

# **GAS DETECTION OF HYDROGEN/NATURAL GAS BLENDS IN THE GAS INDUSTRY**

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## **ABSTRACT**

A key element in the safe operation of a modern gas distribution system is gas detection. The addition of hydrogen to natural gas will alter the characteristics of the fuel and, therefore, its impact on gas detection must be considered. It is important that gas detectors remain sufficiently sensitive to the presence of hydrogen and natural gas mixtures, and that they do not lead to false readings.

This paper presents analyses of work performed as part of the Office for Gas and Energy Markets (OFGEM) funded HyDeploy project, on the response of various natural gas industry detectors to blended mixtures up to 20 volume percent (vol%) of hydrogen in natural gas. The scope of the detectors under test included survey instruments and personal monitors that are used in the gas industry. Four blend ratios were analysed (0, 10, 15 and 20 vol% hydrogen in natural gas). The laboratory testing undertaken investigated the following:

- Flammable response to blends in the ppm range (0-0.2 vol%);
- Flammable response to blends in the lower explosion limit range (0.2-5 vol%);
- Flammable response to blends in the volume percent range (5-100 vol%);
- Oxygen response to blends in the volume percent range (0-25 vol%); and
- Carbon monoxide response to blends in the ppm range (0-1000 ppm).

Catalytic and thermal conductivity based flammable detectors in the volume percent range are, as expected, affected in the form of a relative increase in output. All of the carbon monoxide detectors tested were found to be cross-sensitive to hydrogen in the blended mixtures tested at levels which have the potential to cause false alarms at current permissible leakage rates.

In summary, a number of measurement ranges across multiple detectors commonly used in the gas industry have been found to be cross-sensitive to hydrogen in natural gas blends to differing degrees. This required the HyDeploy project to select alternative instruments for the purpose of gas detection as part of the trial. This paper relates to the preparatory work to introduce hydrogen into the Keele closed network.

## **INTRODUCTION**

Concerns relating to the production of carbon dioxide (CO<sub>2</sub>) and its effects on global background temperatures have led to international efforts to reduce CO<sub>2</sub> emissions. One of the main contributors to CO<sub>2</sub> emissions is the burning of fossil fuels supplied for domestic and commercial heating applications. The most significant applications involve the burning of natural gas (NG), which is comprised primarily of methane (CH<sub>4</sub>). HyDeploy [1] is a demonstration project funded by OFGEM, Cadent and Northern Gas Networks to establish the feasibility of supplementing NG supplies with hydrogen (H<sub>2</sub>), which when combusted, does not produce CO<sub>2</sub>. As gas fired heating is used in the majority of UK households, the reduction of CO<sub>2</sub> emissions achieved by H<sub>2</sub> injection in a number of country-wide locations would allow the UK to contribute positively to a reduction in a gas linked to global warming. With a view to helping achieve this reduction in CO<sub>2</sub> emissions, a consortium formed of Cadent, Northern Gas Networks, the Health and Safety Laboratory (HSL), ITM Power,

Progressive Energy and Keele University have worked together to study the feasibility of injection of up to 20 vol% H<sub>2</sub> into the natural gas supply. Previous work by the Health and Safety Executive (HSE) indicates that this level of hydrogen injection will not cause a significant change to the risk to people or equipment [2]. This work forms part of a larger body of research investigating the fundamental properties of NG and NG/H<sub>2</sub> blends, this is pertinent to supporting the application to the HSE for an exemption to the Gas Safety (Management) Regulations (GS(M)R), for the safe use of NG/H<sub>2</sub> blends containing up to 20 vol% H<sub>2</sub> in NG within a demonstration scheme at Keele University. An exemption to GS(M)R is required as the current maximum permitted level of H<sub>2</sub> in NG is 0.1 vol%.

The Role of Gas Detection: Gas detection instruments are widely used to assess the presence of dangerous atmospheres. The way these are used varies by gas distribution network (GDN). Any changes due to gas composition will most likely affect procedures rather than the quantitative risk assessment (QRA). The aim of the pre-deployment phase of HyDeploy for gas detection was to understand:

- If the addition of H<sub>2</sub> up to 20 vol% in NG will cause current gas detection instruments to display uncorrected readings; and
- What measures might be needed to ensure accurate readings.

A key element in the safe operation of a modern GDN is gas detection. During the HyDeploy project the addition of H<sub>2</sub> to NG has been predicted to alter the characteristics of the blended gas relative to the pure constituents and the impact on gas detection must be considered. It is clearly important that detectors for any component (e.g. oxygen (O<sub>2</sub>), carbon monoxide (CO)) remain sufficiently sensitive and selective in the presence of H<sub>2</sub> and NG mixtures, so that they do not undermine the integrity of procedures.

Instruments for gas detection can be divided into two basic categories, ‘portable’ and ‘fixed’:

- PORTABLE instruments, can be further subdivided into:
  - Survey instruments – intended for quantitative assessment and location of gas escapes;
  - Personal safety monitors – intended to protect staff from dangerous atmospheres.
- FIXED instruments, which can be subdivided into:
  - Domestic monitors – intended for use in the home with the public;
  - Plantroom monitors – provide multiple alarm levels and can isolate gas supplies.

In most cases each type of instrument will need to respond to three target gases: CO, NG and O<sub>2</sub> deficiency. For the purposes of instrument assessment, CH<sub>4</sub> has been used as a chemical analogue of NG as it forms the main constituent of NG and can be purchased to a recognised standard and purity (whereas NG can vary significantly depending on supply).

Commercially available gas detectors can use a number of different measurement technologies depending on the gases of interest. Most gas detectors have an interaction with one or more gases that are not the target gas so selection is critical to ensure accurate reading of a target gas. Of particular relevance to this work is that electrochemical CO, catalytic and thermal conductivity detectors are known to be sensitive to H<sub>2</sub> to various degrees. The levels of sensitivity can vary hugely depending on the exact sensor used and how it is implemented. Table 1 shows the common gas sensor technologies and a guide to the range of concentration values that can be measured and some potential problems.

Table 1: Gas sensor mechanism attributes

Gas Sensor Technology	Sensitive to NG	Sensitive to H <sub>2</sub>	Typical Range	Notes
Catalytic [3]	Yes	Yes	0-100% LEL*	Can be poisoned by non-target gases Can give false reading above LEL
Thermal conductivity [4]	Yes	Yes	0-100% LEL 0-100 vol%	Accuracy is dependent on the composition of the background gas
Semiconductor [5]	Yes	Yes	0-0.5 vol%	Can be poisoned by non-target gases Non-linear response

Flame ionisation [6]	Yes	No	0-0.1 vol%	A very linear detector
Infra-red (IR) absorption [7]	Yes	No	0-100% LEL 0-100 vol%	Completely insensitive to H <sub>2</sub>
Electrochemical [8]	No	Yes	0-100% LEL	Very slow response
*Lower Explosive Limit (LEL)				

## METHODS

In order to assess the response of various gas detectors that are used on the UK gas network, a programme of testing was performed. This can be categorised into:

- i. Low concentration (<600 ppm) H<sub>2</sub> testing with a CO exposure baseline test;
- ii. Flammable blend testing at the LEL range (0-4.0 vol%) - 0, 10, 15 and 20 vol% H<sub>2</sub> in CH<sub>4</sub>; and
- iii. Flammable blend testing at the volume range (0-100 vol%) - 0, 10, 15 and 20 vol% H<sub>2</sub> in CH<sub>4</sub>.

Several gas detection instruments were tested, focussing primarily on portable instruments that may be used by first call operatives during the trial at Keele. Table 2 details the ranges and sensor technologies used for each detector within each instrument. Three instruments of each type were tested for repeatability. The instruments' makes and models have been anonymised. Fixed detectors were tested as part of early scoping tests and indicative results obtained. A detailed review of these devices is not included in this paper; however, the technologies overlap considerably with those of the portable instruments. All instruments tested were calibrated and were bump tested at the start of each day to confirm the calibrations. Additional bump tests were also performed after certain test regimes to assess effects of the test gases on the detectors. It is of note that different instruments utilise different ranges for the LEL of NG, some take 5.0 vol% and others take 4.4 vol% as 100% LEL. It was subsequently found that GDNs use instruments with different LEL ranges, therefore introducing baseline variability in operations.

Table 2: List of instruments under test including gas ranges and sensing technology

Instrument Type	Instrument Reference	Gas/Ranges Tested	Sensor Technology	Comments	
Survey Equipment	A	0-40,000 ppm NG	Catalytic		
		0-100% LEL NG	Catalytic	100% LEL = 5.0 vol%	
		0-100 vol% NG	Thermal conductivity		
		0-2000 ppm CO	Electrochemical		
		0-40 vol% O <sub>2</sub>	Electrochemical		
	B	0-1000 ppm NG	Semiconductor		
		0-100% LEL NG	Catalytic	100% LEL = 4.4 vol%	
		0-100 vol% NG	Thermal conductivity		
		0-1000 ppm CO	Electrochemical		
	C	0-1000 ppm NG	Semiconductor		
		0-100% LEL NG	Catalytic	100% LEL = 5.0 vol%	
		0-100 vol% NG	Thermal conductivity		
		0-1000 ppm CO	Electrochemical		
		0-25 vol% O <sub>2</sub>	Electrochemical		
	D	0-2650 ppm NG	Semiconductor		Range nominally 1000 ppm
		0-100% LEL NG	IR		100% LEL = 4.4 vol%
0-100 vol% NG		IR			
0-25 vol% O <sub>2</sub>		Electrochemical			
Personal Monitor	E	0-100% LEL NG	Catalytic	100% LEL = 4.4 vol%	
		0-1000 ppm CO	Electrochemical		
		0-25 vol% O <sub>2</sub>	Electrochemical		

Low concentration tests were performed by flowing H<sub>2</sub> gas at concentrations between 0-600 ppm in air across a manifold connected to the instruments under test. The intention of these tests was to understand the concentration of H<sub>2</sub> required to trigger nuisance alarms on CO detectors, although the testing also provides data on flammable detector response at the ppm range. This method of using H<sub>2</sub> rather than a blend was chosen as the CO detectors were found to be totally insensitive to NG and it enabled a wider gas range to be tested with the same equipment. A further test was also performed using 200 ppm CO in air to assess whether any potential cross-sensitivity was present within the flammable ppm detectors. The test set-up relies upon calibrated span<sup>1</sup> gases of H<sub>2</sub> in air and CO in air and then dilutes them with air using mass flow controllers accurate to  $\pm 0.1\%$  of full scale. Additional measurements of ambient temperature and pressure were taken for completeness at the start of each test series. The test set-up was designed to feed gas at a constant flow rate (10 l/min) through an open-ended tube with a teed manifold for the test instruments. It was designed to ensure no pressurisation of the internal tubing occurs and that the flow rate is sufficient to feed gas to each instrument without drawing fresh air in through the exit. This is a potential problem as each instrument has a pump. It was therefore verified using a rotameter that there was a positive flow exiting the release system at all times.

A second test set-up was used in order to assess the effect of blended mixtures of H<sub>2</sub> and CH<sub>4</sub> in air across the LEL and vol% range. The aim of this testing was to generate a wider dataset across both measurement ranges for multiple instruments whilst also assessing reliability and repeatability of measurements. The test set-up was similar to that used for the ppm H<sub>2</sub> tests; however, the test gases were CH<sub>4</sub>, H<sub>2</sub> and air rather than span gases. These test gases were high purity (99.5% pure) and dried to remove any water which may have an effect on the detectors.

## RESULTS

Figure 1 shows the relative responses of each instruments' CO detector to low levels of H<sub>2</sub>; instrument D is not included as it had no CO detector fitted. Keele University's CO action levels of 10, 30 and 200 ppm have been included for reference. These are based around National Grid's procedures [9] and the UK HSE's workplace exposure limits [10], although these have subsequently been reduced [11].

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<sup>1</sup> The term 'span gas' refers to a calibrated gas mixture which has been pre-mixed and certified as such.

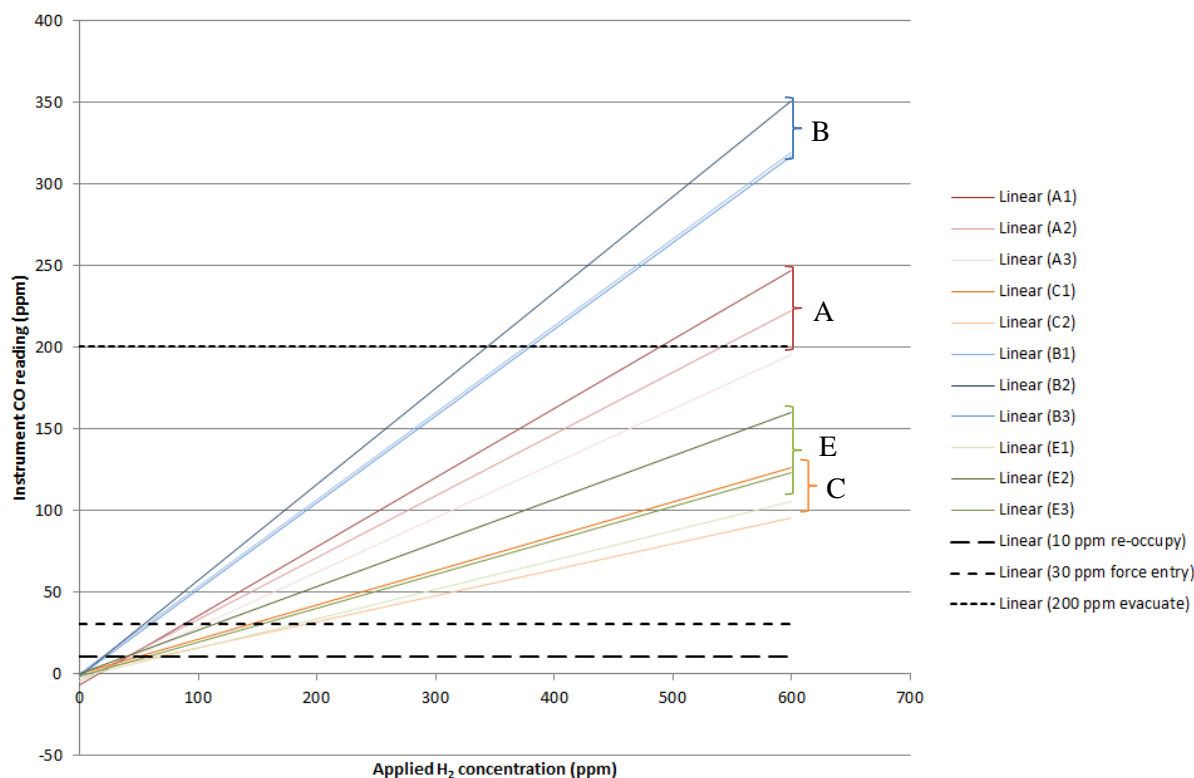


Figure 1: CO detector response to H<sub>2</sub>

In summary: all of the instruments' CO detectors are significantly cross-sensitive to H<sub>2</sub>; some of the flammable detectors are cross-sensitive to CO; no O<sub>2</sub> detector tested showed any cross-sensitivity to ppm levels of CO or H<sub>2</sub>; all CO detectors saturated when exposed to high levels (>1 vol%) of blended gas; detectors required recovery times in hours before passing a bump test; and no long-term desensitisation was observed after 24 hours in clean air.

Results from the LEL detector testing showed that all of the instruments tested exhibited a small increase in relative detector output (≈6% for all blends tested) when exposed to a blend with the exception of instrument D. D exhibited a relative decrease in output proportional to the increase of H<sub>2</sub> in the blend. This difference in response is expected as the majority of the instruments (A, B, C and E) use a catalytic detector for the LEL which is known to increase in output with the blend [3] and instrument D uses an IR detector which is blind to H<sub>2</sub>, thus creating a relative decrease in output. In order to counteract the effects that the blend has on gas detector readings, a 'correction factor' can be used. This factor allows the user of an instrument to convert the measured output from an instrument, taking account of the variation in the gas being measured, to maintain an accurate (actual) reading. In this case the correction factor would counteract the difference caused by the blends in comparison with CH<sub>4</sub>. Three correction factors can be used to counteract three separate effects:

- i. The LEL physically changes with the addition of H<sub>2</sub> to CH<sub>4</sub> for blended mixtures;
- ii. The LEL range that the instruments are calibrated to differ between 4.4 vol% and 5.0 vol% [12] for NG/CH<sub>4</sub> depending on the standard taken; and
- iii. The instruments' outputs are affected differently by the H<sub>2</sub> content of the H<sub>2</sub>/CH<sub>4</sub> blends.

### ***Correction Factor – Blend***

Whilst the relative outputs of the instruments' LEL detectors change with increasing blend concentration, so does the actual LEL of the given blended mixture. This is because the LEL of H<sub>2</sub> (4.0 vol% [12]) is lower than CH<sub>4</sub><sup>2</sup> (4.4 vol% [12]), so the greater the concentration of H<sub>2</sub>, the more

<sup>2</sup> CH<sub>4</sub> is the gas used for testing as an analogue to NG and therefore 4.4 vol% is taken as the LEL.

influence this has. Table 3 shows the associated correction factor for the LEL of the different blended mixtures calculated using Le Chatelier's rule [13].

Table 3: Correction factors due to the physical LEL change from blended mixtures

H <sub>2</sub> in CH <sub>4</sub> (%) ratio	LEL based on Le Chatelier (vol%)	Blend correction factor
0	4.40	1.000
10	4.36	1.009
15	4.33	1.016
20	4.31	1.021

Actual LEL = Instrument reading x correction factor

#### **Correction Factor – Range**

As well as a correction factor for the physical LEL change from H<sub>2</sub> addition, further correction due to the relative difference in pre-set LEL range may be required. This is due to the fact that different instruments are calibrated to different LEL ranges (4.4 vol% and 5.0 vol%) even by the same manufacturers. This could be normalised using a correction factor but a common value should really be agreed and implemented to avoid unnecessary confusion. Due to this it has been excluded from this paper.

#### **Correction Factor – Instrument Response**

A final correction factor is then required based solely on the effect the H<sub>2</sub> in the blend has on each instruments' output. If the concept of LEL is ignored, this is the only correction which would need to be made. These H<sub>2</sub> correction factors are shown in Table 4 for different blend levels along with a summary of the total correction required.

Table 4: Correction factors due to variation in instrument response to blended mixtures

Instrument Reference	Blend ratio of H <sub>2</sub> in CH <sub>4</sub> (vol%)	Blend factor	Instrument response	Final correction factor
A	0	1.000	1.000	1.000
	10	1.009	0.947	0.956
	15	1.016	0.954	0.970
	20	1.021	0.938	0.958
B	0	1.000	1.000	1.000
	10	1.009	0.977	0.986
	15	1.016	0.994	1.010
	20	1.021	0.922	0.941
C	0	1.000	1.000	1.000
	10	1.009	0.974	0.983
	15	1.016	0.978	0.994
	20	1.021	0.951	0.971
D	0	1.000	1.000	1.000
	10	1.009	1.149	1.160
	15	1.016	1.147	1.165
	20	1.021	1.282	1.309
E	0	1.000	1.000	1.000
	10	1.009	1.014	1.023
	15	1.016	0.972	0.987
	20	1.021	0.957	0.977

Actual LEL = Instrument reading x correction factor

Example: Instrument A was used to measure the LEL of a 20% blended gas mixture at 2.00 vol% in air and gave an instrument reading of 42.6% LEL. In order to get the corrected value, the instrument reading must be multiplied by the corresponding final correction factor to get:

$$42.6\% \times (0.958) = 40.8\% \text{ LEL}$$

Testing across the flammable vol% range showed that nearly all of the instruments exhibited an appreciable increase in detector output due to the addition of H<sub>2</sub> in CH<sub>4</sub> as a blend (≈+1.5% output per 1% increase in H<sub>2</sub> in the blend). The only exception to this was instrument D, which displayed a linear decrease in output with increasing blend concentration (≈-1% output per 1% increase in H<sub>2</sub> in the blend introduced). Instrument E does not have a vol% range and has been excluded. In order to quantify the level of cross-sensitivity of the flammable volume detectors to the blend, a fit has been performed on the averaged data. For instruments A, B and C this fit is a 2nd order polynomial when a blend is introduced. Instrument D displays a linear fit with blend addition. This difference in detector response is due to the difference between the output of thermal conductivity and IR technology. Table 5 shows the individual instrument correction factors derived from the lines of best fit for each blend ratio and an example of the instrument output if a 50 vol% gas in air mixture is applied at different blend ratios.

Table 5: Correction factors for determining change in instrument flammable volume output for blends of H<sub>2</sub> in CH<sub>4</sub>

Instrument Reference	Blend ratio of H <sub>2</sub> in CH <sub>4</sub> (vol%)	Instrument correction factor (x = instrument reading)	Example instrument output at applied gas concentration of 50 vol%
A	0	0.984x	51
	10	0.00008x <sup>2</sup> + 0.7455x	68
	15	-0.0007x <sup>2</sup> + 0.7242x	74
	20	-0.0006x <sup>2</sup> + 0.6637x	81
B	0	0.9914x	51
	10	-0.0015x <sup>2</sup> + 0.9275x	60
	15	-0.0025x <sup>2</sup> + 0.9198x	67
	20	-0.0026x <sup>2</sup> + 0.8787x	74
C	0	0.982x	51
	10	-0.0022x <sup>2</sup> + 1.0269x	56
	15	-0.0049x <sup>2</sup> + 1.1565x	59
	20	-0.0051x <sup>2</sup> + 1.1309x	65
D	0	0.9697x	52
	10	1.0668x	47
	15	1.1356x	44
	20	1.1982x	42
Actual gas concentration = Instrument reading x correction factor			

Example: If instrument A was used to measure the 20% blended gas mixture at 50 vol% in air it would give an instrument reading of 81%. In order to get the corrected value and hence the actual % the instrument reading must be substituted into correction factor equation to get:

$$-0.0006 \times (81^2) + 0.6637 \times 81 = 49.8\%$$

Results from testing of the O<sub>2</sub> detectors with flammable blends across the ppm, LEL and vol% ranges showed little-to-no cross-sensitivity to blended mixtures of H<sub>2</sub> and CH<sub>4</sub>.

### IMPACT OF FINDINGS ON HYDEPLOY

In order to understand how the results of the testing impact on HyDeploy and the trial at Keele, it is necessary to understand what scenarios the detectors may be used for. A summary of the scenarios where current gas network procedures mandates the use of gas detection are summarised in Table 6.

Table 6: Impact of findings on HyDeploy

Scenario	Issue for current detectors?
Indoor CO leak	No
Indoor leak of blended gas at current permissible leakage rates	Possibly, false CO alarms may occur although it's difficult to estimate dispersion, room volumes and air change rates

Scenario	Issue for current detectors?
Indoor leak of blended gas up to evacuation level (20% LEL)	Yes, cross-sensitivity of CO detectors to blends will cause false alarms/evacuations
Indoor leak of blended gas and CO	Yes, can't distinguish between them so false alarms/evacuations may occur
Outdoor leak of blended gas or NG	Possibly, blend percentage won't be known so difficult to get accurate instrument reading but will get a detect/no-detect reading
Confined space entry	No
Purging of pipework	Yes, incomplete purging from air to gas may occur due to blend increasing instrument reading

In order to assess whether these concentrations might lead to false CO alarms and action levels being reached, an assessment of gas dispersion based on a set leakage level can be performed. For the purposes of this assessment, the maximum permissible leakage rates (MLPR) for NG [14] for two different domestic room sizes and ventilation rates are provided as an example [15]:

- A large well-ventilated room, with a volume of 22 m<sup>3</sup>, a ventilation rate of 2.5 air changes per hour (ach) and a maximum NG leakage rate of 1.1x10<sup>-2</sup> m<sup>3</sup>/hr would give rise to a maximum homogeneous H<sub>2</sub> concentration of 40 ppm (200 ppm of H<sub>2</sub>/CH<sub>4</sub> for a 20% blend);
- A small poorly-ventilated room, with a volume 12.4 m<sup>3</sup>, a ventilation rate of 0.5 ach and a maximum NG leakage rate of 6.2x10<sup>-3</sup> m<sup>3</sup>/hr would give rise to a maximum homogeneous H<sub>2</sub> concentration of 200 ppm (1000 ppm of H<sub>2</sub>/CH<sub>4</sub> for a 20% blend).

Table 7 shows whether a false CO alarm is possible based on the two scenarios for each instrument assuming, a 20 vol% blend is used, and a leak occurs at the MLPR.

Table 7: False CO alarm possibility based on 20% blend leakage indoors at the MLPR

Instrument Reference	CO Trigger Action Level (ppm)					
	10	30	200	10	30	200
	A large well-ventilated room			A small poorly-ventilated room		
<b>A</b>	✓	✗	✗	✓	✓	✗
<b>B</b>	✓	✗	✗	✓	✓	✗
<b>C</b>	✗	✗	✗	✓	✓	✗
<b>D</b>	✗	✗	✗	✓	✓	✗
	✓ indicates a false alarm is possible					
	✗ indicates a false alarm is unlikely					

Based on Table 7 it is possible that, for a large well-ventilated room, the 10 ppm CO level (re-occupation after a confirmed leak) may be triggered on instrument A and B based on the theoretical room size and ventilation rate. For a small poorly ventilated room, the higher 30 ppm CO level (force entry to premises to investigate) may be triggered on all instruments tested. The implications of this for fixed domestic detectors is that they may be more likely to suffer false alarms in the event of acceptable leakage of a 20% NG blend in small poorly-ventilated rooms as their alarm level is typically a time-averaged 30 ppm.

A common leak scenario indoors is a gas escape which leads to an ever increasing gas level within a room or property. Once this level reaches 20% of the LEL it becomes actionable to evacuate the property. It is therefore important to know how a blend will affect detectors before this evacuation level is reached, i.e. will cross-sensitivities or offsets in output cause false-readings leading to unsafe or early evacuations. The first issue to consider is that all of the instruments tested displayed significant levels of CO cross-sensitivity to H<sub>2</sub>, the level of which is shown in Table 8 for the different



CO action levels. The table also shows which concentrations could be detected by odour, based on the effective olfactory detection level<sup>3</sup> for NG at current levels [16].

Table 8: H<sub>2</sub> and 20% blend concentrations in air required to trigger CO action levels

Instrument Reference	CO Trigger Action Level (ppm)		
	10	30	200
	Concentration of 20 vol% H <sub>2</sub> in CH <sub>4</sub> blend gas to trigger alarm (ppm)		
A	202	469	2740
B	101	283	1832
C	278	830	5524
E	274	746	4756
	Leak is below effective odorant level and may not be smelt		
	Leak is above effective odorant level and should be smelt		

Table 8 shows that with current odourisation levels, a leak of flammable gas could trigger a CO alarm before any smell is detectable by the human nose. The second issue is the accuracy of LEL detection for blends being affected by the H<sub>2</sub> component. For catalytic-based detectors, the relative difference is minimal and also conservative from a safety perspective, i.e. a blend would cause the instrument to alarm at a lower flammable gas level. The opposite is true of an IR detector, i.e. a blend would only cause the instrument to alarm at a higher flammable gas level. This does not preclude the use of IR technology but would mean that recalibration of the LEL level would be needed. Figure 2 highlights the minimal effect on LEL of the blend for catalytic-based instruments (A, B, C, E), and the greater effect on IR-based instruments (D) assuming the instruments' LEL ranges are set the same (i.e. 5.0 vol%).

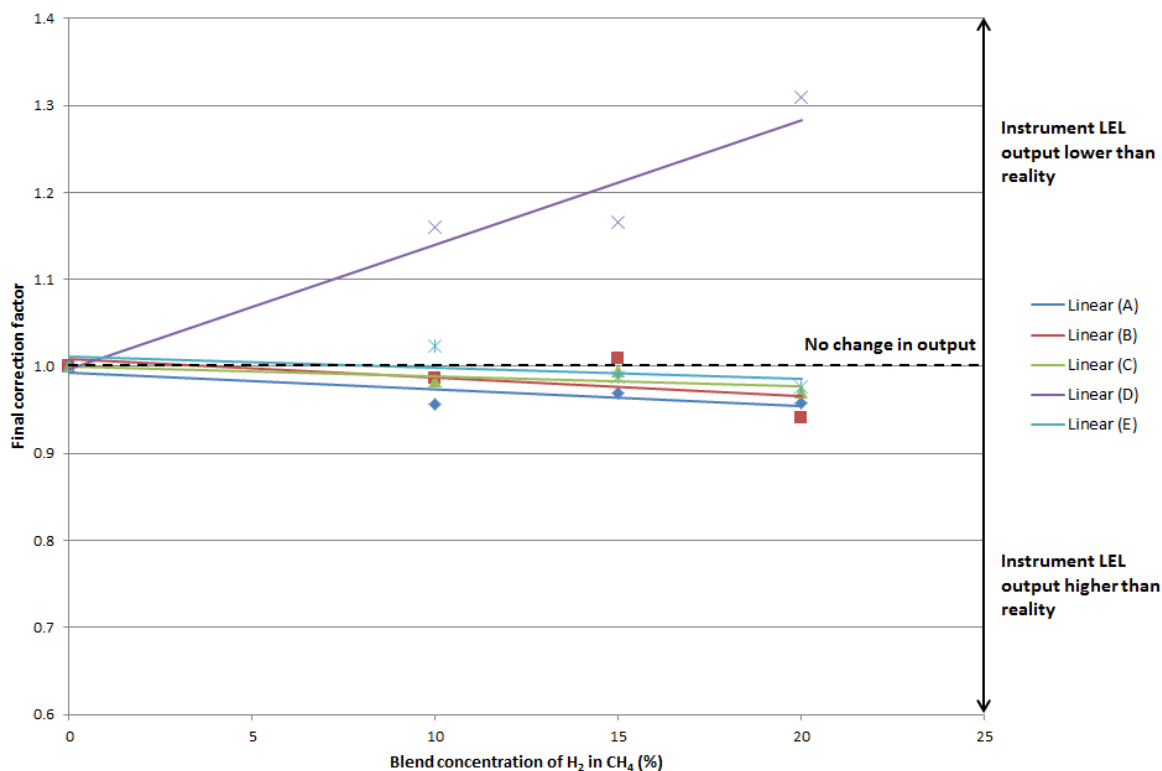


Figure 2: Flammable LEL correction factors based on H<sub>2</sub> content

<sup>3</sup> The effective odorant level requires an odour intensity of 2° (i.e. olfactory degree providing 99% certainty of detection) at 20% LEL for NG (1% NG in air). This equates to an H<sub>2</sub> concentration level (20% blend in NG) of 1% x 20% = 0.002% or 2000 ppm.

An example for instrument A: If a 5.0 vol% is assumed for the baseline LEL, accounting for the blend reduces LEL. If you then account for the fact that the instrument over-reads with a blend, this results in an increase in LEL. Hence:  $5.0 \text{ vol\%} \times 0.958 = 4.79 \text{ vol\%}$  (96% LEL).

It was found that with the instruments tested it was not possible to differentiate between an NG blend and a combined CO and H<sub>2</sub>/NG blend. In theory a compensation could be made to calculate the proportion of the CO measurement that is due to the cross sensitivity, thus allowing the distinction to be made. However, the reliability and practicality of such a method is outside the scope of this work. Although this scenario of a dual gas leak seems unlikely it cannot be ruled out, therefore another technique would be needed to identify such a leak. One possible method would be to use a CO detector which is not cross-sensitive to NG blends (i.e. the H<sub>2</sub> component).

In an outdoor setting, the flammable detection levels required would initially be in the ppm range. If ppm levels are detected they would not be accurate for a blend. However, all instruments tested would provide a means of a YES/NO to whether gas is present, at which point the leak would be investigated further by a process known as bar-holing which involves pushing a probe into the ground. If bar-holing is undertaken subsequently, LEL or vol% ranges may be encountered, in which case a YES/NO gas presence may still be sufficient although accuracy issues may need to be mitigated. Perhaps the biggest issue would be saturating any CO detector with high concentrations of blend i.e. LEL range and above leading to long term damage or de-sensitisation.

Purging is required when maintenance is needed on gas mains. This either involves purging from gas-to-air, or air-to-gas when putting the main back into service. Gas-to-air does not present a particular issue as current detectors would still function safely for a blend; however, air-to-gas requires accurate vol% measurement. The issue is at vol% levels the cross-sensitivity error caused by the addition of H<sub>2</sub> in the blend is significant, Figure 3. A thermal conductivity-based instrument would reach 100 vol% before complete purging has occurred in reality and could create a safety issue. To maintain accuracy in thermal conductivity based instruments (A, B and C), correction factors coupled with an accurate measure of the H<sub>2</sub> concentration of the blend would be needed. An IR instrument on the other hand would never reach 100 vol% when in reality the pipework would be fully purged. An IR-based instrument (D) could be used assuming a reduced pre-set minimum value of gas-in-air is taken, rather than the 95 vol% currently used.

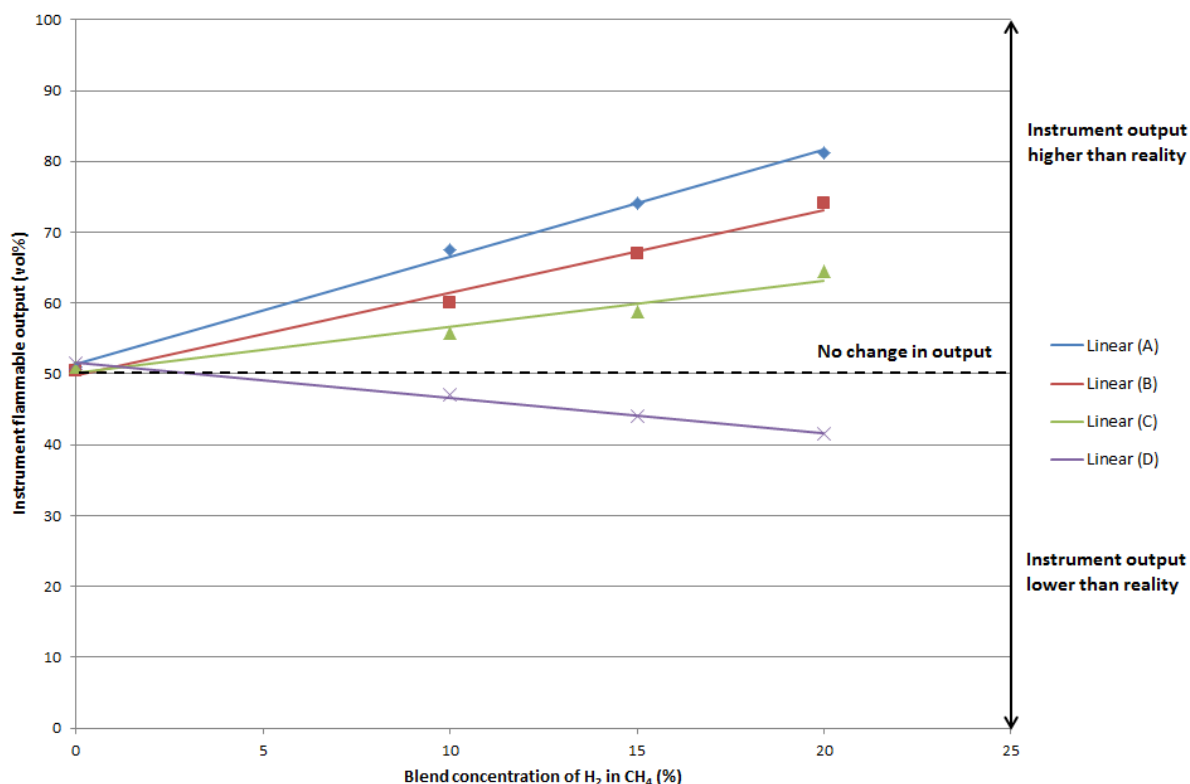


Figure 3: Flammable volume instrument output with 50 vol% flammables applied

## CONCLUSIONS

In order to assess the issues created by adding up to 20 vol% H<sub>2</sub> to NG in the gas grid and for the trial at Keele University, a number of test programmes were undertaken at HSL. Although cross-sensitivities of sensor technologies to H<sub>2</sub> is well-known, the aim of this work was to understand the extent of these effects and subsequently how they could be mitigated without significant changes to equipment or procedures.

In order to counter the considerable issue of CO detector cross-sensitivity, an H<sub>2</sub> compensated CO detector in a standalone portable personal instrument is to be used. A maximum CO cross-sensitivity to H<sub>2</sub> of  $\leq 1.5\%$ <sup>4</sup> is required, i.e. if the sensor is exposed to 100 ppm of hydrogen, it should read a maximum of 1.5 ppm of CO. This solution is primarily because CO detection technologies which are not affected by H<sub>2</sub>, i.e. FTIR, are not portable or sensitive enough currently. Current domestic fixed CO detectors will remain unchanged with the possibility of false alarms, again primarily because there are no known compensated domestic CO detectors.

In terms of flammable leak detection an IR based instrument has been chosen with an LEL calibrated for a worst-case blend concentration, i.e. LEL = 3.7% for 20 vol% H<sub>2</sub> in NG. This is a conservative approach to achieve the minimal changes to procedures and to allow the use of a single instrument for all ranges of flammable measurement. Although catalytic-based detectors would be conservative at the LEL range, issues with over-reading during purging have precluded their use. For thermal conductivity-based detectors to be suitable would need to independently identify H<sub>2</sub> composition of gas to get correct flammable reading.

<sup>4</sup> 1.5% is based on a CO action level of 30 ppm and an assumed maximum blend of 20 vol% H<sub>2</sub> in NG at 20% LEL; i.e. 20% LEL = 1 vol% = 10,000 ppm. 20% of 10,000 ppm blend = 2000 ppm H<sub>2</sub>. 30 ppm / 2000 ppm x 100 = 1.5% allowable cross sensitivity.

The original backstop was to use bottled NG when purging operations are required; however, this is not ideal in the long term so an alternative procedural approach has been chosen based on a reduced gas-in-air value using an IR-based vol% instrument. This ensures a conservative purging regime which cannot exceed a displayed 100% by the instrument.

If H<sub>2</sub> blending into the NG grid is to be considered, development of gas detectors is required to ensure the continuing safety of users and operators. The solutions proposed for the trial at Keele are designed to be safe, but in some cases are more conservative than ideal due to the lack of options available on the market. The following points outline the challenges for instruments in the future:

- A CO detector that can be incorporated into a portable instrument and is sufficiently compensated/insensitive to H<sub>2</sub> such that no provision needs to be made even at the vol% range;
- A domestic fixed CO detector which is sufficiently compensated/insensitive to H<sub>2</sub>;
- Flammable detectors across the ppm, LEL and vol% range which can make accurate flammable measurements accounting for variability in the blend and the subsequently changing LEL;
- An ability to measure the concentration of H<sub>2</sub> and adjust calibrations accordingly, to allow accurate use across both NG and blended networks; and
- Instruments need to be suitably ATEX rated for the maximum H<sub>2</sub> concentration to be encountered. It should be noted that the ATEX gas group for <25 vol% H<sub>2</sub> blend with NG remains as IIA up to 25 vol%. Pure H<sub>2</sub> has an ATEX gas group of IIC [17].

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