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FUNCTIONAL SPECIFICATION FOR HYDROGEN BLENDING INFRASTRUCTURE

1 INTRODUCTION

The UK government has legislated for ambitious plans to end its contribution to global warming by 2050. The recent Energy White Paper suggests that in order to contribute to meeting such a target, the GB gas network will need to transition to one conveying hydrogen, biomethane, or a mixture of the two. The UK's gas transporters have responded to this need to transition the gas networks through the Energy Network Association's Gas Goes Green programme. Gas Goes Green aims to research, co-ordinate and implement the changes needed to convert GB's gas network.

The UK's gas transporters have commissioned, through the Gas Goes Green programme, Dave Lander Consulting Limited, in conjunction with Thyson Technology, to develop a generic functional specification and outline the infrastructure and equipment required to facilitate injection of hydrogen into the existing gas networks as a blend with natural gas.

2 SCOPE

This document sets out the overarching principles and minimum functional requirements to permit safe, efficient, and fit-for purpose grid injection of hydrogen and blending with natural gas. Ownership and responsibility for operation and maintenance of such facilities may rest with the GT, the DFO or a combination of the two. Three models are envisaged, and these are discussed in Section 6 in more detail.

A series of Technical Reports have been produced that support the requirements set out in this document and these are listed in Appendix A.

3 INJECTION OF HYDROGEN INTO THE NTS

In the context of injection of hydrogen into the NTS, the regulatory obligations of National Gas Transmission (the GT responsible for the NTS) may differ from those GTs operating local transmission systems and distribution systems. These differences – and hence different requirements – are set out in the Table below.

Section(s)	Difference	Requirements
5. Definitions	In the context of hydrogen injection into the NTS, a reference calorific value is not required because injection occurs upstream of entry into the LDZ and the appropriate GT for the LDZ will determine GCV of the blend at the NTS offtake under the terms of a Letter of Direction.	The GT responsible for operation of the NTS may wish to apply a target CV so as to mitigate risk of triggering a cap in FWACV within the LDZ into which blend gas flows.
6.5 3) Provisions of the GT	In the context of injection of hydrogen into the NTS, there is no requirement for odorisation of hydrogen or the hydrogen-natural gas blend.	Because the blend will have a lower value of LFL, gas entering an LDZ via the NTS offtake will require a higher concentration of odorant than that normally employed for natural gas. This in turn means that the odorant injection rate of the odorant injection system at the NTS offtake shall be capable of injecting at the appropriate injection rate.

Section(s)	Difference	Requirements
6.5 5) Provisions of the GT 8.2.2 Commingled point 13.2 Operational Systems and Procedures	In the context of hydrogen injection into the NTS, injection occurs upstream of entry into the LDZ and the appropriate GT for the LDZ will determine GCV of the blend at the NTS offtake under the terms of a Letter of Direction.	The GT responsible for operation of the NTS may wish to apply a CV target so as to mitigate risk of triggering a cap in FWACV within the LDZ into which blend gas flows. The CV target could apply either at the relevant NTS offtake(s) or – for ease of control – at a comingled point agreed between the GT and the DFO.
8.5 FWACV Functionality	In the context of hydrogen injection into the NTS, blend will flow through one or more NTS offtakes operated by the relevant GT for the LDZ.	Any Directed sites at NTS offtakes into which blend will flow shall be appropriate for determination of CV of natural gases containing hydrogen.

4 REFERENCES

4.1 LEGISLATION

SI 1996 No. 551 - Gas Safety (Management) Regulations 1996

SI 1996 No. 439 - Gas (Calculation of Thermal Energy) Regulations 1996

SI 1997 No. 937 - Gas (Calculation of Thermal Energy) (Amendment) Regulations 1997

4.2 DESIGN STANDARDS

4.2.1 BRITISH STANDARDS

PAS 4444 - Hydrogen-fired gas appliances – Guide

4.2.2 INSTITUTION OF GAS ENGINEERS AND MANAGERS

IGEM/GL/5 - Management Procedure for Managing New Works, Modifications and Repairs

IGEM/GM/8 - Non-domestic meter installations. Flow rate exceeding 6 m^3 h^{-1} and inlet pressure not exceeding 38 bar

IGEM/TD/13 - Pressure regulating Installations for transmission and distribution systems.

IGEM/SR/16 - Odorant systems for gas transmission and distribution

IGEM/SR/25 - Hazardous areas classification of natural gas installations.

IGEM/H/1 - Reference Standard for low pressure hydrogen utilisation

4.2.3 JOINT OFFICE OF GAS TRANSPORTERS

T/PR/ME/2 - Work Procedure for Validation of Equipment Associated with Measurement Systems for the Calculation of Mass, Volume and Energy Flowrate of Gas

4.2.4 CADENT, NATIONAL GAS TRANSMISSION AND WALES & WEST UTILITIES

IGEM/GL/5 - Management Procedure for Managing New Works, Modifications and Repairs

T/PM/G/19 - Management Procedure for Application of Model Design Appraisals

T/PM/GQ/8 - Management Procedure for Assessing the Requirement for Gas Quality, Calorific Value and Flow Measurement Systems.

T/PM/PT/1 - Management Procedure for pressure testing of pipework, pipelines, small bore pipework and above ground austenitic stainless-steel pipework.

T/SP/ME/1	-	Specification for Gas Measurement Systems Connected to the NGN Network

4.2.5 NORTHERN GAS NETWORKS

NGN/PM/G/17	-	Management Procedure for the Management of New Works
NGN/PM/G/19	-	Management Procedure for Application of Model Design Appraisals
NGN/PM/GQ/8	-	Management Procedure for Assessing the Requirement for Gas Quality, Calorific Value and Flow Measurement Systems.
NGN/PR/PT/1	-	Work Procedure for pressure testing of pipework, pipelines, small bore pipework and above ground austenitic stainless-steel pipework.
NGN/SP/ME/1	-	Specification for Gas Measurement Systems Connected to the NGN Network

4.2.6 SGN

SGN/PM/G/17	-	Management Procedure for the Management of New Works
SGN/PM/G/19	-	Management Procedure for Application of Model Design Appraisals
SGN/PM/GQ/8	-	Management Procedure for Assessing the Requirement for Gas Quality, Calorific Value and Flow Measurement Systems.
T/PM/PT/1	-	Management Procedure for pressure testing of pipework, pipelines, small bore pipework and above ground austenitic stainless-steel pipework.
SGN/SP/ME/1	-	Specification for Gas Measurement Systems Connected to the NGN Network

5 DEFINITIONS

The definitions applying to this specification are listed below.

Blending point, comingled point	-	The HSE Guide to the Gas Safety (Management) Regulations 1996 defines a blending point as 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. The point at which gas samples are taken for determination of the reference calorific value against which capping of FWACV is assessed according to regulation 4A(1) (b) (i) of the Gas (Calculation of Thermal Energy) Regulations. For the purposes of this specification the blending point and comingled point are deemed to be same point. Note: In the context of hydrogen injection into the NTS, a reference calorific value is not required because injection occurs upstream of entry into the LDZ and the appropriate GT for the LDZ will determine GCV of the blend at the NTS offtake under the terms of a Letter of Direction. However, the GT responsible for operation of the NTS may wish to apply a target CV so as to mitigate risk of triggering a cap in FWACV within the LDZ into which blend gas flows.
Calorific value	-	For the purpose of this document, calorific value is the gross calorific value on a volumetric basis of the real gas at ISO reference conditions of 15°C (combustion) and 15°C and 101.325 kPa (metering). See BS EN ISO 6976.
Delivery facility	-	The facility from which hydrogen may be tendered for delivery at the LDZ System Entry Point.
Delivery Facility Operator (DFO)	-	The operator of the delivery facility.

Directed site	-	Site at which the GT has been directed by Ofgem to determine calorific value under Regulations 6(a) and 6(b) of the Gas (Calculation of Thermal Energy) (Amendment) Regulations 1997.
Gas Transporter (GT)	-	A body holding a licence under Section 7 of the Gas Act 1986 as amended by the Gas Act 1995 and by the Utilities Act 2000.
Hydrogen Blending and Grid Entry unit (HBGEU)	-	Facility to facilitate the injection and blending of hydrogen into gas distribution systems.
Hydrogen Transporter (HT)	-	A GT that owns and operates the pipeline conveying hydrogen from its place of production to the HBGEU.

6 PRINCIPLES

6.1 FUNDAMENTAL PRINCIPLES

1) The legal obligations upon the GT in respect of gas introduced into its gas systems by a third party, as set out in the GSMR[1] and GCOTER, are such that criminal liability cannot be delegated to a third party. The GT may therefore wish to retain control of key aspects of some or all parts of the HBGEU including ownership, design, operation, and maintenance. The closure of the ROV shall be under the control of both the DFO and the GT. The opening of the ROV shall be under the sole control of the GT.
2) Gas not complying with the requirements of Part 1 of Schedule 3 of the GSMR shall not be conveyed in a gas grid unless an exemption has been granted by the Health and Safety Executive from a particular requirement. In such a situation the DFO and GT shall ensure that any requirements conditional to the granting of such an exemption are met.
3) Nominally pure hydrogen is not compliant with the requirements of Part 1 of Schedule 3 of the GSMR and has to be blended with natural gas in order to become compliant. There is some ambiguity associated with the definition of "gas" in the GSMR, which in turn creates ambiguity over whether hydrogen injection and mixing is recognised as blending by the GSMR and hence as a means by which out-of-specification gas can be conveyed through pipes and processed prior to introduction into the network. There is further ambiguity over whether gas has to be fully mixed in order to be compliant with the GSMR. These areas of ambiguity are discussed the Technical Report (see Appendix A) discussing legislative framework. Depending on interpretation by HSE this may mean that some pipes may on different occasions convey out-of-specification gas (and therefore shall not be treated as part of the network being governed by GSMR). If this is so, the safety case of the gas transporter shall address this situation.
4) Where the GT has been directed by Ofgem to determine calorific value, the facility and its operation shall be in accordance with the relevant Letter of Direction.
5) The costs associated with the capping of area calorific value in accordance with regulation 4A(1) of GCOTER are disproportionate to the quantity of hydrogen being injected. It is therefore essential that measures are taken to ensure that capping is avoided by blending with other gas being conveyed by the GT.

6.2 GAS QUALITY MEASUREMENT RISK ASSESSMENT

1) The DFO and GT shall participate in a measurement risk assessment in accordance with T/PM/GQ/8 to determine which parameters shall be monitored, the frequency of measurement and the speed of response of measurement system.

[1] 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).

2) The recommended limit values shall be assessed by risk assessment.

3) The initial risk assessment shall set out those changes (for example, regulatory framework, hydrogen source and composition, equipment changes, etc.) that will require review of the risk assessment. In the event of one or more such changes, the risk assessment shall be reviewed. Where a particular parameter shows increased risk then a change in the monitoring scheme may be appropriate.

6.3 PROVISIONS OF THE HYDROGEN TRANSPORTER

1) The hydrogen transporter shall provide hydrogen to the HBGEU that is compliant with the requirements in Table 5 of IGEM/H/1 and Table 2 of PAS 4444.

6.4 PROVISIONS OF THE DELIVERY FACILITY OPERATOR

1) The DFO shall control hydrogen injection rate so as to chieve a minimum gross calorific value at the comingled point that equals or exceeds the target CV agreed with the GT. The target CV may vary during the day so as to reflect the forecast FWACV, which in turn will reflect changing patterns of gas supply and demand.

2) Where the GT owns and operates the sole odorant injection equipment and the DFO owns and operates the hydrogen metering equipment the DFO shall agree with the GT the interface between the hydrogen metering and odorant injection equipment. This is to permit control of odorant injection rate and achieve the required odorant concentration for the hydrogen blend.

3) Where the DFO owns and operates odorant injection equipment to odorise the hydrogen separately the DFO shall add odorant at the rate agreed with the GT. The GT may for operational reasons require injection at rates higher or lower than that generally required.

4) Where the DFO owns and operates the HBGEU the DFO shall also provide to the GT's telemetry system signals from the HBGEU of those parameters identified by risk assessment (see 5.2) and receive signals from the HBGEU for ROV operation.

5) The DFO shall agree with the GT a local operating procedure for the management of non-compliant gas or non-compliant hydrogen blends, including issue of TFA, advance notification of Remotely Operated Valve (ROV) shutdown and procedures for restoration of hydrogen flow following ROV closure.

6.5 PROVISIONS OF THE GT

1) The GT shall provide full details of the format of data for the telemetry interface so as to enable the DFO to procure suitable equipment to achieve appropriate repeat signals.

2) Where the GT owns and operates the sole odorant injection equipment and the DFO owns and operates the hydrogen metering equipment the GT shall agree with the DFO the interface between the hydrogen metering and odorant injection equipment so as to permit control of odorant injection rate so as to achieve the required odorant concentration for the hydrogen blend.

3) Where the GT owns and operates the sole odorant injection equipment the GT shall add odorant to meet its obligations under the GS(M)R.

   See section 8.4.5 for hydrogen injection into the NTS.

4) The GT shall agree with the DFO a local operating procedure for the management of non-compliant gas or non-compliant hydrogen blends, including issue of TFA, advance notification of Remotely Operated Valve (ROV) shutdown and procedures for restoration of hydrogen injection and blending following ROV closure. Typically, this would be through use of a Network Entry Agreement – see Section 6.1.

5) The GT shall, at appropriate intervals, provide a target CV to the DFO.

   Note: In the context of hydrogen injection into the NTS, injection occurs upstream of entry into the LDZ and the appropriate GT for the LDZ will determine GCV of the blend at the NTS offtake under the terms of a Letter of Direction. However, the GT responsible for operation of the NTS may wish to apply a CV target so as to mitigate risk of triggering a cap in FWACV within the LDZ into which blend gas flows. The CV target could apply either at the relevant NTS offtake(s) or – for ease of control – at a comingled point agreed between the GT and the DFO.

7 CONTRACTUAL FRAMEWORK, ASSET OWNERSHIP AND OPERATING AND MAINTENANCE RESPONSIBILITY

7.1 CONTRACTUAL FRAMEWORK

The DFO shall be required to sign a Network Entry Agreement in accordance with the Uniform Network Code (UNC applicable to the GT that owns the system into which hydrogen is being injected. The NEA should contain or refer to documents that contain:

- Requirements to ensure the GT's legal and regulatory obligations are met (including gas quality specifications)
- Local operating procedures
- Network entry provisions

Typically, the above requirements are set out in the following sections of the NEA:

a) Schedule 1A – Ownership – containing diagrams showing site layout and ownership demarcation of equipment.
b) Schedule 1B – Communications – 24/7 contact details for each party and maintenance details and notification arrangements.
c) Schedule 3 – Gas Entry Conditions – Details of gas quality, temperature as per GSMR and GQ8 assessments. PPD PSSR maintenance frequency. DNO Alarm set points low-low, Low, high, high-high. Operational considerations under fault and or emergency conditions.
d) Schedule 4 – Measurement Provisions, metering energy and volume of gas, measurement of calorific value and gas quality requirements, validation of equipment, inspection and maintenance considerations. Table 1 provides an indicative list of gas quality requirements.
e) Schedule 6 – Capacity – variable or fixed minimum flowrates of gas.
f) Schedule 7 – Information Provision – containing a list of telemetered points that the DFO must provide to the GT and a list of points that the GT will provide to the DFO with a description.

7.2 ASSET OWNERSHIP MODELS

Assets associated with the HBGEU are those that carry out the following functions:

a) Hydrogen supply management, metering, and gas analysis
b) Odorisation of hydrogen
c) Blending control, either to ensure an agreed hydrogen content or a minimum gross calorific value at the comingled point.
d) Blend gas analysis at the comingled point
e) Blending/mixing unit
f) FWACV functionality
g) Supervisory system
h) The ROV
i) The telemetry unit
j) Satellite communication system, where fitted
k) Compression and storage, where required

Assets associated with the blending gas supply may or may not be part of the HBGEU, depending on asset locations and the asset ownership model. Such functions include:

l) Blending gas supply management, metering, and gas analysis
m) Odorisation of blend gas

For the purposes of this functional specification, other functions required for production of hydrogen are assumed to not be associated with the HBGEU. Such functions include:

n) Hydrogen production and purification

o) Conveyance of hydrogen to the HBGEU

Three models of asset ownership are set out below. Note that the figures associated with the models are intended to show asset ownership and not the physical arrangement of equipment or devices associated with a particular functional block.

For the purposes of this functional specification, it is assumed that the primary responsibility for operation and maintenance of any asset rests with the asset owner, although it is recognised that commercial arrangements may be put into place with third parties to delegate operation and maintenance.

7.3 MODEL 1 – THE "MINIMUM CONNECTION" MODEL

In this model the GT owns the ROV. All other assets associated with the HBGEU are owned by the DFO. Figure 1 shows the functional blocks and asset ownership for this model.

Note that under this model:

- The GT owns and operates separate natural gas pressure regulation and metering equipment (j), and natural gas odorant injection equipment (k), that is not part of the HBGEU – and in fact may not be at the same location as the HBGEU
- The section of pipe including the gas injection and mixing facility and the comingled point is owned and operated by the GT

7.4 MODEL 2 – THE "MAXIMUM CONNECTION MODEL

In this model, the GT owns all of the assets associated with the HBGEU. No asset associated with the HBGEU is owned by the DFO. Figure 2 shows the functional blocks and asset ownership for this model.

Note that under this model:

- The GT employs a single odorant injection system to ensure the blend is odorised at the appropriate injection rate for the hydrogen content of the blend.
- The GT may choose to combine analysis of natural gas and blend into a single gas analysis system.

7.5 MODEL 3 – THE "MIXED CONNECTION" MODEL

This model is a mixture of models 1 and 2, in that the GT may own assets additional to those of the Minimum Connection Model. In this model, the GT may typically own, in addition to the ROV, one or more of:

- the telemetry unit
- the satellite communication system
- the odorant injection system
- the comingled point gas analysis equipment.

All other assets associated with the HBGEU are owned by the DFO. Figure 3 shows a typical arrangement of the functional blocks and asset ownership for this model.

Note that under this model:

- The GT may employ a single odorant injection system to ensure the blend is odorised at the appropriate injection rate for the hydrogen content of the blend.
- The GT may choose to combine analysis of natural gas and blend into a single gas analysis system.

8 FUNCTIONAL REQUIREMENTS

8.1 HYDROGEN PRESSURE REGULATION AND METERING

Hydrogen pressure regulation and control is required to ensure there is sufficient pressure at the point of injection into the gas transporter's system. Pressure regulation and control shall be to IGEM/TD/13.

Daily hydrogen volume and daily energy flowrate are required for input into the daily FWACV calculation for the charging area and the metering system shall be appropriate for hydrogen that is compliant with Table 5 of IGEM/H/1 and Table 2 of PAS 4444. Measurement of volume and energy flows shall be to T/SP/ME/1, SGN/SP/ME/1, or NGN/SP/ME/1, depending on the GT.

8.1.1 ACCURACY

The hydrogen metering system shall meet the accuracy requirements of Table 2.

8.2 HYDROGEN/GCV CONTROL

Hydrogen injection rate shall be controlled so as to achieve:

- a minimum gross calorific value of gas at the comingled point
- a hydrogen content of the blend that is no greater than the maximum value permitted by either Schedule 3 of the GSMR; or the conditions of any relevant exemption granted by the HSE from the hydrogen requirements of the Schedule 3 of the GSMR
- a Wobbe index of the blend that is no less than the lower Wobbe limit permitted by Schedule 3 of the GSMR.GAS SAMPLING AND ANALYSIS

8.2.1 HYDROGEN SUPPLY

Gas sampling and analysis shall continuously or continually monitor the hydrogen supplied to the HBGEU. For Directed Sites, calorific value of the hydrogen supply shall be determined using an instrument approved by Ofgem for determination of calorific values for the purposes of determining the number of kilowatt hours, under Section 12 of the Gas Act 1986. For Directed Sites, the instrument shall comply with the requirements listed in an appropriate Letter of Approval from Ofgem.

8.2.2 COMINGLED POINT

Gas sampling and analysis shall continuously or continually monitor the blend at the comingled point and provide confirmation that it is compliant with the requirements of Part 1 of Schedule 3 of the GS(M)R and that calorific value meets the minimum requirements agreed with the GT. A schedule of parameters that shall be monitored is given in Table 1.

Calorific value shall be determined using an instrument approved by Ofgem for determination of calorific values for the purposes of determining the reference point against which FWACV capping shall apply. The instrument shall comply with the requirements listed in an appropriate Letter of Approval from Ofgem.

Note: In the context of hydrogen injection into the NTS, a reference calorific value is not required because injection occurs upstream of entry into the LDZ and the appropriate GT for the LDZ will determine GCV of the blend at the NTS offtake under the terms of a Letter of Direction. However, the GT responsible for operation of the NTS may wish to apply a target CV so as to mitigate risk of triggering a cap in FWACV within the LDZ into which blend gas flows.

The location of the comingled point shall be agreed with Ofgem, and this may require suitable evidence to demonstrate that the hydrogen and blending gas are sufficiently mixed at this point.

A facility shall be provided to permit representative spot samples of hydrogen for laboratory analysis to be safely taken.

8.2.3 ACCURACY

The gas analysis system(s) shall meet the accuracy requirements of Table 3.

8.3 REMOTELY OPERATED VALVE

A Remotely Operated Valve (ROV) shall be supplied, which shall be capable of manual remote or automatic closure in the event of variation in blend outside of the agreed conditions given in Table 1, failure of odorisation where required, or inability to provide sufficient blending where this is practiced. A more detailed description of trip and reset philosophy is given in the Gas Quality and Supervisory system functional block. The means of actuation of the ROV shall be the choice of the GT.

8.4 ODORANT INJECTION

8.4.1 ODORISATION OF HYDROGEN – NATURAL GAS BLENDS

Blends of hydrogen with natural gas have lower values of Lower Flammability Limit (LFL) than natural gas alone and hence will require a higher concentration of odorant than that normally employed with natural gases. Odorant requirements of blends are discussed in detail in the Odorisation Technical Report supporting this specification, but in essence, achieving this higher concentration of odorant can be achieved in two ways:

- Directly, by odorising the hydrogen prior to blending with natural gas that has already been odorised.
- Indirectly, by blending un-odorised hydrogen with natural gas that has been odorised to an increased odorant concentration.

The choice of direct or indirect odorisation will depend on the location of the hydrogen blending unit, the location of the natural gas odorant injection system and which odorisation system(s) the GT chooses to own, operate and control.

8.4.2 DIRECT ODORISATION

In the cases of the direct odorisation, hydrogen is odorised separately, and natural gas used for blending will have already been odorised by the GT. The hydrogen odorant injection system shall be designed in accordance with the principles of IGEM/SR/16.

The hydrogen odorant injection system shall inject odorant in order to achieve - under normal circumstances - an odorant concentration of 7.3 mg/m^3 in the hydrogen being injected. This will lead to an odorant concentration of 6.25 mg/m^3 in a blend containing 20% hydrogen, which will achieve an appropriate Odour Intensity for a gas-air mixture at 20% LFL.

In some circumstances variation of hydrogen odorant injection rate from 7.3 mg/m^3 in the hydrogen may be required in order to achieve satisfactory odour intensity in the network and so the system shall be designed to achieve odorant concentrations over the range 2-19 mg/m^3.

The odorant injection system shall employ a suitable liquid pump; evaporative or wick odorisers shall not be used.

The odorant pump controller shall accept a signal from the hydrogen metering system corresponding to the instantaneous flowrate of hydrogen at reference conditions and compute and control the required odorant injection rate to achieve the required odorant concentration.

8.4.3 INDIRECT ODORISATION

In the cases of the indirect odorisation, it is appropriate to adjust the odorant injection rate of an existing odorant injection system for the natural gas used for blending so as to achieve an odorant concentration of 6.25 mg/m^3 in a blend containing 20% hydrogen, which will achieve an appropriate odour Intensity for a gas-air mixture at 20% LFL. The (existing) natural gas odorant injection system shall have been designed in accordance with the principles of IGEM/SR/16.

In some circumstances variation of blend odorant injection rate from 6.25 mg/m^3 may be required in order to achieve satisfactory odour intensity in the network and so the system shall be designed to achieve odorant concentrations over the range 2-16 mg/m^3.

Odorant injection rate for blends containing less than 20% hydrogen can either be reduced according to linear interpolation between 0% and 20% hydrogen, or simply left at 6.25 mg/m^3 whenever hydrogen injection is practiced, because – in practice – the impact on odour intensity is not significant.

The odorant injection system shall employ a suitable liquid pump; evaporative or wick odorisers shall not be used.

The odorant pump controller shall accept a signal from the hydrogen metering system and natural gas metering system corresponding to the instantaneous flowrate of blend at reference conditions and compute and control the required odorant injection rate to achieve the required odorant concentration.

8.4.4 ODOUR INTENSITY ASSESSMENT

An odour assessment test point suitable for use by trained rhinologists to assess Odour intensity shall be installed downstream of the odorant injection point at a location agreed with the GT.

8.4.5 INJECTION OF HYDROGEN INTO THE NTS

In the context of injection of hydrogen into the NTS, there is no requirement for odorisation of hydrogen or the hydrogen-natural gas blend. However, because the blend will have a lower value of LFL, gas entering an LDZ via the NTS offtake will require a higher concentration of odorant than that normally employed for natural gas. This in turn means that the odorant injection rate of the odorant injection system at the NTS offtake shall be capable of injecting at the appropriate injection rate.

8.5 FWACV FUNCTIONALITY

The system shall deliver the functionality required for the FWACV regime, namely requirements set out in the Gas (COTE) Regulations, and for Directed Sites, the conditions specified by both the Ofgem Letter of Direction for the HBGEU and the Letter of Approval for the chosen CV determination device. Conditions currently specified include the following:

1) Acquisition and storage of gross CV of the supplied hydrogen from the approved CV determination device, together with a flag indicating its quality/suitability for use. For non-continual CV determination devices, the System - CV determination device interface shall be such that only one value of each CV determination is acquired.
2) Acquisition and storage of instantaneous volumetric flowrate of hydrogen at the time of acquisition of gross CV.
3) Initiation of daily calibration of CV determination device.
4) Automated tests of apparatus and equipment at periods not exceeding 35 days in accordance with Regulation 6(e) of the Gas (COTE) Regulations. The facility to manually initiate tests of apparatus and equipment either by, or at the request of, the Gas Examiner. Provision of a report of results of automated or manual tests in accordance with Regulation 6(e) of the Gas (COTE) Regulations.
5) Calculation of the daily average CV of the hydrogen at the end of each Gas Day in the manner specified by the Letter of Direction. This will require confirmation of the quality of individual records (records are Good if the CV determination device is operating within agreed limits) and averaging of only those records that are Good and for which gas is flowing past the sample point. In addition, a flag shall be stored indicating whether the resulting daily average CV is Valid (i.e., the maximum time between Good records is less than 8 hours). Gross CV values during calibration or tests of apparatus and equipment shall not be included for averaging.
6) Acquisition and storage of integrated daily volume at the end of the Gas Day.
7) In addition to local storage of individual data acquired, appropriate means of secure transfer of data to the High Pressure Metering Information System (HPMIS) owned and operated by the GT (or similar system in the case of Cadent Gas and National Gas Transmission). HPMIS currently accepts data as CSV files with an appropriate check sum to ensure corrupted data is identifiable and not accepted. A list of files and file structure is provided in Appendix A.

FWACV functionality may vary if alternatives to the CV determination devices currently approved by Ofgem become available.

Any software and hardware solutions are acceptable provided they deliver the required FWACV functionality, but the GT will require demonstration that the required functionality has been delivered. In addition, Ofgem may require testing and approval of some parts of or all of such software and hardware by their service provider.

In the context of hydrogen injection into the NTS, any Directed sites at NTS offtakes into which blend will flow shall be appropriate for determination of CV of natural gases containing hydrogen.

8.6 GAS QUALITY AND SUPERVISORY SYSTEM

The Gas Quality and Supervisory system shall monitor hydrogen and blend quality signals from the HBGEU instrumentation, the remote monitoring unit instrumentation and the delivery facility instrumentation. Monitoring shall be continuous or continual and provide confirmation that the blend at the comingled point is compliant with the requirements of Table 1 or any other parameters agreed by risk assessment (see 5.2).

In the event of an excursion in any of the parameters in Table 1 or any other parameters agreed by risk assessment (see 5.2) the trip system shall initiate closure of the ROV and prevent further grid injection of hydrogen.

The limit values in the parameters of Table 1 are indicative and site-specific values shall be agreed during design approval and may be subject to review if risk assessment confirms such a requirement (see 5.2). All alarms and trips shall therefore be configurable.

If closure of the ROV has been initiated because of non-compliance with the parameters in Table 1 or any other parameters agreed by risk assessment (see 5.2), then its subsequent opening shall be under the sole control of the GT.

9 VARIATIONS

9.1 REMOTE MONITORING UNIT

Under most circumstances the distance from the injection point to the comingled point is expected to be such that monitoring of gas quality at a location remote from the HBGEU will not be required.

However, should the distance from the injection point to the comingled point be so large as to extend outside of the AGI in which the HBGEU is located, a remote location may be required. In this situation for Directed Sites the remote monitoring unit shall contain a remote CV determination device approved by Ofgem, together with telemetry to send the measured values CV at the comingled point back to the main HBGEU or the GT's telemetry unit as appropriate.

Note that employment of remote monitoring units carries risk of significant lengths of pipe conveying gas that is not compliant with the GSMR, impacts on whether such pipe is considered relevant main, and may expose the GT to increased connection costs. Remote monitoring should therefore be avoided whether possible.

10 DESIGN APPROVAL

10.1 ASSETS OWNED BY THE GT

Design approval for all assets owned by the GT shall be managed in accordance with IGEM/GL/5 and T/PM/GL/5 (for Wales & West Utilities) or the Management Procedure G/17 pertaining to the relevant GT (for other GTs). Note that if a valid model design appraisal for the HBGEU is available then site specific design approval within Management Procedure G/17 by application of Management Procedure G/19 pertaining to the relevant GT is acceptable.

10.2 ASSETS OWNED BY THE DFO

For those assets owned by the DFO the GT shall be afforded the opportunity to review the design of interfaces to assets owned by the GT

11 TESTING

11.1 ASSETS OWNED BY THE GT

Pressure testing of all pressure containing components and systems shall be carried out in accordance with Management/Work Procedure PT/1 pertaining to the relevant GT. Testing of electrical and instrument systems and equipment shall be carried out in accordance with BS 7671 and BS EN 60079-14.

11.2 ASSETS OWNED BY THE DFO

All pressure containing components and systems shall be pressure tested and declared safe to commission by the DFO. Testing of electrical and instrument systems and equipment shall be carried out in accordance with BS 7671 and BS EN 60079-14

12 COMMISSIONING AND INITIAL VALIDATION

12.1 GENERAL REQUIREMENTS

All personnel carrying out commissioning and initial validation shall be competent and adequately trained to do so.

A written commissioning procedure shall be agreed and shall take into account relevant Permit to Work procedures.

Initial validation shall be carried out in order to demonstrate the accuracy of the measurement system complies with the requirements of Table 2. Suitable systems, software or procedures shall be provided or agreed to ensure that compliance can be demonstrated.

12.2 ASSETS OWNED BY THE GT

Following satisfactory commissioning, validation of the flow and gas quality measurement system shall be carried out in accordance with the relevant parts of T/PR/ME/2 or an alternative documented procedure if appropriate.

12.3 ASSETS OWNED BY THE DFO

Following satisfactory commissioning, validation of the flow and gas quality measurement system shall be carried out in accordance with a documented procedure agreed with the GT.

13 OPERATION

13.1 OPERATIONAL SYSTEMS AND PROCEDURES

Operational procedures specific to the particular installation shall be developed by the DFO and agreed with the GT. The operational procedures shall be held by both the DFO and GT. Operational procedures shall be subjected to periodic review and any subsequent amendments agreed by both the DFO and GT.

Special operations not covered by the operational procedures shall be undertaken within an appropriate Permit to Work System, such as IGEM/GL/6.

13.2 CONTROL AND MONITORING OF CALORIFIC VALUE

The requirements for control and monitoring of calorific value shall be agreed in the NEA, which may refer to a Local Operating Procedure that provides detailed arrangements.

The GT shall at appropriate intervals calculate an appropriate target CV so as to minimise the risk of FWACV capping and communicate its value to the DFO and HBGEU.

The hydrogen injection flowrate shall be controlled so as to ensure that instantaneous CV at the comingled point does not fall below the prevailing target CV, subject to:

- hydrogen content of the gas at the comingled point shall not be greater than that permitted by the NEA
- Wobbe index of the gas at the comingled point shall not be less than that permitted by the NEA.

For Directed Sites, CV, volume flowrate and energy flowrate of the hydrogen injected into the network shall be monitored in accordance with the requirements of the relevant Letter of Direction and in order to deliver the required FWACV functionality.

Note: In the context of hydrogen injection into the NTS, a reference calorific value is not required because injection occurs upstream of entry into the LDZ and the appropriate GT for the LDZ will determine GCV of the blend at the NTS offtake under the terms of a Letter of Direction. However, the GT responsible for operation of the NTS may wish to apply a target CV so as to mitigate risk of triggering a cap in FWACV within the LDZ into which blend gas flows.

13.3 CONTROL AND MONITORING OF GAS QUALITY

Gas Quality of the gas at the comingled point shall be monitored so as to ensure compliance with the requirements set out in the NEA. The frequency of monitoring shall be determined though measurement risk assessment.

13.4 CONTROL AND MONITORING OF ODORISATION

Odorisation shall be controlled and monitored in accordance with the guidance set out in IGEM/SR/16.

Odorant injection rate shall be agreed between the DFO and GT in the NEA which may refer to a Local Operating Procedure that provides detailed arrangements.

14 MAINTENANCE AND PERIODIC VALIDATION/CALIBRATION

14.1 GENERAL

A planned maintenance system for the odorant plant shall be established and integrated with the overall maintenance programme for the site. General guidance is available in IGEM/TD/13.

A programme of appropriate inspection should be incorporated into the maintenance programme. For instance, visual inspection, non-destructive testing (NDT) techniques etc.

> Note: In GB there is a statutory requirement under the Pressure Systems Safety Regulations 2000 to follow a written scheme of examination for a pipeline and its protective devices where the pressure exceeds 0.5 bar.

Electrical and instrumentation equipment installed in hazardous areas shall be maintained to meet the requirements of BS EN 60079-17. Frequency of periodic inspections should not exceed three years, with typical detailed and close inspections carried out annually.

Electrical equipment must be maintained to meet the requirements of BS 7671.

14.2 MAINTENANCE OF SPECIFIC SUB-SYSTEMS

Consideration shall be given to the guidance provided in Section 8 of IGEM/SR/16 on maintenance of odorant injection systems.

Consideration shall be given to the guidance provided in Section 14 of IGEM/TD/13 on maintenance of pressure regulation installations.

14.3 VALIDATION AND CALIBRATION

Equipment shall be validated and calibrated in accordance with industry guidance. Site specific requirements should be specified in the NEA.

Table 1: Parameters to be monitored and indicative limits to be applied

Parameter	Units	low limit	high limit
Delivery temperature	°C	(See note 1)	(See note 1)
Delivery pressure	barg	(See note 1)	(See note 1)
Wobbe index	MJ/m^3	47.20 (See note 8)	51.41
Incomplete combustion factor	-	not applicable	0.48 (See note 8)
Sooting index	-	not applicable	0.60 (See note 8)
Gross calorific value	MJ/m^3	(See note 2)	(See note 2)
Hydrogen	mol%	not applicable	(See note 3)
Carbon dioxide	mol%	not applicable	2.5
H_2S	mg/m^3	not applicable	5
Water dew temperature (see note 4)	°C	not applicable	-10
Odorant injection rate	mg/m^3	(See note 5)	(See note 5)
Odorant injection pump operation (see note 6)	-	not applicable	not applicable
Odorant tank level	-	(See note 7)	not applicable

Notes:

1. Limits for delivery temperature and pressure to be agreed during design review.
2. Targets for calorific value shall be set by the GT at appropriate intervals.
3. Hydrogen content high limit will be set by the GT and dictated by any future amendment of Schedule 3 of the GSMR, or as agreed by the HSE as part of an exemption certificate.
4. Water dew temperature to be calculated using the LRS equation of state at a pressure of 7 barg (for injection into below 7 barg systems) or at the highest anticipated pressure (for injection into above 7 barg systems).
5. Odorant injection rate (typically 6.25 mg/m^3 for blends and 7.3 mg/m^3 for hydrogen) and high/low limits to be agreed during design review.
6. Confirmation is required that the odorant pump is operating.
7. Low level on odorant tank shall trigger alarm and at extra low level shall initiate closure of the process shut down valve.
8. 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). The first amendment removed incomplete combustion factor and sooting index as parameters, replacing them with an upper limit in relative density. In addition, the first amendment amended the low limit in Wobbe index from 47.2 MJ/m^3 to 46.5 MJ/m^3 and the second amendment prescribed that the change in lower limit shall come into effect on 6th April 2025. It is likely, therefore that Network Entry Agreements for hydrogen injection and bending projects will reflect these amendments.

Table 2: Accuracy requirements for metering systems

Design daily volume	MPB (Note 1)		MPE (Note 2)	
	Daily volume	Daily energy	Daily volume	Daily energy
All daily volumes	0.09%	0.10%	1.0%	1.1%

Note 1: Compliance with MPB shall be deemed if |mean error| ≤MPB

Note 2: Compliance with MPE shall be deemed if |mean error| + U(mean error) ≤MPE

Note 3: The thresholds in Table 1 above should ensure accuracy consistent with or better than the 2007 requirements of the EU-ETS Measurement Reporting Guidelines ("MRG2007").

Note 4: Compliance with Table 1 shall be demonstrated by detailed uncertainty analysis in accordance with GUM / ISO 5168

Table 3: Accuracy requirements for gas analysis systems

Location	Parameter	Range	MPB (Note 1)	MPE (Note 2)
Hydrogen supply	Gross CV, MJ/m^3	11.6 - 12.1	0.1	0.2
Comingled point	Gross CV, MJ/m^3	tbc	0.1	0.2
	Wobbe index, MJ/m^3	47.2 – 51.4	0.1	0.2
	Hydrogen, % mol/mol	0 - 25	0.1	0.17

Note 1: Compliance with MPB shall be deemed if |mean error| ≤MPB

Note 2: Compliance with MPE shall be deemed if |mean error| + U(mean error) ≤MPE

Figure 1: Asset ownership under Model 1 ("Minimum Connection")

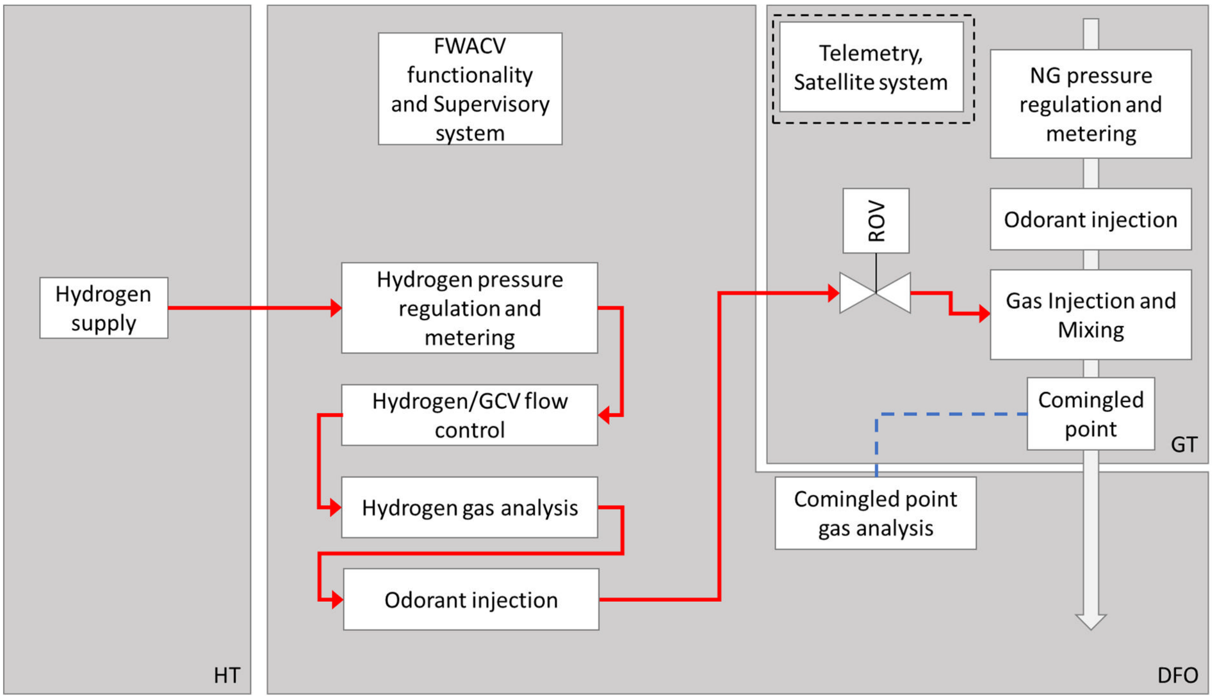


Figure 2: Asset ownership under Model 2 ("Maximum Connection")

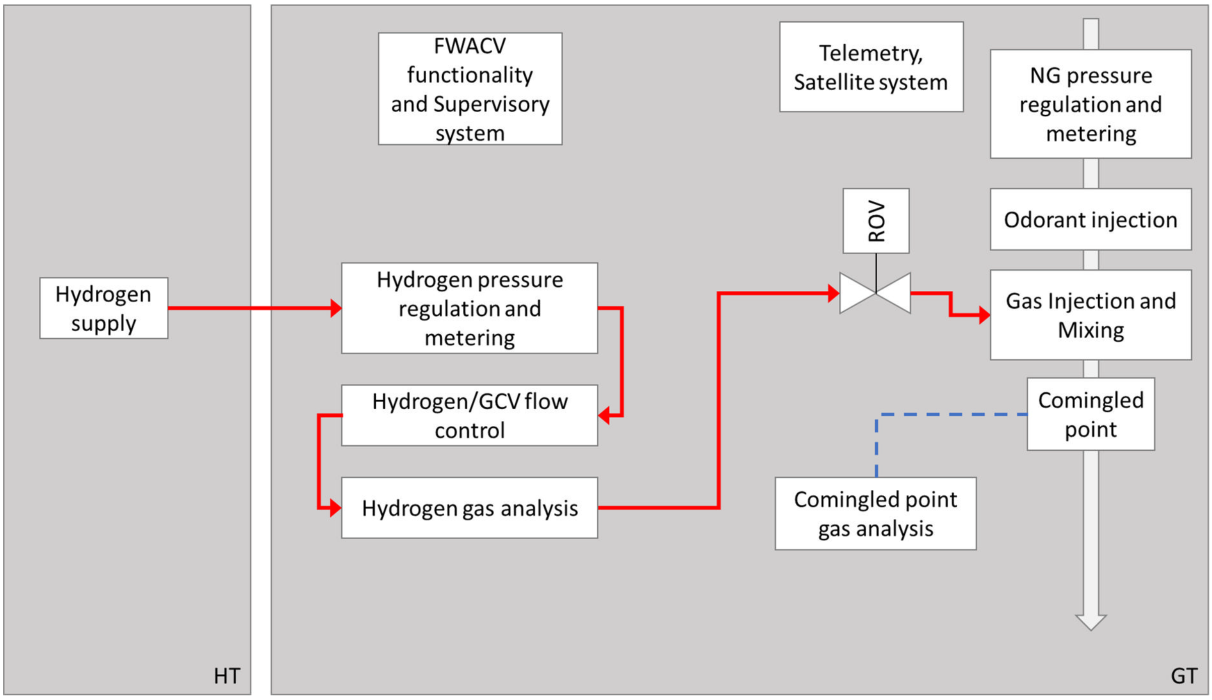
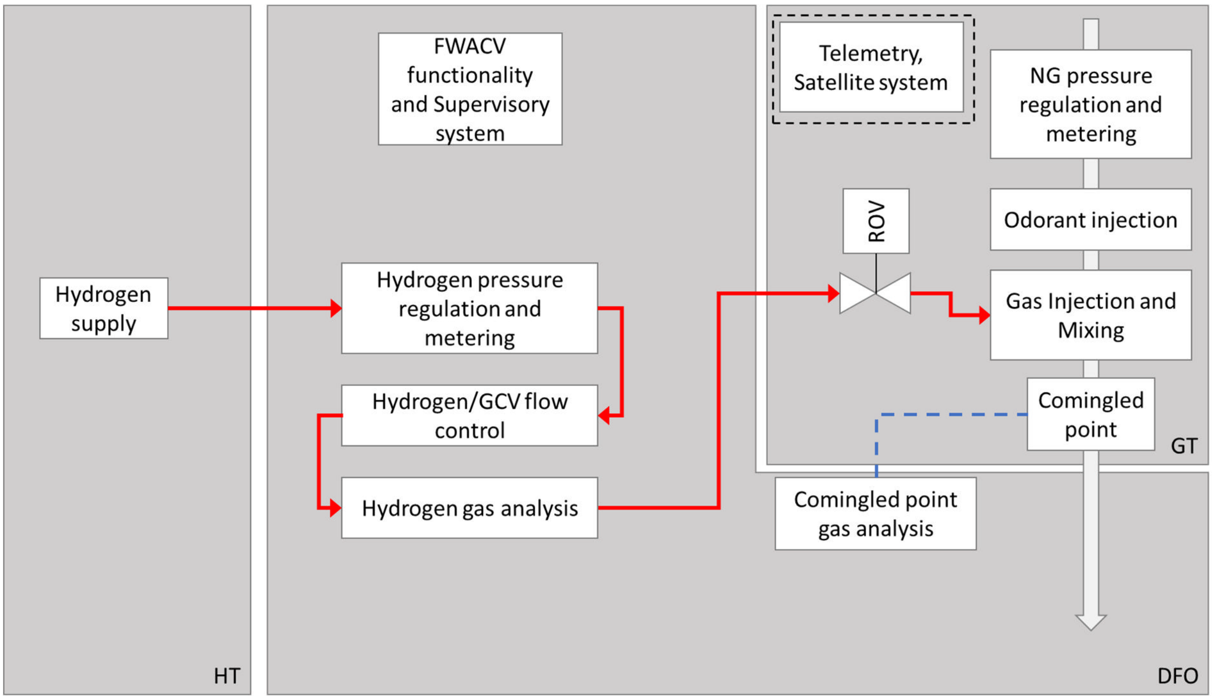


Figure 3: Asset ownership under Model 3 ("Mixed Connection")



APPENDIX A
LIST OF SUPPORTING TECHNICAL REPORTS

Report No	Issue	Author	Title
DLC/0212		D.F. Lander	Technical Report for Functional Specification for Hydrogen Blending Infrastructure Project: Legislative framework for hydrogen blending
DLC/0214		D.F. Lander	Technical Report for Functional Specification for Hydrogen Blending Infrastructure Project: Odorisation
DLC/0215		D.F. Lander	Technical Report for Functional Specification for Hydrogen Blending Infrastructure Project: Hydrogen demand, supply and storage

APPENDIX B
DATA FILES AND FILE STRUCTURE

INTRODUCTION

HPMIS (Marquis for Cadent Gas and National Gas Transmission) is an Oracle (SAP for Cadent Gas and National Gas Transmission) database located at a central server and forms the basis by which many of the Gas Transporter obligations under the Gas (Calculation of Thermal Energy) Regulations can be managed. Data is imported as CSV files with a fixed data structure that must be adhered to if data is to be located correctly into the database.

The following Table lists the file naming and format for the daily average CV file to be returned from the HBGEU.

The existing approved instruments are multi-stream and have between 3 and 5 gas streams: Stream 1 (calibration gas); Stream 2 (Gas Examiners' test gas) and Streams 3-5 (gas for analysis). For single-stream instruments that have neither calibration nor GE test gases, the extension ".ST3" is recommended for consistency.

HPMIS file name: Hsite.AByymmdd.Y0n.		
This file contains the results of the end of day averaging process and is generated at the end of the Gas Day (currently 06:00, although it is recommended that this is configurable). The stream number is indicated by "n".		
Line	Structure	Example
1:	Header comprising the Instrument number and location description followed by the name and version number of the software generating the data. (Under current arrangements the software that performs the averaging process is approved by Ofgem, so software name and version number must be included.)	"Instrument1234 at location: EODAVE v3.7"
2:	Time and date of the last record used in the file that contains individual CV data.	"06:02-20/01/2012"
3:	Stream number	3
4:	Blank (intentional)	-
5:	Indication if the average CV is valid (Y,N, or X)	Y
6:	Number of records used in the averaging process.	98
7:	Average CV (rounded to 1 dp using the normal rules of rounding).	38.5
8:	Blank? (Average RD)	0.6324
9:	Blank? (Number of records used in tracker averaging)	-
10:	Blank (Tracker CV)	-
11:	Blank (Tracker RD)	-
12:	Blank (Attribution flag)	-
13:	Blank (intentional)	-
14:	Blank (Total number of non-zero flow records in the file containing data for averaging)	-
15:	Blank? (24hr integrated flow)	-

HPMIS file name: Hsite.AByymmdd.Y0n.		
This file contains the results of the end of day averaging process and is generated at the end of the Gas Day (currently 06:00, although it is recommended that this is configurable). The stream number is indicated by "n".		
Line	Structure	Example
16:	Blank? (24 hr integrated energy)	-
17:	Blank? (Sample gas minimum pressure and temperature)	-
18:	Blank? (Calibration gas pressure at end and temperature at calibration)	-
19:	Blank? (test gas end pressure and minimum temperature)	-
20:	Blank? (the two carrier gas cylinder pressures at end)	-
21:	Name of file containing the data that was averaged.	C:\DATA\DATA0101.ST3
22:	Configuration parameters for the for the averaging software: end of day time, loss of record time (hrs), stream sequence, FWACV flag, streams with a flow computer and the no flow time (hrs)	"06:00",8,"3","Y","3",0
23:	File terminator: @ plus 6 character checksum.	@XXXXXX