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SPECIFICATION OF WATER DEW TEMPERATURE OF BIOMETHANE INJECTED INTO GAS DISTRIBUTION SYSTEMS

1 INTRODUCTION

Gas Distribution Networks typically make no distinction in the gas quality specification for gas entering their Local Transmission Systems (LTS) or their Gas Distribution Systems (GDS). For water dewpoint, a typical Network Entry Agreement requires water dewpoint to be no more than -10°C at 85 barg. Gas with this water dew temperature is extremely dry and corresponds to a water content of around 57 ppm (molar)[1] and is difficult to achieve when drying biomethane at conditions typically employed in its production (typical biogas clean-up to remove CO_2 and main contaminants is carried out at a pressure of around 10 barg).

Measurement risk assessment to assess the monitoring requirements for biomethane entry into a below 7 bar GDS has highlighted that the risk posed by concentrations of water greater than 57 ppm (molar) may not be sufficient to warrant such a strict specification. This report provides information on historical water dewpoint specifications and offers an approach to deciding a more appropriate requirement.

2 HISTORICAL SPECIFICATIONS

Originally the normal water dew temperature specification employed by the then British Gas Corporation was -10 °C at 1000 psig (68.95 barg). A pressure of 1000 psig was employed because that the line pressure at which gas typically entered its National Transmission System (NTS) and water dew temperature was determined for compliance purposes by measurement with a chilled mirror instrument.

Following metrication of the UK gas industry, the water dew temperature specification employed by the British Gas Corporation changed slightly by the adoption of -10 °C at a pressure of 69 barg.

After some parts of the NTS were reinforced to permit its pressure to be increased to 85 barg, Transco (the monopoly gas transporter following privatisation of the British Gas Corporation) changed the water dew temperature requirement in their Ten Year Statement to -10 °C at 85 bar. Note that the ten year statement does not specify gauge pressure and so the assumption is that the water dew temperature requirement should be assessed at 85 bar absolute pressure.

The determination of water dew temperature for compliance purposes by measurement is now relatively rare for gases entering the NTS. National Grid typically employs equipment that measures the concentration of water and converts this measurement into a water dew temperature at the desired pressure using GasVLE and the LRS equation of state. The pressure typically employed by National Grid for these calculations is 69 barg.

Table 1 summarises the concentrations of water that correspond to these three historical water dew temperature specifications. Also included is the water content corresponding to -10 °C at 85 barg, because of the ambiguity over National Grid's current Ten Year Statement.

Table 1: Historical water dew temperature specifications

Water dew temperature	water concentration ppm (molar)
-10°C at 1000 psig	63.45
-10°C at 69 barg	63.42
-10°C at 85 bar	57.89
-10°C at 85 barg	57.65

[1] Calculated using GasVLE using a typical natural gas composition and the LRS equation of state.

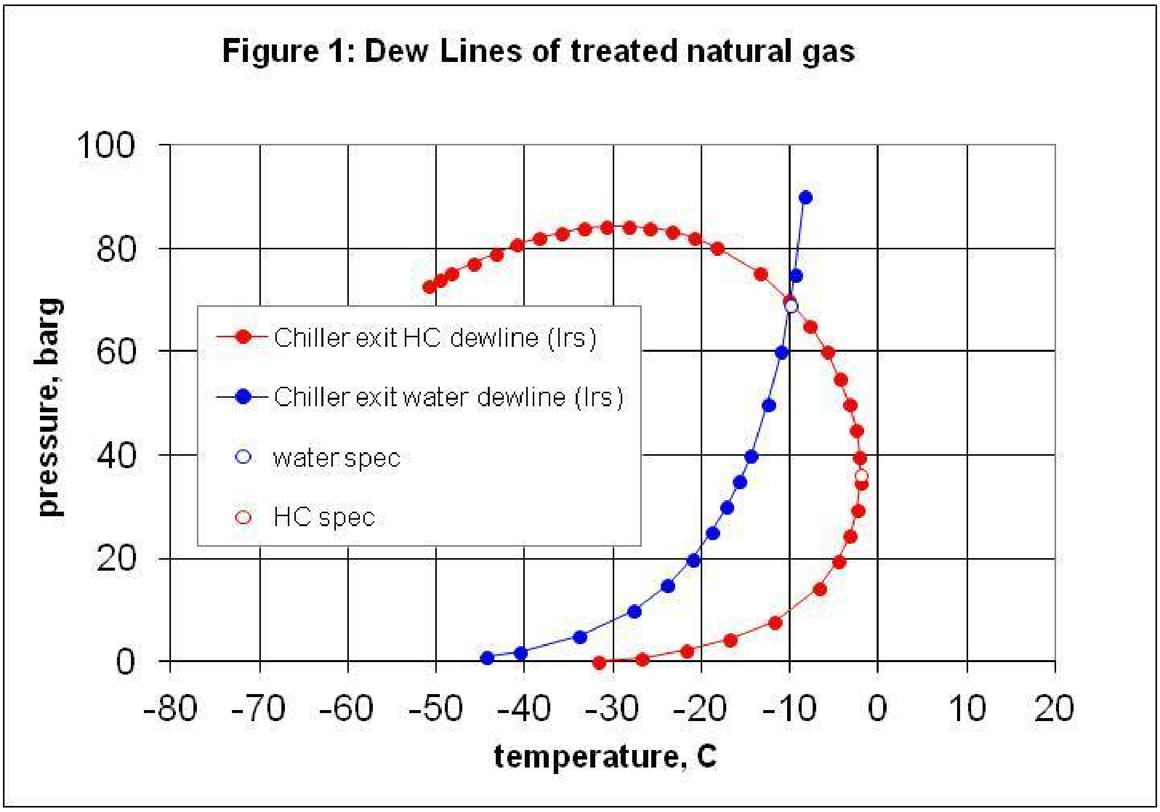
The water dew temperatures were carried out with GasVLE and the LRS equation of state for a natural gas with the dry gas composition shown in Table 2.

Table 2: Composition of natural gas employed for water dew temperature calculations (mol%)

methane	88.790
ethane	5.820
propane	1.865
i-butane	0.162
n-butane	0.339
neo-pentane	0.002
i-pentane	0.052
n-pentane	0.057
n-hexane	0.042
nitrogen	1.055
carbon dioxide	2.255

Historically, most natural gas entering the NTS was treated by chilling at line pressure so as to meet the hydrocarbon dew temperature requirement, i.e. the cricondentherm temperature should be no greater than -2 ^{o}C. In order to achieve such a hydrocarbon dew temperature, typically the gas at 1000 psi has to be chilled to around -10 ^{o}C. As a result, the gas exiting the chiller typically had a dew temperature of around -10 ^{o}C at 1000 psi.

Figure 1 illustrates the correspondence between hydrocarbon and water dew lines and shows how a chilling natural gas to -10^{o}C results in a gas with a cricondentherm of -2^{o}C. Figure 2 was constructed using a GasVLE model of chilling of a "water and hydrocarbon wet" natural gas.



3 APPROPRIATE WATER DEW TEMPERATURE SPECIFICATIONS

The purpose of a dew temperature specification is to ensure that liquid cannot form if gas is cooled. Liquid water formation can lead to corrosion issues with metallic pipe and significant liquid formation can lead to plugging and cause operational problems. Gas can be cooled by sensible heat loss through the pipe to its surroundings and also through Joule-Thomson cooling at pressure reduction stations.

Assuming that sensible heat loss is unlikely to result in gas temperature below 0^oC, a hydrocarbon liquid cannot form at any pressure if the cricondentherm is set at -2 ^oC through specification. Joule-Thomson cooling can cause the temperature to fall below 0^oC, and preheating is typically employed at NTS offtakes to ensure gas temperature does not fall to less than 0^oC.

It is believed that because chiller temperatures of -10 ^oC at 1000 psi were typically employed to meet hydrocarbon dew temperature requirements, NTS entry specifications were set to that typically observed and not what is required to provide an adequate margin to prevent liquid water corrosion.

For gas entry at distribution pressures, the water content can be relaxed somewhat and still provide an adequate degree of protection from liquid water formation.

One further factor must also be considered. For the purpose of consumer billing natural gas is assumed to be perfectly dry (i.e. water-free) when its calorific value is calculated. As increasing water content decreases its calorific value and hence the consumer of such gas will have been billed for energy not received.

Section 12(2) of the Gas Act 1996 ("the Act") gives a discretion to Ofgem to determine the quantity of water vapour in gas supplied to consumers. Under the Wet Gas Administration Scheme (discontinued by Ofgem in 2003) Ofgem classified gas as being "wet" if the dew point is -26 ^oC or greater, otherwise it is considered to be dry. Gas containing water vapour with a dew point of -26 ^oC causes a billing error of around 0.06%.

In order to explore possible dew temperature specifications, Table 3 shows a number of water content and dew temperatures that can be examined for their impact with respect to the above two considerations, i.e. consumer billing and liquid water formation.

Table 3: Water dew points and concentrations for four alternative specifications

Dew temperature, ^oC Pressure	-10 16 barg	-10 10 barg	-10 7 barg	-26 1 atm	-2 7 barg	-10 2 barg
water content, ppm (molar)	187.60	280.18	378.66	564.82	692.72	979.50
Water dew T (1 atm), ^oC	-36.48	-32.77	-29.91	-26.00	-23.96	-20.41
Water dew T (7 barg), ^oC	-18.67	-13.80	-10.00	-4.76	-2.00	+2.84
Water dew T (10 barg), ^oC	-15.04	-10.00	-6.07	-0.64	+2022	+7.24
Water dew T (16 barg), ^oC	-10.00	-4.71	-0.59	+5.11	+8.12	+13.41

Notes:

1. Water dew temperature at 1 atm calculated using Sonntag equation so as to correspond with Ofgem "wet gas" criterion. All other dew temperatures calculated with the LRS equation of state

2. Dry gas composition 98 mol% CH_4, 2 mol% CO_2

The specifications, in order of increasing water content, correspond to the following water dew temperature specifications:

a) -10°C at 16 barg

b) -10°C at 10 barg

c) -10°C at 7 barg

d) -26°C at 1 atmosphere

e) -2°C at 7 barg

f) -10°C at 2 barg

4 DISCUSSION

A specification of -10 °C at the maximum pressure likely to be encountered in a Gas Distribution system is an obvious alternative specification value to the current one. This maximum pressure could be specified either explicitly (e.g. 2 barg, 7 barg and, in view of potential increase in scope of IGE/TD/3, 10 barg and 16 barg) or implicitly (i.e. "-10 °C at the maximum pressure of the distribution system into which the biomethane is injected").

However, an implicit pressure would mean different specifications for different biomethane entry points and could be construed as not being even-handed. In addition, changes in the system pressure could have impacts on the producer in the future. An appropriate compromise might be to employ an explicit pressure for injection into below 7 bar pressure systems (arguably the majority of biomethane injection projects) and an implicit pressure for injection into above 7 bar systems.

Of the options outlined in Table 3:

a) A specification of -2°C at 7 barg or -10°C at 2 barg gives a higher water content than that corresponding to Ofgem's "wet gas" criterion and would clearly be perceived to disadvantage some consumers.

b) A specification of -26°C at 1 atmosphere would be "just dry" according to Ofgem's criterion and would provide a safety margin of around 4.8 °C from gas at a temperature of 0 °C for gas at 7 barg to prevent liquid formation. However, there would be little margin for additional water ingress to cause consumer billing issues. Moreover, at 10 barg the margin would be just 0.7 °C, so injection into systems above 7 barg (or re-compression back into a higher pressure tier) would need to ensure that there was sufficient dilution to provide adequate safety margin to prevent liquid water formation.

c) A specification of -10 °C at either 7 barg, 10 barg or 16 barg might therefore be appropriate, giving safety margins of 10 °C to prevent liquid water formation. In addition the specifications would result in dew temperatures around 4°C, 7 °C and 10 °C lower, respectively, than Ofgem's "wet gas" criterion.

d) A specification of -10 °C at 16 barg is equivalent to -36.48 at 1 atmosphere and this might be only just attainable with drying systems typically employed in biogas treatment. A specification of -10 °C at 10 barg is equivalent to -4.71 °C at 16 barg, which still provides a reasonable safety margin to prevent liquid water formation should gas be injected into (or recompressed back into) a future 7-16 barg distribution system.

e) Calculated water dew temperatures are sensitive to the equation of state, so the equation of state to be used should accompany the specification. A simpler specification would be to simply state a maximum water content, such as 280 ppm (molar) for a future above 7 barg distribution system, or 390 ppm (molar) for a below 7 barg distribution system.

5 CONCLUSIONS

1. Typical NTS water dew temperature specifications are more stringent than required for gas distribution systems.
2. A more appropriate specification would be to require:
    a. water dew temperature to be no greater than -10 °C at 7 barg for injection into below 7 barg distribution systems, or

b. water dew temperature to be no greater than -10 ^{o}C at the maximum anticipated pressure for injection onto an above 7 barg (7-16 barg) distribution system

An equation of state to be used in calculating the water dew temperature should accompany any specification. The current equation employed by NG NTS, and in the calculations report here, is the LRS equation of state and is recommended.