increases to 35.6 cm/s. (For comparison a stoichiometric methane/oxygen flame has a burning velocity of over 300 cm/s.) The increase in the burning velocity caused by oxygen content up to 1% in the fuel is not expected to give rise to significant change to the burning velocity and as such not increase the likelihood of burner mal-function through flash-back or lift-off. Higher oxygen concentrations will perturb the burning velocity but it is expected that levels up to 3% will not lead to any substantial change leading to increased appliance failure rates.

5.4 Impact on flame stability and process efficiency

There is no indication that levels of oxygen in gas-based fuels have any impact on flame stability, for oxygen levels up to 1%. The contribution made by oxygen in the gas supply to the fuel efficiency of gas appliances in the combustion process is also believed to be negligible.

5.5 Impact on emissions

There is no indication that levels of oxygen in gas-based fuels have any substantial impact on emissions, for oxygen levels up to 1%. However, there will be minor changes to the emission levels as a result of the change to the heat input and air:fuel ratio in some combustion systems. The absolute change will be system specific but the changes are expected to be lower than ±5% on a relative basis.

5.6 Impact on utilisation equipment

As described in earlier sections the impact of the presence of trace levels of oxygen in the gas supply to the combustion process is expected to be negligible.

The air-fuel ratio of the combustion process determines most of the associated emissions behaviour, and this is linked to the primary and secondary air entrainment as the gas leaves an appliance injector nozzle. Oxygen in the fuel gas, at low levels, is not expected to change the overall combustion process significantly.

The following table highlights some points regarding oxygen in gas:

Application		
Domestic/Commercial appliances	Partially premixed burners (eg. cookers, fires, etc) and Premixed burners (Condensing boilers, etc)	No impact, the presence of small amounts of oxygen in the fuel gas are outweighed by the air required for full combustion. Little impact if the oxygen content is a maximum of 1%
Gas engines		Some concerns raised by manufacturers regarding the presence of oxygen but generally for levels greater than 1%. Possible impact on high pressure operation.
Industrial boilers	Package burners Regenerative and recuperative burners	No impact, the presence of small amounts of oxygen in the fuel gas are outweighed by the air required for full combustion. Oxygen in the fuel gas could promote hydrocarbon cracking in regenerative and recuperative burner systems. This is not expected to significantly impact on their operation but may impact on emissions

Gas turbines	Diffusion flame combustors Premixed combustors (DLE and DLN)	No impact on this robust combustor Possible impact through presence of oxygen with change to autoignition properties linked to gas preheat at high pressure. Specific gas quality information often required by OEM before performance guarantees supplied
Fuel cells		Reforming catalysts unlikely to be affected up to a few % oxygen. For direct internal reforming systems possible damage to anode though increased level of oxygen in the feed gas
Natural Gas Vehicles	Engines, compressors	Unlikely to be an impact as 100,000s of NGVs operating in countries with O_2 spec up to 3%

Summary table of impacts of oxygen in gas on specific burner/combustion systems

5.7 Impact on industrial processes

Some industrial process and applications rely on consistent gas quality. The presence of oxygen in the fuel may impact on the air/fuel ratio, Wobbe Index (calorific value), flame temperature and emissions and result in a combustion product composition that varies dependent on the oxygen content. This has the potential to impair the performance of some systems. In addition if the gas is used as a chemical feedstock then the presence of oxygen may impact on the product quality or the overall chemical process. The following table provides a short summary of these impacts:

Application		
Glass manufacture	Regenerative burner systems Controlled atmospheres	Possible impacts on glass processes, both the melting and finishing Any controlled atmospheres may be impacted by presence of oxygen – possible impact on product quality
Fertilizer manufacture	Feedstock fuel impacts	Oxygen in the gas may impact on the chemical process or the product quality
Ceramics	Controlled atmospheres Glazing/final product colouring	Possible impacts on manufacturing processes. Any controlled atmospheres may be impacted by presence of oxygen – possible impact on product quality

Summary table of impacts of oxygen in gas on specific industrial applications

When considering only a 1 - 2% oxygen content in the gas, it is expected that the impact on industrial/chemical processes is small.

6 Impact of oxygen on Materials of Construction

6.1 Pipelines

No impact of increased oxygen levels is expected for HDPE or similar thermoplastic materials used for distribution pipes. This is since HDPE does not suffer oxidative degradation mechanisms at ambient temperatures although oxygen can be an issue when preparing these materials for extrusion.

The situation with iron pipelines is more complex. At present internal corrosion of cast iron pipes is not a major problem since gas in the UK system is dry for the majority of the time, and would conform to the German definition of a dry network (where 3% oxygen is currently allowed). Corrosion only occurs for a limited period during upset conditions when water can enter the pipes from external sources or through leaking joints. When corrosion does occur it is driven by the carbon dioxide content of the gas, carbon dioxide dissolves in water to form carbonic acid which then corrodes the iron.

The effect of increased oxygen levels has been examined using a CO_2 corrosion model[1] which includes oxygen effects. Increasing oxygen from 0.2% to 1% causes a five fold increase in carbonic acid corrosion rates due to destabilisation of protective iron carbonate films. Thus, increased oxygen levels will increase the pipe wall loss during the periods when water enters the distribution system allowing corrosion to occur (i.e. corresponding to the “wet” network case for German networks in Table 1). This may require internal corrosion to be considered when formulating integrity management plans for distribution systems as is presently required in the United States. However the likelihood that the Didcot network will experience any wet gas is extremely low.

The practical implications can be assessed using an example calculation with the parameters shown in the following table. It has been assumed that water enters the system for a limited period each year and the system is dry for the remainder of the time.

Parameter	Value
Pipe Material	Cast iron
Diameter	6 inches
Wall thickness	7 mm
Temperature	15°C
Pressure	2 bar
Flow velocity (liquid)	0.5 m/s
CO_2 content	2.5%
O_2 content	0.2 or 1% (equivalent to 0.1 ppm and 0.45 ppm in water phase)
pH	6.3 (assumes 25 ppm iron present due to corrosion)
Time water present	30 days per year

Table 4: Parameters for corrosion calculations

The total wall loss over 100 years is shown in the following figure. It can be seen that, although increasing oxygen content causes corrosion rates to rise in both cases the pipe will not fail due to internal corrosion within 100 years. It has been assumed that the pipe will fail by perforation rather than rupture which is reasonable for a low pressure distribution system. This example shows that external corrosion or mechanical damage will remain the predominant risks even at an oxygen level of 1%. A sensitivity calculation was performed to determine the oxygen level required to give a pipe lifetime of 30 years. It was found that even at an oxygen content of 20% (i.e. as in air) it would take 31.5 years to perforate the pipe wall, so long as water was not always present. It is unlikely that any susceptible pipe will be present in the network in 30 years from now.

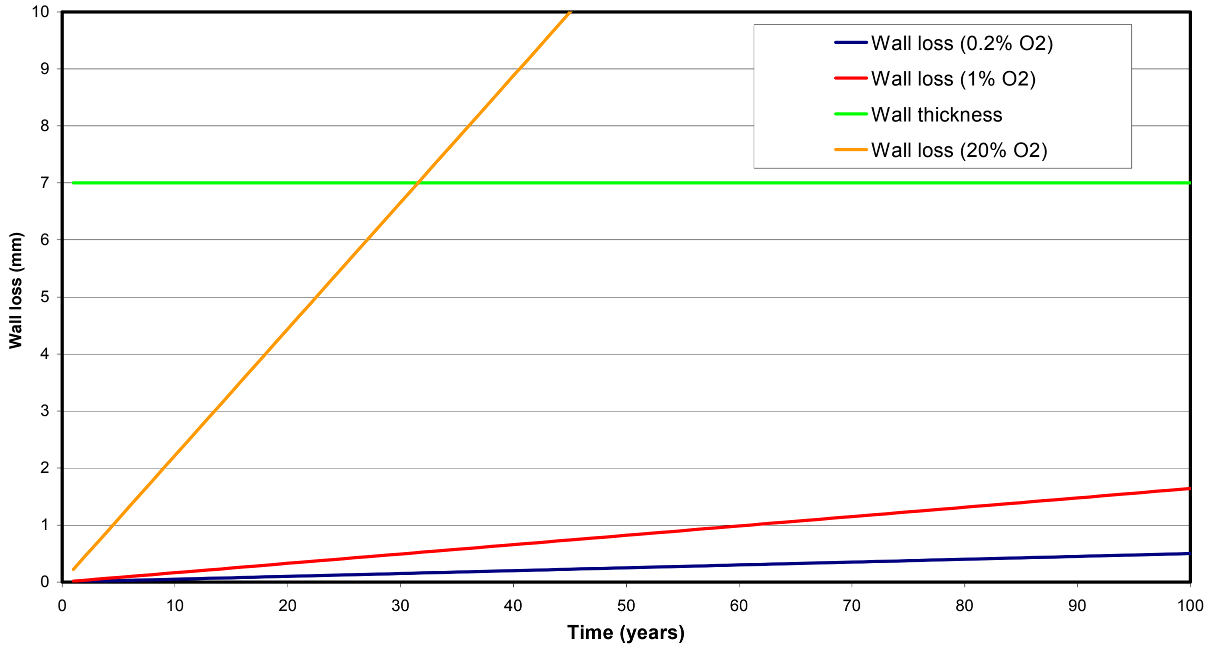


Figure 4: Wall loss in typical distribution main at differing oxygen contents

6.2 Appliances and meters

The majority of domestic appliances utilising gas are designed to withstand combustion conditions and the resulting chemical combustion products. For this type of equipment an increased oxygen level will have little or no effect on the materials performance.

The main effect of an increased oxygen level will be on sulphidation of copper carcassing and copper alloy components within meters. Studies have indicated that oxygen greatly increases the rate of copper sulphidation[2,3] and increased oxygen levels would thus be expected to increase instances of appliance burners and valves/meters being blocked by flaking copper sulphide. For example laboratory studies[2] have shown that increasing oxygen content from 0.5% to 1.5% increases the rate of sulphidation attack by 1.6 times. This would be expected to lead to an increase in customer inconvenience due to blockages in burners or meter malfunctions but at present should not present a safety hazard.

7 Conclusions

The quality and composition of natural gas and biomethane does have an impact on the safe, efficient and reliable utilisation of the fuel.

This report has surveyed the oxygen content in gas regulations used throughout Europe and there is not a consensus of values. The values range from 0.001% to 3% depending on country and on the type of gas grid.

The oxygen content of the fuel does impact on fundamental combustion parameters, like flame temperature, ignition energy, air:fuel ratio, as well as emissions and operational performance of combustion systems. However, if the content of oxygen is only a maximum of 1% then the changes are expected to be small.

Some gas utilisation equipment is more sensitive than others and particular reference to gas turbines, engines and fuel cells is raised. In addition some industrial processes may have negative impacts if oxygen is present in the fuel.

Overall, a concentration of 1% oxygen in the fuel gas is not expected to result in significant changes to

- the risks of using the gas
- the safety aspects related to gas use
- the efficiency of using the fuel
- the pollutant emissions
- the operability of equipment, appliances and processes.

Additionally, although steel corrosion rates are likely to increase five-fold for a corresponding increase in oxygen concentration, the ensuing rate will still be small enough not to impact on asset lifetimes.

Taking the conclusions from this work one stage further, there is unlikely to be a safety or operations impact on the distribution network up to an oxygen concentration of several percent. The limiting factors are more likely to be due to Wobbe Number falling below the lower bound of the GS(M)R limit for leaner natural gases. For an average natural gas composition corresponding to that expected for the Didcot part of the SGN network (gas currently received via Bacton), this corresponds to an oxygen concentration of 2-4% depending on CO_2 concentration.

8 References

1. FREECORP CO_2 corrosion model, http://www.corrosioncenter.ohiou.edu/freecorp/
2. HSE Contract Research Report CRR 164/1998, “Safety Aspects of the Effects of Hydrogen Sulphide in Natural Gas”, Crown Copyright, 1998.
3. HSE Contract Research Report CRR 287/2000, “Safety Aspects of the Effects of Hydrogen Sulphide in Natural Gas”, Crown Copyright, 2000.

Appendix A Network Analysis

Oxygen content - Network Analysis (communicated by SGN)

Summary
The customer profile for biomethane usage from the Didcot plant will be limited to a Low pressure industrial estate and the plant itself, other than in exceptional circumstances. Dilution with gas from the network will ensure that the mol% of Oxygen supplied to customers will very quickly be significantly less than what is injected and within current tolerance of 0.2mol%. It is therefore highly unlikely that customers will see O_2 levels in excess the current tolerance. This could be proved by gas sampling during the trial.

Normal to High demand

During periods of normal to high demand it is predicted that the injection of biomethane will be 20 - 40% absorbed by the AD itself, with the remainder being absorbed by a Low Pressure industrial/commercial estate supplied via a District Governor immediately adjacent to the biomethane plant. The mains within this estate are all Polyethylene. There are approximately 50 customers within this industrial/commercial estate and as they are all downstream of the DG no single customer will absorb the biomethane injection which will be largely diluted with natural gas from the grid at the DG inlet. None of these customers have compressed or atypical loads, but even if they did the Biomethane would make up only a very small proportion of the total load. The current average composition of SGN Southern network's gas is below (this was provided to NAEI - National Atmospheric Emissions Inventory), detailing negligible O_2 content.

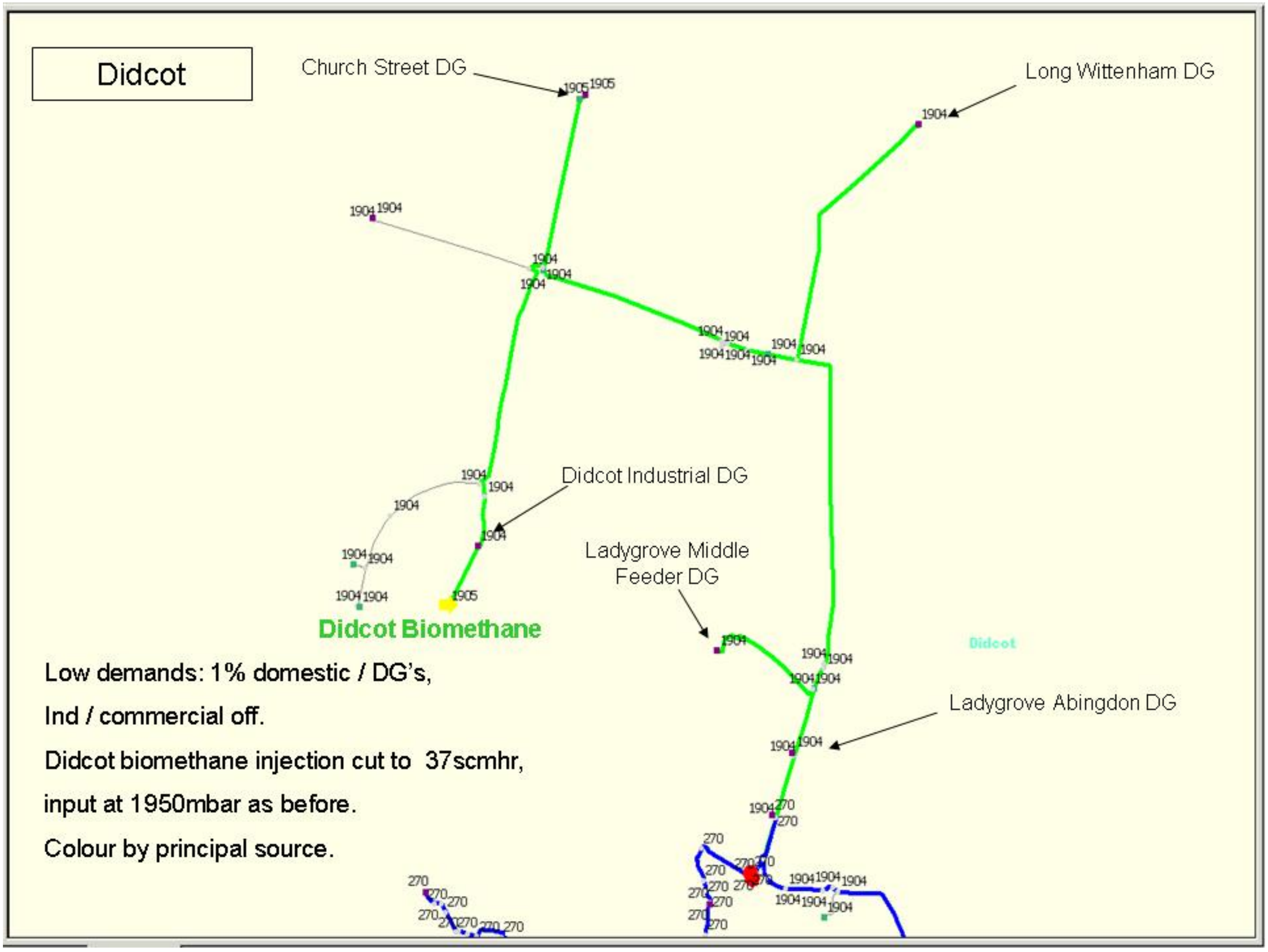
Low demand
Very conservatively, assuming worst case low demand for an extended period (1% of peak flowrate) and no Industrial & Commercial usage, the maximum anticipated distance the biomethane could travel would be to any one of 200 customers. This will be over an extended area and will again be subject to dilution with natural gas from SGN's existing network. The existing infrastructure will already have a significant volume of gas within it, i.e. it is not empty. At this time it is not possible to carry out transient analysis on <7bar network models, but to illustrate the point analysis in SynerGEE has been carried out to trace the % flow within the integrated network, with a 0.5% - 3% O_2 range. This unrealistically assumes that there is no existing natural gas volume mixed in.

Integrity
Didcot Holder is approximately 6km from the biomethane source in terms of mains length. Although unlikely, it is possible that the holder will receive an element of biomethane when it is filling during periods of low demand, although this will be very much diluted by natural gas from within the integrated grid, and will certainly be within current tolerances.

SGN are not aware of any recorded instances of 'Wet Gas' within this area and gas is within tolerance of $50mg/m^3$. To confirm this hygrometric test points could be installed.

Again the current modelling tools utilised are primarily designed for peak flow analysis, as opposed to Low flow. It would be beneficial for some support from GL on the modelling of the dispersal of the Biomethane via SynerGEE and modelling of Biomethane entry points in general. As BtG develops, component property tracing will become more important.

The Synergee simulation below shows the zone of influence at low demand.



Low demands: 1% domestic / DG's,

Ind / commercial off.

Didcot biomethane injection cut to 37scmhr,

input at 1950mbar as before.

Colour by principal source.