davelanderconsulting

Project number	0248
Report number	DLC/0212
Title	Technical Report for Functional Specification for Hydrogen Blending Infrastructure Project: Legislative framework for hydrogen blending
Author	D.F. Lander
Status	Final
Revision	E
Date	30/03/2023
Clients	Cadent Gas, National Grid Gas, Northern Gas Networks, SGN, Wales & West Utilities

Revision History:	
0	Draft for comment (01/08/2022)
A	Amended section 3.2 to include measurement of volume and energy of hydrogen stream and CV determination of hydrogen. Amended section 3.3 to include discussion of measurement and monitoring arrangements for GSMR and "presumption of conformance". Miscellaneous amendments to extracts of regulations (02/08/2022)
B	Incorporated minor changes following comments from Cadent Gas. Corrected lower WI limit from 37.2 to 47.2 MJ/m3 in section 2.3 (24/08/2022)
C	Added sections on accuracy requirements (20/10/2022)
D	Added commentary on hydrogen injection into the NTS (08/02/2023)
E	Update following amendments to the GSMR (30/03/2023)

Initial Distribution:	
Cadent Gas	National Grid Gas
Northern Gas Networks	SGN
Wales & West Utilities	

Dave Lander Consulting Limited

Registered in England and Wales, No 06725912 94 Sudeley, Dosthill, Tamworth, Staffordshire B77 1JU

tel: +44 (0)7901 510 905

e-mail: dave@davelanderconsulting.co.uk

TECHNICAL REPORT FOR FUNCTIONAL SPECIFICATION FOR HYDROGEN BLENDING INFRASTRUCTURE PROJECT:

LEGISLATIVE FRAMEWORK FOR HYDROGEN BLENDING

1 INTRODUCTION

A consortium of GB gas transporters comprising Cadent Gas, National Grid Gas, Northern Gas Networks, SGN, and Wales & West Utilities has engaged the services of Dave Lander Consulting Ltd and Thyson Technology Ltd to develop and test a functional specification for blending of hydrogen into natural gas networks. The functional specification will set out the required equipment functionality to achieve acceptable blending of hydrogen into gas transmission or distribution systems, based on consideration of both regulatory and engineering requirements. A "sister" project[1] is considering the commercial requirements for successful blending.

The functional specification will consider a number of key principles and this technical report summarises the legislative framework, the regulatory basis by which blending of hydrogen may operate and presents the key functionality requirements emerging from legislative considerations.

2 SUMMARY OF LEGISLATIVE FRAMEWORK

2.1 OVERALL FRAMEWORK

<u>In the context of gas quality,</u> the main items of legislation affecting the conveyance of natural gas and the duties of gas transporters are set out in two items of secondary legislation:

- The Gas (Calculation of Thermal Energy) Regulations (GCOTER) 1996, as amended 1997
- The Gas Safety (Management) Regulations (GSMR) 1996

Both the GCOTER and GSMR are examples of secondary legislation: law created by ministers (or other bodies) under powers given to them by an Act of Parliament. Secondary legislation – typically introduced as a Statutory Instrument (SI) – is used to fill in the details of Acts (primary legislation). These details provide practical measures that enable the law to be enforced and operate in daily life. Parliament can either approve or reject an SI but cannot amend it. Parliament's role in considering an SI varies depending on what is stated in its parent Act.

Note that the parent Act for the GCOTER is the Gas Act, and that for the GSMR is the Health and Safety at Work Etc. Act. As a consequence, the GCOTER place powers for much of its administration on Ofgem (acting in support of the Gas and Electricity Market Authority - GEMA), whereas the GSMR place powers (particularly for approval of safety cases and amendments) on the Health and Safety Executive. Note also that the Gas Act 1986 was itself amended by the Utilities Act 2000. Many of the amendments to the Gas Act were structural but it is noteworthy that amendment 101 introduced the power for the Authority to prescribe "standards of pressure and purity" and "other standards with respect to the properties, condition and composition" of gas conveyed by gas transporters:

Gas Act, Section 16.— (1) The Authority may, with the consent of the gas quality. Secretary of State, prescribe—

(a) standards of pressure and purity to be complied with by gas transporters in conveying gas to premises or to pipe-line systems operated by other gas transporters; and

(b) other standards with respect to the properties, condition and composition of gas so conveyed

Note that although Ofgem (through GEMA) effectively have the power to prescribe standards of gas quality, no such standards have been prescribed to date.

2.2 THE GAS (CALCULATION OF THERMAL ENERGY) REGULATIONS (SI 1996/437)

The GCOTER originally came into force in 1996 and provide for the way in which the amount of energy that a gas consumer has consumed and hence set out the basis upon which they are billed by a gas supplier. The provisions contained in the GCOTER prescribe that most consumers would be billed on the basis of the volume of gas supplied (converted to a volume at reference conditions of 15°C and 101.325 kPa), multiplied by a billing calorific value (CV).

[1] "Enabling Hydrogen Blending from Industrial Clusters". Frontier Economics.

2.3 THE GAS (CALCULATION OF THERMAL ENERGY) (AMENDMENT) REGULATIONS (SI 1997/937

The calculation of billing CV and conversion of volume of gas to reference conditions is set out in the regulations, but in 1997 an important amendment was approved covering the calculation of billing CV. Previously billing CV for a given charging period was an arithmetic average of daily charging area CV and daily charging area CVs were calculated on the basis of the lowest daily average CV determined at entry points to the charging area. This methodology (Lowest Source CV, or LSCV) essentially always leads to an overall underbilling of gas consumers by gas suppliers and the underbilling was corrected by the 1997 amendment, which permits calculation of the daily charging area CV on the basis of a Flow Weighted CV (or FWACV) instead of the LSCV.

Use of the FWACV as the daily charging area CV instead of the LSCV ensures no overall underbilling of consumers but introduces the possibility of some consumers being under-billed (because they actually received gas with a CV higher than the FWACV) and others being over-billed (because they actually received gas with a CV lower than the FWACV). In order to limit localised over-billing of consumers the regulations cap the value of daily charging area CV, such that it can be no more than 1 MJ/m^3 greater than the daily LSCV.

Although the GCOTER does not contain a definition of "gas", Section 48 of Gas Act 1986, provides the following definition:

> *Gas Act Section 48. -(1) In this Part, unless the context otherwise requires –*
>
> *" gas " means*
>
> > *(a) any substance in a gaseous state which consists wholly or mainly of-*
> >
> > > *(i) methane, ethane, propane, butane, hydrogen or carbon monoxide;*
> > >
> > > *(ii) a mixture of two or more of those gases; or*
> > >
> > > *(iii) a combustible mixture of one or more of those gases and air;*

In principle, therefore, blends of natural gas and hydrogen fall within the remit of both the Gas Act (and the amendments provided by the Utilities Act 2000) and the GCOTER.

2.4 THE GAS SAFETY (MANAGEMENT) REGULATIONS 1996 (SI 1996/551)

The GSMR came into force in 1996 and provide for the preparation and acceptance of safety cases in respect of the conveyance of gas in a network and impose requirements in respect of gas escapes, the content and characteristics of gas, and the pressure of gas.

In terms of gas quality, Regulation 8 of the GSMR requires gas transporters, under normal conditions, to convey only gas that conforms with the requirements set out in Part I of Schedule 3. Regulation 8 also requires for operations under conditions necessary to prevent a gas supply emergency and the requirements under these conditions are set out in Part II of Schedule 3.

The requirements set out in Schedule 3 are summarised in Appendix A

The GSMR do contain a definition of "gas:

> *GSMR Regulation 2 – (1) In these Regulations, unless the context otherwise requires –*
>
> > *"gas" means any substance in a gaseous state which consists wholly or mainly of methane*

In the context of blending hydrogen and natural gas, the two key requirements of the GSMR are that:

- Hydrogen content shall be no more than 0.1 %
- Wobbe Number shall be no less than 47.2 MJ/m^3

Clearly, the current provisions of the GSMR prohibit meaningful blending of hydrogen with natural gas. In addition, hydrogen has a relatively low Wobbe Number of 45.88 MJ/m^3 and so adding hydrogen to natural gases will lower the Wobbe number of the resulting blend. For UK natural gases, which have Wobbe numbers covering a typical range of 48.5 – 51.12 MJ/m^3, the lower Wobbe number limit of 47.2 MJ/m^3 would limit hydrogen content to a range of 10.8 – 30.1 % mol/mol.

Note: In March 2023, six amendments to the Gas Safety (Management) Regulations 1996 received Government approval and the Gas Safety (Management) (Amendment) Regulations 2023 (GSMAR) were laid in Parliament. GSMAR includes amendments to GSMR along with new legislation to regulate gas transmission and distribution. GSMAR 2023 contained a drafting error, which was rectified in The Gas Safety (Management) (Amendment) (No. 2) Regulations 2023 (GSMA2R).

In the context of hydrogen blending, an important amendment within GSMAR and GSMA2R, is the change in the lower Wobbe index limit for normal operation from 47.2 MJ/m^3 to 46.5 MJ/m^3. This amendment will come into force 6th April 2025 and, in the context of hydrogen blending, the effect of this change will be to reduce the numbers of occasions in which low Wobbe index (as opposed to capping of billing CV under the GCOTER) limits the proportion of hydrogen that can be blended.

3 REGULATORY BASIS FOR BLENDING OF HYDROGEN INTO NATURAL GAS SYSTEMS

3.1 SCOPE

Both the GSMR and GCOTER apply to conveyance of "gas" and a blend of up to 20% mol/mol hydrogen with natural gas would fall within the (direct) definition of gas within the GSMR and the (indirect) definition of gas provided in the Gas Act, which is the Parent Act of the GCOTER.

> Note: The definition of "gas" in the GSMR and GSMAR creates some ambiguity regarding blending of hydrogen because Regulation 2(4) only considers blending to be the process of bringing out of conformity "gas" into conformity of the requirements of Schedule 3. This introduces some ambiguity over whether hydrogen should be considered to be a "gas" or not and hence whether hydrogen injection should be considered as blending within the meaning of the GSMR.
>
> This issue is discussed further in Section 3.3.2.

3.2 GAS (CALCULATION OF THERMAL ENERGY) REGULATIONS

3.2.1 INJECTION OF HYDROGEN INTO THE LDZ

Hydrogen has a relatively low calorific value (12.1 MJ/m^3) and so any hydrogen injected into a charging area will always become the lowest source CV and hence always cap daily charging area CV to 12.1 + 1 = 13.1 MJ/m^3. Given that typical GB daily charging area CVs are around 39-40 MJ/m^3, such capping would lead to significant under-billing and hence significant disruption to commercial operations.

However, the GCOTER do provide for blending of low CV gases in the form of paragraph (b) of Regulation 4A(1):

> GCOTER *Regulation 4A.— (1) The daily calorific value of gas conveyed to any take off point situated in a charging area in respect of a gas day shall be the lower of —*
>
> *(a) the area calorific value; and*
>
> *(b) the calorific value obtained by adding one megajoule per cubic metre to the lowest of—*
>
> *(i) any of the average calorific values determined on the gas day by the public gas transporter pursuant to directions given under regulation 6(a) and (b) below on the basis of samples of gas which is a commingling of gas flowing past an input point for the take off points in the charging area and other gas, where the gas flowing past the input point is not conveyed to any take off point in the charging area without being commingled with the other gas; and*
>
> (ii) *any of the average calorific values applicable on the gas day to any input point for the take off points in the charging area, where sub-paragraph (i) above does not apply.*

Whereas, under normal circumstances, the daily charging area CV is capped to no more than 1 MJ/m^3 greater than the lowest daily average CV of the inputs, regulation 4A(1) paragraph (b) permits application of the cap to the daily average CV of a co-mingled point, provided it can be shown that no gas is conveyed to consumers before co-mingling.

In essence, therefore, although the daily energy and daily volume of hydrogen flowing into a charging area is included in the calculation of the daily charging area CV, the daily average CV of hydrogen would not be the reference point for capping and instead the reference point would be the CV at the co-mingled point. The constraint on blending is therefore the CV at the co-mingled point, and this will be dictated by the CVs of the hydrogen and blending gas, as well as the proportion of hydrogen at the co-mingled point.

Regulation 6 sets out a number of provisions for the manner in which CV is determined. In particular the gas transporter shall

(a) make determinations of calorific values of the gas conveyed by him to premises, or to pipe-line systems operated by other public gas transporters, on the basis of samples of gas taken at such places or premises, at such times and in such manner as the Authority may direct
(b) make such determinations at such places or premises, at such times and in such manner as the Authority may direct
(c) provide and maintain such premises, apparatus and equipment for the purpose of making such determinations as the Authority may direct
(d) make available for inspection free of charge during normal office hours by any person the results of such determinations made by the transporter during the preceding twelvemonths at
  (i) an office reasonably accessible to the public; and
  (ii) the place or premises at which any such determinations were made
(e) *carry out tests of apparatus and equipment provided and maintained by virtue of paragraph (c) above for conformity with the requirements of directions given under that paragraph at intervals not exceeding 35 days*

It is likely that Ofgem will require demonstration that the CV at the co-mingled point is sufficiently high enough to avoid CV capping and essentially this will dictate that CV is measured at a suitable co-mingling point and telemetered to a central location[2]. Currently, blending of low CV gases consists of blending of biomethane, typically in above 7 barg systems, and blending of low CV natural gas into the NTS at Lupton.

The mechanism by which "the Authority"[3] directs location, time and manner in which CV is determined is a Letter of Direction. Typical existing Letters of Direction require that CV is determined using a CV determination device that is Approved by Ofgem. Proof of such approval is provided via a Letter of Approval issued by Ofgem. Approval is subject to demonstration of satisfactory performance with the expected gases.

Although the CV determined at the co-mingled point is not employed for the calculation of FWACV, regulation 4A(1) paragraph (b) (1) requires that CV at the co-mingled point shall be determined pursuant to Regulations 6 (a) and (b) and hence use of anything other than an Ofgem-approved CV determination device would require agreement of Ofgem (and set out in the Letter of Direction).

Daily CVs of gas entering charging areas are typically determined at NTS offtakes and at lower pressure tiers where injection of gases occurs (typically biomethanes and onshore natural gas sources). Hydrogen injected into the NTS would lower the CV of the natural gas exiting via the NTS offtakes, but the CV of the resulting blend, and hence the FWACV, would be determined under the existing provisions and not those of paragraph (b) of Regulation 4A(1). The CV determination device at the NTS offtake would need to be approved by Ofgem for use with hydrogen-natural gas blends, however.

3.2.2 INJECTION OF HYDROGEN INTO THE NTS

Hydrogen injected into the NTS will flow into one or more LDZs via one or more NTS offtakes as a blend of hydrogen and natural gas and not as "pure" hydrogen. Capping of daily charging area CV to 13.1 MJ/m^3 is not therefore expected to occur, although some (less extreme) capping would occur if the hydrogen content were sufficiently high enough to reduce the CV of the blend to 1 MJ/m^3 less than the FWACV. Because capping results in costs across the industry it may be appropriate to consider application of a target CV for the hydrogen-natural gas blend. Such a target could in principle be applied at either an agreed commingled point within the NTS, or at one or more NTS offtakes.

Note that injection of hydrogen into the NTS that results in blend flowing into an LDZ will require that any existing CV determination device at the NTS Offtake is upgraded for determination of CV of a hydrogen-natural gas blend.

NGT is currently directed by Ofgem to determine CV at some strategic points within the NTS so as to ensure that a valid daily average calorific value is available for attribution to other locations owned and operated by GTs.

[2] Currently, calculation of FWACV and management of capping is carried out by National Grid Gas, but this duty will be transferred to Xoserve at some point in the future.

[3] The Gas Act 1986 employs the term "the Director" but it was amended by the Utilities Act 2000 and one amendment, 1.—(1), abolished the role of Director of Gas Supply and transferred its functions to the Gas and Electricity Markets Authority (the Authority).

Typically, attribution is made either to so-called tracker-only sites, or to other sites in the event of a failure to determine calorific value at that site. Ofgem may therefore consider it appropriate to direct NGT to determine CV of the blend at an agreed commingled point on the NTS so as to provide a valid CV for attribution to an NTS offtake conveying blend into the LDZ. Such a direction would mean that CV determination at the commingled point would attract the requirements set out in Section 3.2.1. Note that if hydrogen injection and blending is also practiced at the NTS offtake(s) then the CV of the blend at the NTS commingled point would not be representative of that of the blend downstream of injection at the NTS offtakes and hence not appropriate for attribution purposes.

Daily energy and volume flows of hydrogen into the NTS would need to be determined to the same level of accuracy as all existing inputs to the NTS.

3.3 GAS SAFETY (MANAGEMENT) REGULATIONS

3.3.1 MEASUREMENT AND MONITORING ARRANGEMENTS

The GSMR are goal-setting regulations and, unlike the GCOTER, do not prescribe the measurement technology requirements. Instead, the gas transporter is expected to set out in their safety case the arrangements in place to demonstrate that the gas conveyed is compliant with the requirements of Schedule 3.

Measurement and monitoring of conformance with the requirements the GSMR is not normally carried out for natural gases entering a gas network from another gas transporter's gas network provided the gas leaving the "donor" network is subject to measurement and monitoring arrangements (usually set out in the safety case of the gas transporter whose gas network is supplying the gas). This "presumption of conformance" is made at the NTS offtakes for all gas entering LDZs from the NTS and the GDNs' safety cases generally cite the measurement and management arrangements put in place at entry points to the NTS. Presumption of conformance also applies to (private) gas networks connected to the GDNs' gas networks.

Gases entering GDNs' gas networks directly (as opposed to via the NTS) are subject to demonstration of conformance with the requirements of the GSMR. The GDNs' safety cases contain evidence to demonstrate conformance, and this is usually achieved through a mixture of direct measurement and monitoring arrangements and risk assessment for those parameters where the risk of non-conformance is low. Risk assessment is normally carried out through application of management procedure XXX/PM/GQ/8 (where XXX designates the GDN)

3.3.2 HYDROGEN CONTENT

Schedule 3 of the existing GSMR prohibit the conveyance of gas that contains more than 0.1% of hydrogen and so there are currently two options for blending hydrogen:

(a) Blending is carried out under an exemption from the specific requirements for hydrogen. Regulation 11 provides for the HSE to exempt the gas transporter from any of the requirements of the GSMR. Hydrogen blending for the HyDeploy field trial at Keele university and the HyDeploy2 field trial at Winlaton was carried out under exemptions granted by the HSE. However, exemptions are by their nature, time-limited and it is not likely that hydrogen blending on an enduring basis would be sustainable under the terms of an exemption.

(b) Revision of Schedule 3 of the GSMR. This is likely to be the enduring basis for hydrogen blending and the HyDepoy2 project aims to gather evidence to provide for the HSE to revise the requirements of Schedule3. HyDeploy2 has a target of a maximum hydrogen content of 20% mol/mol, although FWACV capping and the Wobbe number limit in Schedule 3 may limit actual hydrogen content to less than this.

Continuous measurement and monitoring of hydrogen content is likely to be required at the comingled point. It is likely that the hydrogen content will be determined by the CV determination device installed for CV monitoring with respect to the GCOTER.

Such non-conformance is discussed in the GSMR and the Guide to the GSMR[4]:

> *GSMR Regulation 2(4): Where gas which does not conform with the requirements referred to in regulation 8(1) is conveyed from a gas processing facility for treatment or blending so as to bring it into conformity with those requirements, any pipes used exclusively for conveying gas from that facility to the point where*

4 Health and Safety Executive. "A Guide to the Gas Safety (Management) Regulations 1996". ISBN 978 0 7176 1159 1. (1996)

> *the gas is treated or blended or to non-domestic premises or to both, shall not be treated as part of a network for the purposes of these Regulations.*
>
> *GSMR Guidance 2(4):Pipes which are used to convey out-of-specification gas to a treatment or blending point, or to non-domestic premises, or both, are not part of the network and will not require a safety case…A blending point is the point where out-of-specification gas is mixed with other gas on the network to produce gas of a new composition which is within the specification set out in Part 1 of Schedule 3…However, when gas which conforms to Part 1 of Schedule 3 is conveyed periodically through the same pipes, these pipe will form part of the network. Safety Cases will need to address both situations.*

There are two areas of ambiguity within the GSMR and the GSMR Guide:

- Firstly, there is some ambiguity as to whether the definition of "gas" within the GSMR excludes nominally pure hydrogen and hence whether the operation of hydrogen injection may not be recognised as "blending" because it is not "gas" (within the meaning of the GSMR) that is being brought into conformity. However, in the definition of gas in the GSMR

  > *GSMR Regulation 2 – (1) In these Regulations, <u>unless the context otherwise requires</u> (emphasis by author) –*
  >
  > *"gas" means any substance in a gaseous state which consists wholly or mainly of methane*

  It could be argued that for the case of hydrogen injection Regulation 2(4) the phrase *"Where gas which does not conform with the requirements referred to in regulation 8(1) is conveyed…"* the <u>context</u> requires that "gas" should be interpreted as gas in the broader sense of the word and not the strict definition of the GSMR.

- Secondly, although the pipework immediately downstream of the injection point will have an average hydrogen content equal to that planned, local concentration may vary about this average, depending on the flow pattern induced by the mixing arrangement. So, for instance, hydrogen content may be higher than average at the pipeline wall and lower than average in the central section, or *vice-versa*, depending on the flow pattern. Neither the GSMR nor the GSMR Guide indicate whether conformity with requirements shall be determined on the basis of the average concentration or local concentration within the pipe. This implies that if the intended average hydrogen concentration is close to that concentration permitted (either by GSMR revision or exemption) the Gas Transporter could be deemed to be conveying gas that is non-compliant with respect to hydrogen content, if the highest hydrogen content – rather than the average hydrogen content – is considered the basis for conformity.

The following interpretation is offered from the above:

a) The pipework conveying hydrogen to the injection point is not part of the network and does not require a safety case. Although there is ambiguity over whether GSMR recognises hydrogen injection as "blending", the pipework conveying nominally pure hydrogen is not "gas" and hence is not part of the network.
b) Regarding conformity with requirements
   - If conformity with requirements is determined on the basis of average composition the pipework downstream of the injection point would be considered "gas" and in conformance with requirements and would be considered part of the network, whether injection hydrogen or not.
   - If conformity with requirements is determined on the basis of localised composition, the pipework between the injection point and the point at which gas conforms with the requirements of Schedule 3 could be considered part of the network when <u>not</u> injecting hydrogen and <u>not</u> part of the network when hydrogen <u>is</u> being injected.
c) The gas transporter's safety case will need to cover both situations and hence will need to discuss hydrogen injection. In particular it is suggested that the safety case considers the relevant section of pipe to be that between the injection point and the comingled point, since the comingled point is where the gas transporter evidences conformance. The safety case will also need to demonstrate the suitability of the relevant section of pipeline for conveyance of gas that contains hydrogen at the highest expected level within that relevant section.

It is therefore recommended that, in parallel with any amendment of the hydrogen limit of the GSMR/GSMAR/GSMA2R, clarification should be requested from HSE of both the definition of "gas" and whether average hydrogen content is the intended basis for determining conformance with the requirements with respect to hydrogen content.

3.3.3 OTHER GSMR PARAMETERS

In addition to hydrogen, there are eight additional parameters that, in principle, ought to be considered for measurement and monitoring arrangements to demonstrate conformance when blending hydrogen: the three interchangeability parameters (Wobbe number, ICF and SI); hydrogen sulphide content; total sulphur content; oxygen content; hydrocarbon dew temperature; water dew temperature.

The three interchangeability parameters are influenced by the properties of the blending gas and the proportion of hydrogen in the blend. It is likely, therefore, that monitoring of these three parameters at the co-mingled point would be required.

> Note: The amendments introduced by the GSMAR and GSMA2R remove requirements with respect to the interchangeability parameters ICF and SI, and introduce an interchangeability requirement with respect to relative density (RD).

The remaining five GSMR parameters could in principle arise from either the natural gas or (depending on its production route) the hydrogen being injected. Measurement risk assessment according to GQ/8 would establish whether direct measurement would be required or whether presumption of conformance for the blending gas – in conjunction with presumption of conformance for the hydrogen – is appropriate. Presumption of conformance for hydrogen could be validated by monitoring arrangements at the point(s) of hydrogen production, especially because hydrogen sulphide in hydrogen sources is likely to be at low levels by virtue of is production routes.

4 ACCURACY

4.1 CV DETERMINATION

4.1.1 HYDROGEN FLOW INTO THE CHARGING AREA

Ofgem may be expected to direct the gas transporter to determine the CV of the hydrogen being blended since the energy and volume flows of that hydrogen will feature in the calculation of the daily charging area CV. The GCOTE regulations do not specify what level of accuracy is required for these streams but provide that

> *"a gas transporter shall…provide and maintain such premises, apparatus and equipment for the purpose of making such determinations as the [Authority] may direct"* (GCOTE regulation 6)

The means by which "the Authority may direct" is through a Letter of Direction sent to the Gas Transporter by Ofgem. Typically, the letter of Direction will require that the CV determination device (CVDD) is approved by Ofgem, and such approval is demonstrated by issue by Ofgem of a Letter of Approval for a particular device.

Until 2017, the Ofgem Letter of Approval specified accuracy in terms of a Maximum Permissible Error in calorific value of ±0.1 MJ/m^3, when carrying out a performance evaluation according to BS EN ISO 10723. The Letter also specified a tolerance of 0.14 MJ/m^3, when carrying out periodic tests in accordance with regulation 6(e) of the GCOTE regulations. A tolerance of 0.14 MJ/m^3 refers to the maximum difference between the calorific value of the test gas measured by the CVDD and the certified calorific value of the test gas. The tolerance value of 0.14 MJ/m^3 arises[5] from an assumption that the CVDD under test and the CVDD used to certify the test gas both have an MPE of 0.1 MJ/m^3 and hence the (expanded) uncertainty of the difference between the two is given by

$$\sqrt{0.1^2 + 0.1^2} = 0.14$$

In 2017, following an industry consultation by Ofgem, Ofgem published a Decision Letter[6] relaxing the accuracy requirements of CVDDs to an MPE of 0.2 MJ/m^3. This implies a tolerance of 0.24 MJ/m^3, i.e.

[5] Private communication with Courtney Sayer (Director of Ofgem Technical Directorate)

[6] Ofgem. "Decision letter: Relaxing the accuracy requirements of Calorific Value Determining Devices". 13th April 2017.

$$\sqrt{0.2^2 + 0.1^2} = 0.24$$

CV determination for the source hydrogen could be relatively simple, depending on its production route. Hydrogen produce by electrolysis is likely to be free of contaminants with the exception of oxygen and water vapour; hydrogen via reforming-type routes may contain trace amounts of other contaminants. If the hydrogen were compliant with IGEM/H/1 and contained a minimum of 98 % mol/mol hydrogen, CV measurement simply by measurement of hydrogen content and an appropriate assumption of the balance (e.g., balance is nitrogen or carbon dioxide) is likely to provide an adequate level of accuracy. Assuming that the source of hydrogen contains a minimum of 98% mol/mol hydrogen, CV determination could be achieved relatively simply, solely by analysis of hydrogen content and an assumption that the 2% balance was an inert gas such as nitrogen or carbon dioxide. This would result in an MPE requirement for hydrogen of ±0.17 % mol/mol.

Any arrangement for CV determination would require confirmation by issue of a Letter of Approval from Ofgem, however.

4.1.2 COMINGLED POINT

Provisions for the comingled point to be the reference for FWACV capping are set out in paragraph 4(A)(1)(b)(i) of the GCOTE regulations (see Section 3.2 of this technical Report) and again suggests that a Letter of Direction and Letter of Approval could be a mechanism for defining accuracy. It is likely, therefore that the standard of accuracy for CVDDs at the comingled point should be comparable with those for inputs to the charging area, i.e., an MPE of 0.2 MJ/m^3 when carrying out a performance evaluation according to BS EN ISO 10723 and a tolerance of 0.24 MJ/m^3 when performing periodic tests.

4.2 VOLUME DETERMINATION

The GCOTE regulations do not provide explicit requirements for standard of accuracy in volume determination at input and output points to the charging area when calculating the daily charging area CV. Instead, a general requirement is given in Regulation 3(2) paragraph (b):

> "...*apparatus and equipment for recording, at such locations and with such accuracy as is requisite to calculating daily calorific values under regulation 4A below, the volume of gas flowing past the input point or output point...*"

Ther is no agreed definition of "*requisite to calculating daily calorific values under regulation 4A*", but custom and practice is for daily volumes to be measured with an MPE of 1%. It is likely therefore that the hydrogen metering system should have this level of accuracy. There is no regulatory requirement for volume determination at the comingled point, because this flow is not included in the calculation of daily charging area CV.

EMIB proposed standards of accuracy for injection of biomethane based on an MPE of 1% for daily volumes exceeding 250,000 m^3, and an MPE of 2.9% for daily volumes below 250,000 m^3. This proposal was based on the impact of reduced accuracy on the uncertainty in the calculated value of daily charging area CV. However, Ofgem have not ratified a decreased level of accuracy for biomethane plant.

In summary, in the absence of any specific agreement with Ofgem, it is suggested that the existing requirement of MPE of 1% should apply.

4.3 GSMR PARAMETERS

The GSMR do not place specific standards of accuracy of monitoring arrangements for conformance with the requirements of Schedule 3. Instead, it is left for the gas transporter to demonstrate that their monitoring arrangements are appropriate.

Monitoring accuracy at network entry for the NTS level by National Grid Gas is specified in T/SP/GQ/9 Specification for Gas Quality Measurement Systems Connected to the NTS which are used for Regulatory and Commercial Conformance. Accuracy is dependent on whether the measurement systems are separative devices (i.e., gas chromatography), inferential devices or sensor-based devices.

SGN employ SGN/SP/BIO/2 for injection of biomethane and this sets accuracy requirements for GSMR parameters, expressed as "uncertainty". It is not clear how the uncertainties should be interpreted (e.g., standard uncertainty, expanded uncertainty, MPE).

5 FUNCTIONALITY REQUIREMENTS ARISING FROM THE LEGISLATIVE FRAMEWORK

(a) Although bending of hydrogen in the NTS is catered for by the existing provisions of the GCOTER, it could carry some additional risk of capping of daily charging area CV. It may therefore be appropriate to consider setting a target CV, either at the relevant NTS offtake(s) or at an agreed commingled point. (GCOTER).

(b) Blending of hydrogen in the NTS would require CV determination at the NTS offtake will require use of a CV determination device that is approved by Ofgem for such blends. (GCOTER)

(c) Ofgem may consider it appropriate to direct NGT to determine CV at a commingled point on the NTS so as to provide a valid CV for attribution to an NTS offtake conveying blend into the LDZ. (GCOTER)

(d) Blending of hydrogen into the lower pressure tiers (i.e., the LTS, and DS) is permitted by the GCOTER. The upper limit of hydrogen content will be limited by the need for the CV at the co-mingled point to be no less than 1 MJ/m^3 less than the FWACV. (GCOTER)

(e) Determination of the CV at the co-mingled point is likely to require use of a CV determination device approved by Ofgem. (GCOTER)

(f) It is likely that location of the co-mingled point will need to be agreed with Ofgem. Ofgem may require evidence that sufficient mixing has occurred for the CV to be representative of the co-mingled stream. (GCOTER)

(g) The volume and energy flow of hydrogen entering the charging area will need to be determined for inclusion in the calculation of charging area CV. Ofgem would be expected to direct the gas transporter to determine the CV of the hydrogen stream to be blended. The CV determination device for this purpose would need to be approved, but in principle could be relatively simple and could comprise just hydrogen content determination. (GCOTER)

(h) The GSMR currently effectively prohibit hydrogen blending and any blending operations would have to be carried out under the provisions of an Exemption from the requirements granted by the HSE. Enduring blending of hydrogen will require revision of Scheule 3 of the GSMR. (GSMR)

(i) The gas transporter's safety case will require amendment to cover blending operations and to include the status of the section of pipe between the injection point and the comingled point when blending and not blending, together with the arrangements in place to demonstrate conformance with the requirements of the GSMR. (GSMR)

(j) Measurement and monitoring arrangements to demonstrate conformance of the blend should be determined through application of the management procedure XXX/TM/GQ/8. (GSMR)

APPENDIX A – REQUIREMENTS OF SCHEDULE 3 OF THE GAS SAFETY (MANAGEMENT) REGULATIONS

Part I: Requirements under normal conditions

1. The content and characteristics of the gas shall be in accordance with the values specified in the following table.

Content or characteristic	Value
hydrogen sulphide content	≤5 mg/m^3
total sulphur content (including H2S)	≤50 mg/m^3
hydrogen content	≤0.1% (molar)
oxygen content	≤0.2% (molar)
impurities	shall not contain solid or liquid material which may interfere with the integrity or operation of pipes or any gas appliance (within the meaning of regulation 2(1) of the 1994 Regulations) which a consumer could reasonably be expected to operate;
hydrocarbon dewpoint and water dewpoint	shall be at such levels that they do not interfere with the integrity or operation of pipes or any gas appliance (within the meaning of regulation 2(1) of the 1994 Regulations) which a consumer could reasonably be expected to operate
Wobbe Number[7]	(i) ≤51.41 MJ/m^3
	(ii) ≥47.20 MJ/m^3
Incomplete Combustion Factor[8]	≤0.48
Sooting Index	≤0.60

2. The gas shall have been treated with a suitable stenching agent to ensure that it has a distinctive and characteristic odour which shall remain distinctive and characteristic when the gas is mixed with gas which has not been so treated, except that this paragraph shall not apply where the gas is at pressure of above 7 barg.

3. The gas shall be at a suitable pressure to ensure the safe operation of any gas appliance (within the meaning of regulation 2(1) of the 1994 Regulations) which a consumer could reasonably be expected to operate.

Part II: Requirements for gas conveyed to prevent a supply emergency

1. The requirements of the gas referred to in regulation 8(2) and (4) are—

   (a) Wobbe Number

      (i) ≤52.85 MJ/m3, and

      (ii) ≥46.50 MJ/m3; and

[7] Note that the GSMAR replaces the lower limit of ≥47.20 MJ/m^3 with a lower limit of ≥46.50 MJ/m^3 and the GSMA2R defines a two-year transition for this change

[8] Note that the GSMAR remove the requirements for Incomplete Combustion Factor and Sooting Index, replacing them with an upper limit in relative density of 0.7

(b) ICF[9] ≤ 1.49

and in all other respects the gas shall conform to the requirements specified in Part I of this Schedule, as if those requirements were repeated herein.

9 Note that the GSMAR remove the requirement for Incomplete Combustion Factor, replacing it with an upper limit in relative density of 0.7