

# Comparing subsurface migration of LPG with natural gas

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# Comparing subsurface migration of LPG with natural gas

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A programme of experiments assessed differences in behaviour between leaks of natural gas and Liquefied Petroleum Gas (LPG) from buried pipes, to inform opinion on whether an existing (Advantica) model of the risks from buried natural gas pipework could be useful in assessing the risks associated with buried metallic LPG pipes.

In experiments with two different soil types, LPG or natural gas was injected at a fixed position and samples were then taken from a number of points below and at the surface. The effect of covering the surface was also assessed. Both LPG and natural gas migrated away from the leak into the surrounding soil, gas being detected both above and below the release point and reaching the surface quite quickly. This showed the importance of pressure differences in driving the flow.

In sand, with uniform porosity, LPG was seen to migrate more quickly than natural gas, needing a substantially shorter time to reach a hazardous concentration. In soil with larger, less regular pores, differences in buoyancy were more apparent, and the results showed much more variability.

It was concluded that the Advantica model included the appropriate processes, but that the model would need to be carefully modified to account for the differences in LPG and natural gas behaviour before being used in any prioritisation of LPG pipe replacement.

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# EXECUTIVE SUMMARY

## Objectives

A programme of experiments were carried out to assess whether an existing model of the migration of natural gas through various soil types (the 'Advantica model') could be useful in assessing some of the risks associated with subsurface leaks of Liquefied Petroleum Gas (LPG) from damaged pipes.

Two different soil types were examined in moderate scale experiments. In each experiment, LPG or natural gas was injected at a fixed position and the progress of gas spreading observed by measuring samples taken from a number of points below and at the surface.

As well as the two soil types, the effect of covering the surface (as would be the case with paved areas) was also assessed.

The experiments were designed to minimise any differences other than the gas being assessed.

## Main Findings

With both LPG and natural gas there was a migration away from the point of leakage into the surrounding soil. Gas was detected both above and below the release point, reaching the surface area quite quickly for both natural gas and LPG.

In a sand-based substrate with small scale, evenly distributed porosity, LPG was seen to migrate more quickly through the soil than natural gas. When combined with the smaller volume fraction of gas needed to reach the lower flammable limit for LPG, this gave a substantially shorter time to reach a hazardous concentration.

In a loam-based topsoil, which gave more broken ground with larger, less regular pores, the differences in buoyancy were more apparent. Natural gas spread out through the soil and up to the surface. LPG spread to impermeable walls at the sides and below the leak and then percolated rapidly across these walls, rising to the surface levels. Results in this substrate showed much more variability.

## Recommendations

For the existing natural gas data to be useful for LPG, care needs to be taken to include appropriate factors for the faster LPG movement.

In broken ground or where other spaces exist which might channel gas, it is likely that gas movement (whether LPG or natural gas) will be dominated by flow along such channels.

It was concluded that the 'Advantica model' included the appropriate processes, but the model should be carefully modified to account for the differences in LPG and natural gas behaviour before being used in any prioritisation of LPG pipe replacement.



# 1 INTRODUCTION

Liquefied Petroleum Gas (LPG) is often used in commercial and domestic premises, supplied from a storage tank outside. The pipework connecting the tank to the building frequently runs underground. Modern standards recommend that low pressure underground pipes are made of polyethylene, but previously pipework was often carbon steel usually with an impregnated tape cover ('Densotape').

Underground pipework has a limited lifetime, and it is recognised that the older pipes in service in the UK may be reaching the point where they need to be replaced.

UKLPG (the trade body for LPG supply companies) and their most active members are aware of the need for a replacement programme for metallic underground pipes, and are seeking to prioritise this replacement to minimise the risk of failure through corrosion.

Such prioritisation will probably depend on three factors:

- the likely age of the installation – with older pipes having higher priority,
- the likelihood of harmful corrosion – with those areas where the soil type might give faster corrosion rates having higher priority
- the likelihood of hazardous consequences from a release – with those areas where gas escapes might be difficult to detect or could quickly travel into buildings having higher priority.

The soil type affects the latter two factors.

Similar concerns affect underground pipes distributing natural gas, and significant work has been undertaken to understand the corrosion of natural gas pipework in different environments and the way in which natural gas migrates through different soil types. This led Advantica to carry out the experimental test work and development needed to create a model of pipework and gas behaviour in a range of different soil types. When this was combined with data on local soil types and local pipework history it allowed the relative risk of a hazardous leak from different areas to be assessed. This was then used to prioritise the natural gas pipework replacement programme.

If this model could be used, either directly or with minor modifications, to assess the relative risks for LPG pipework it would provide a useful tool to prioritise an equivalent replacement programme.

The external corrosion effects will be the same for pipe in similar materials, irrespective of the gas being transported. Data obtained for natural gas pipework is equally relevant to similar LPG pipes.

It is likely that, in the event of a leak, migration through soils will change between different gases. Factors such as gas density, viscosity and diffusion rates will affect the movement of gas and change between different gases. Table 1 below compares these properties for methane and propane – the primary constituents of natural gas and LPG respectively.

**Table 1: Some properties of Methane and Propane**

	Density at NTP (kg/m <sup>3</sup> )	Viscosity at ~20°C (mPa.s)	Diffusion Velocity in air at NTP (mm/s)
Methane	0.717	0.011	5.1
Propane	1.868	0.008	3.4

References: Matheson, Gas Data Book, 6<sup>th</sup> Ed., 1980 & <http://wps.com/LPG/WVU-review.html>

This shows that there could be significant differences between natural gas and LPG behaviour.

In order to assess whether the existing data, primarily for natural gas, on which the Advantica model is based, can also be used to inform LPG risk assessments, a series of experiments have been undertaken comparing the behaviour of propane and methane released in underground leaks.

In order to minimise the number of experiments, a limited number of circumstances were examined. These included just two soil types, two types of ground cover and a single volumetric gas flow rate. Rather than look at LPG or natural gas themselves – these are mixtures with a wide range of potential components - the gases used were commercial grades of methane and propane supplied in cylinders. These were chosen as a single gas will guarantee a smaller variability from cylinder to cylinder.

The experiments were carried out with the soils in large, open-topped boxes. These are described in Section 2.

Initial tests were carried out using instruments on loan from Calor Ltd, which were the type of instruments typically used to detect leaks. Unfortunately, it transpired that these were unsuitable for long term exposure to higher gas concentrations.

The instruments had an automatic shutoff (to prevent battery drain in normal operation) which could not be bypassed for longer exposures. This meant that the instrument could turn itself off with gas in the sample cell, which led to the gas detector element being damaged.

Even if the shut-off could be avoided (by operating one of the controls every 4 minutes or so) and with the instruments flushed with air until a zero reading was seen before turning them off, it was found that the sensors were still being damaged. It is probably that some gas remained in dead spots within the instruments and was able to percolate to the sensor element once the pumped flow was stopped.

Discussions with Calor revealed that they, too, had similar problems with the instruments in the past.

A second set of instruments was hired, and these were used for the tests reported in Section 3. The instruments are described in Section 2.

However, the test work carried out with the Calor instruments provided useful information which was able to make the ‘full’ testing much more efficient.

## 2 EXPERIMENTAL WORK

### 2.1 APPARATUS

Two identical boxes were constructed by HSL workshops from reinforced 25 mm thick plywood. The internal dimensions were: length = 2000 mm, width = 800 mm and depth = 1100 mm

In order to investigate the effect of gas permeation through different substrate, the first box was filled with yellow builders 'sharp' sand, sourced from a local builders merchant and the second with topsoil from the same source. Both were filled with approximately 1.5-2 tons of substrate to a depth of 750 mm for sand and 820 mm for soil, leaving wall heights of 350 mm and 280 mm, respectively, above the substrate surfaces.

A single sheet of 20 mm thick plywood was used as a cover or shutter for the box, cut to be a close fit inside the boxes when resting on the substrate surface. The sheet was further cut into sections to facilitate removal and positioning of the cover(s) around the sampling points without disturbing the probes/pipework. A slot at one end of the first section accommodated the gas release pipe.

A length of 3/8" diameter plastic pipe, capped at one end and with a slot cut into the side, served to release the test gas into the substrate. The pipe was pushed vertically downwards into the substrate so that the cut slot was positioned to release gas symmetrically along the centre line of the box from a depth of 250 mm and at a distance of 100 mm from the rear box wall. The schematic drawing in Figure 1 shows the position of the release point within the box while Figure 2 shows photographs of the release pipe and cut slot.

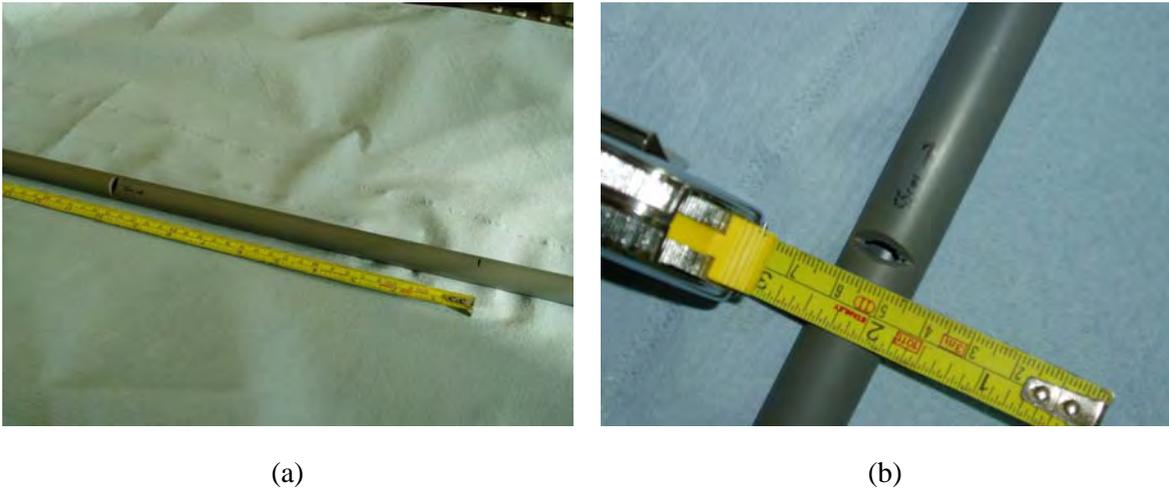
The gas to be tested, either propane or methane, was supplied from a cylinder via a rotameter style flow meter to the release pipe. The gas pressure was regulated to 40 psi and the desired flow set using the rotameter control valve.

Each box was constructed with a 'purge' pipe to enable purging of residual gas from the substrate after each test. This pipe entered at the base of the box and ran parallel to its floor in a loop. 1 mm holes were drilled into it at a regular 300 mm spacing to allow purge gas to permeate. The purge gas was plant compressed air, at a pressure of 40 psi, connected via a rotameter to control the flow.

Gas sampling at various points in the substrate was achieved by inserting a rigid plastic sampling pipe with 6 mm outside diameter vertically into the substrate at the required distance from the release point and to the required depth. During insertion, a wire rod was pushed into the bore of the pipe to prevent blockage. The tube fed into a housing with an integral filter and a 1 m length of flexible tube fed from this into the gas analyser/sampling device with built in sampling pump. Six ATEX certified landfill gas analysers, model GFM430, were available, allowing simultaneous sampling at six points in each test. These are portable, battery powered devices able to be used in flammable or explosive atmospheres and capable of measuring hydrocarbon (methane) concentrations from 0 to 100 % CH<sub>4</sub>. They operate over two ranges, continuously displaying both the gas concentration as %gas and as %LEL (lower explosive limit, 5% for methane). The analysers used held valid calibration for methane, with a worst-case accuracy cited as 3% at the 100% gas level.

The entire system of both boxes and sampling system were contained in a large IP rated flammable store whose doors were closed during testing. To facilitate measurement of concentrations, the six analysers were arranged close to each other and a video camera used to





**Figure 2: Photographs of the Release Point.**

## **2.2 PROCEDURE**

A single test comprised the following steps:

1. Select substrate to be used.
2. Connect gas to be tested to the release pipe in the substrate/box.
3. Insert sampling probes at required positions/depths and connect analysers.
4. Put cover in place if required.
5. Start video recorder and switch on video camera.
6. Start analysers measuring.
7. Start gas flow and adjust to desired flow rate with the rotameter.
8. Observe analyser displays remotely and take measurements live or post-test.
9. Switch off test gas and purge ready for next test.

In practice tests were run for two hours or until all analyser were reading a steady, stable gas concentration. One test was performed per day and the system allowed to purge overnight. A typical test set up is shown in the photographs in Figure 3.

The analysers had a 'feature' of automatically switching off after 10 minutes of inactivity (i.e. if no buttons were pressed). It was necessary to enter the test chamber every 10 minutes during tests to press a button.

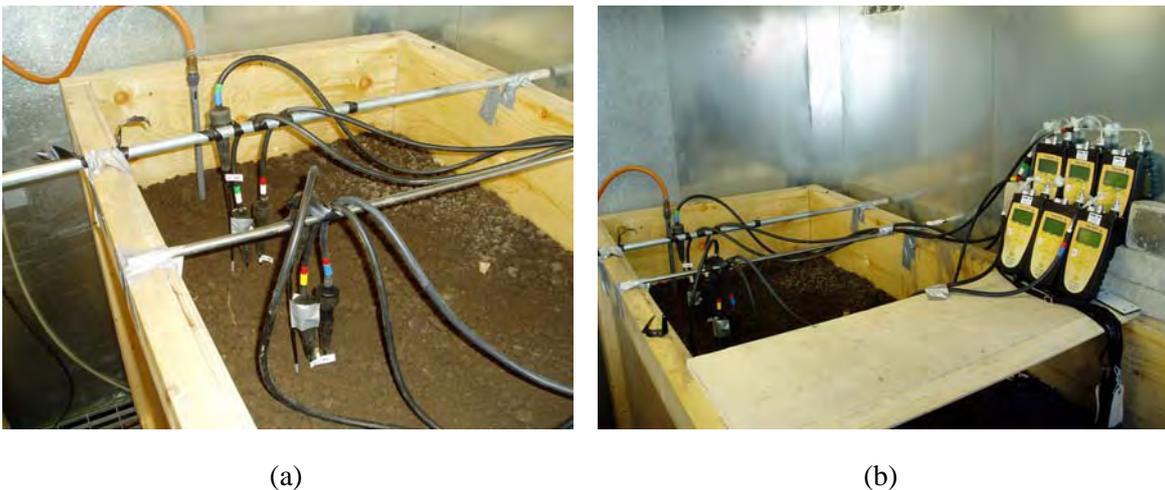
The effect of varying a number of parameters was investigated and a test matrix was constructed to examine each possible combination. The parameters considered were:

- Type of Substrate, either soil or sand.
- Type of Gas, either methane or propane.
- Type of Cover, either covered (equivalent to a non-porous covering such as asphalt) or uncovered (a porous covering such as turf).
- Flow Rate, either a low  $0.25 \text{ m}^3 \cdot \text{hr}^{-1}$  ( $4.2 \text{ l} \cdot \text{min}^{-1}$ ) or a high  $2.5 \text{ m}^3 \cdot \text{hr}^{-1}$  ( $42 \text{ l} \cdot \text{min}^{-1}$ ).

Subsequently it was decided to concentrate on just the low flow rate condition so this parameter was not investigated further.

For the test matrix, the sampling points were set at 300 mm and 600 mm distance from the release point along the centre line of the box and at nominal depths of 40 mm, 250 mm and 500 mm (see Figure 1).

In the final trial, the effect of moving the release point was investigated. The release point and sampling points were moved, as whole, 200 mm sideways towards the long edge of the box (in the soil).



**Figure 3: Photographs of an Experimental Set-up.**

### 2.3 CALIBRATION

The GFM430 analysers used were calibrated in terms of methane, recording 0-100% gas or 0-100% LEL (=5% gas, methane). When testing propane it was necessary to apply a correction factor to the measurements obtained. This factor was measured by running a calibration/span gas through each analyser.

The gases used were:

- Propane, 5000ppm (parts per million, =0.5% gas) supplied from a BOC gas cylinder, V-certified <5% error.
- Methane, 2.5% bottle i.d GS068, Explosion Safety Unit span gas.

# 3 RESULTS

## 3.1 PRELIMINARY TESTING

The preliminary testing was all carried out with the instruments borrowed from Calor Ltd (as discussed in Section 1), which were a mixture of GMI GascoSeeker and Gasurveyor instruments.

Because of the difficulties with these, most of the tests were carried out with only two instruments, set at the release depth of 250 mm below the surface and at distances of 300 mm and 600 mm away along the centreline of the box.

The preliminary tests looked at the repeatability of the results and the general behaviour of the gases.

Repeatability tests were carried out in the sand substrate. Figures 4 and 5 show comparisons between two runs for propane and two for methane, which also compares repeatability with covered (propane) and open (methane) surfaces.

The repeated trials showed that there were only small variations between otherwise similar tests. This allowed the subsequent efforts to be concentrated on different conditions rather than needing to carry out several repeat tests for each situation.

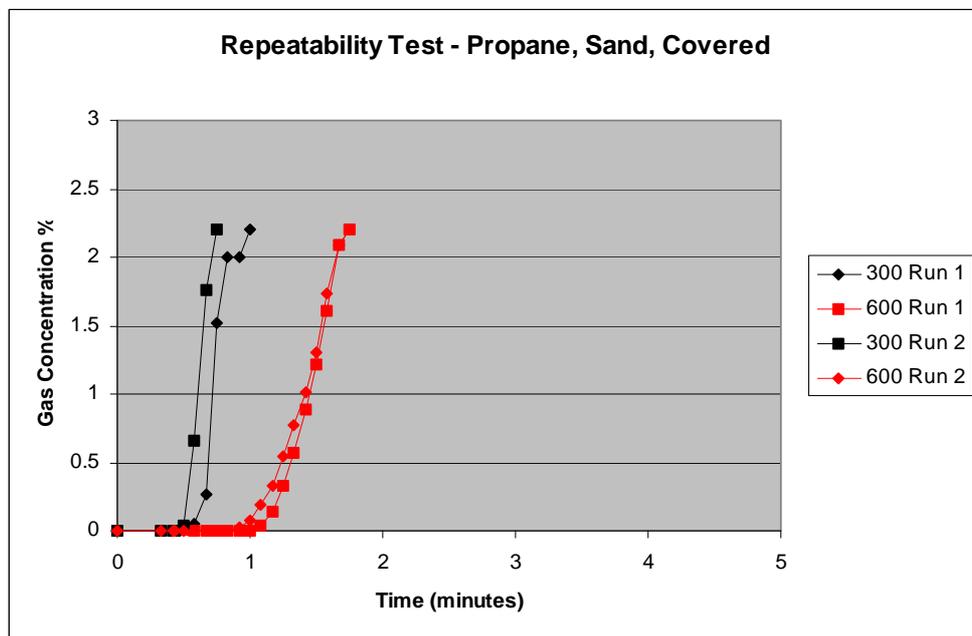
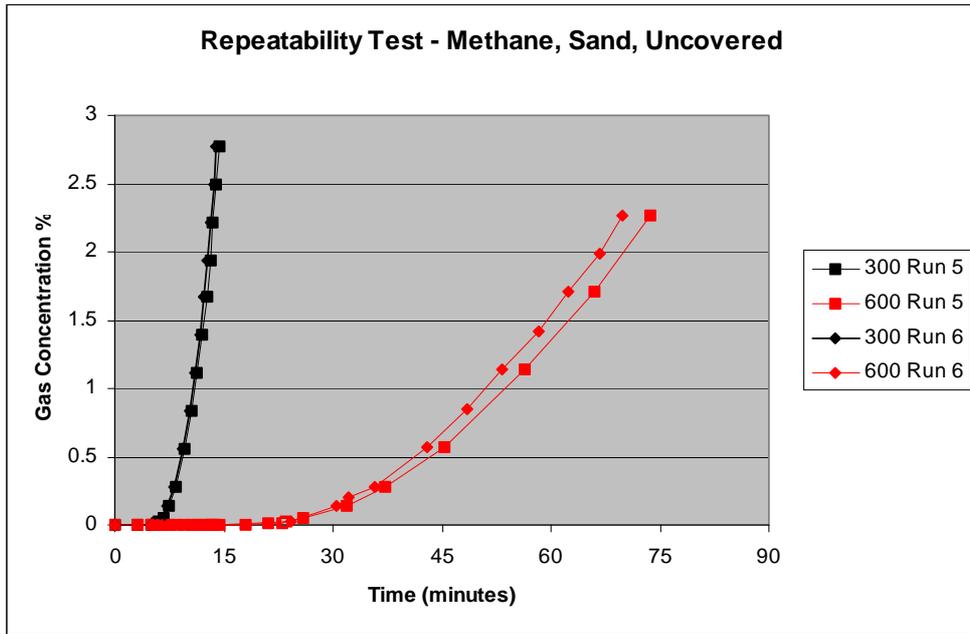
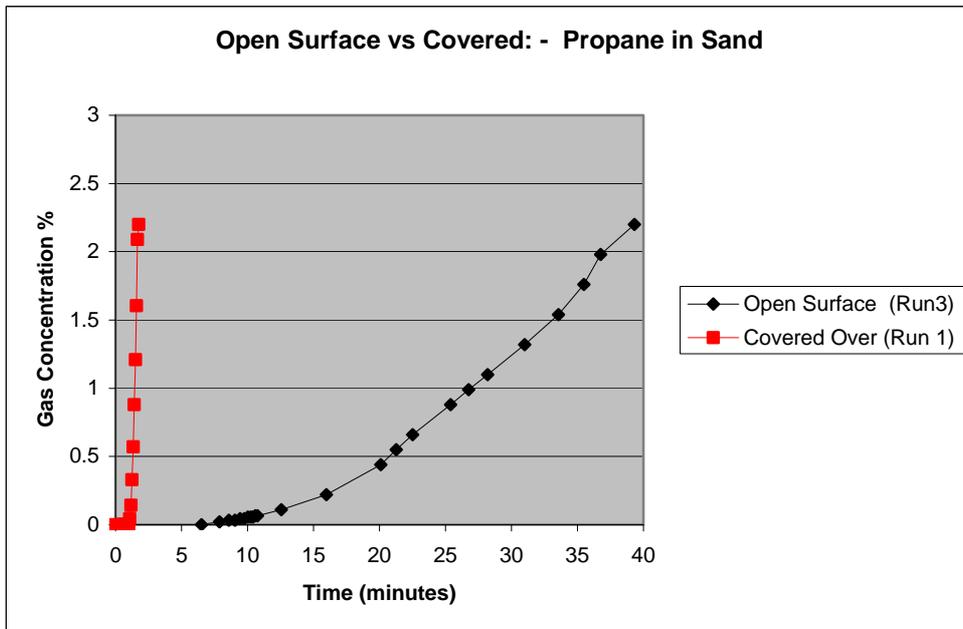


Figure 4: Repeatability Testing - runs with propane in covered sand



**Figure 5: Repeatability Testing – Runs with methane in uncovered sand**

Tests were also carried out to assess the effects of a cover over the surface. The cover was made from several sheets of plywood which could be placed on the surface while allowing the gas sample lines to remaining position. The cover therefore allowed limited leakage, both between the separate sheets at certain distances along the box and at the very edges of the box. In this respect the cover is more like paving slabs than an asphalt or poured concrete surface. Nonetheless, it would be expected that a significant degree of cover would have a marked effect of the progress of gas through the ground.



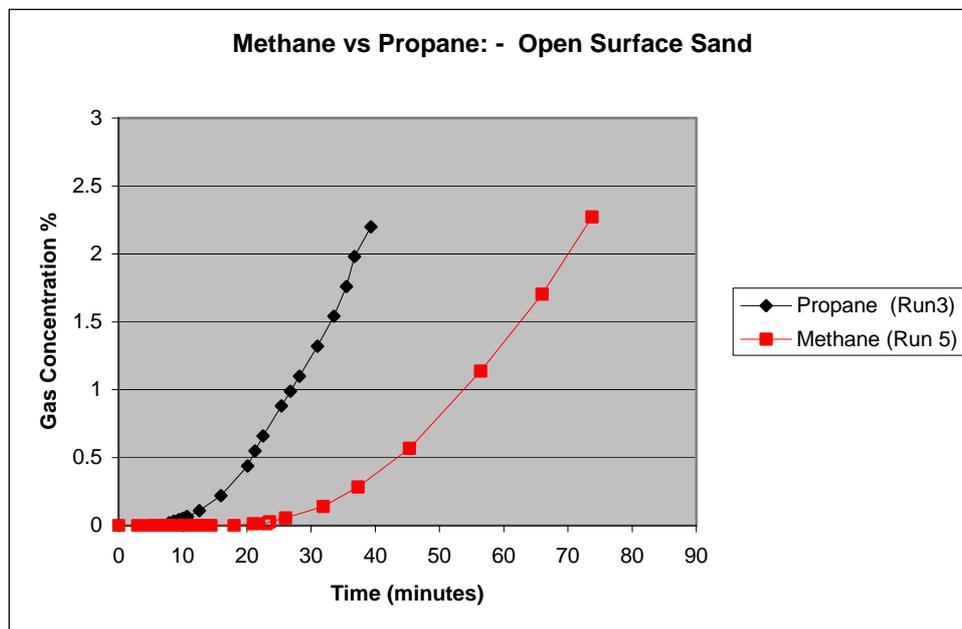
**Figure 6: Effect of surface cover**

Figure 6 shows the results from detectors at the release depth (250 mm) and 600 mm distant from the release point.

This clearly shows that the concentration builds up much more rapidly when it is more difficult for gas to escape from the surface.

The preliminary tests also allowed the first comparison between the behaviour of methane and propane. Tests were carried out in sand without surface cover, and Figure 7 shows the concentration rises measured at 600 mm from the release point (250 mm below the surface).

It is clear that, at least at the same depth as the release, the rate at which propane propagates through the ground is much faster than that for methane.



**Figure 7: Initial Comparison of Methane and Propane**

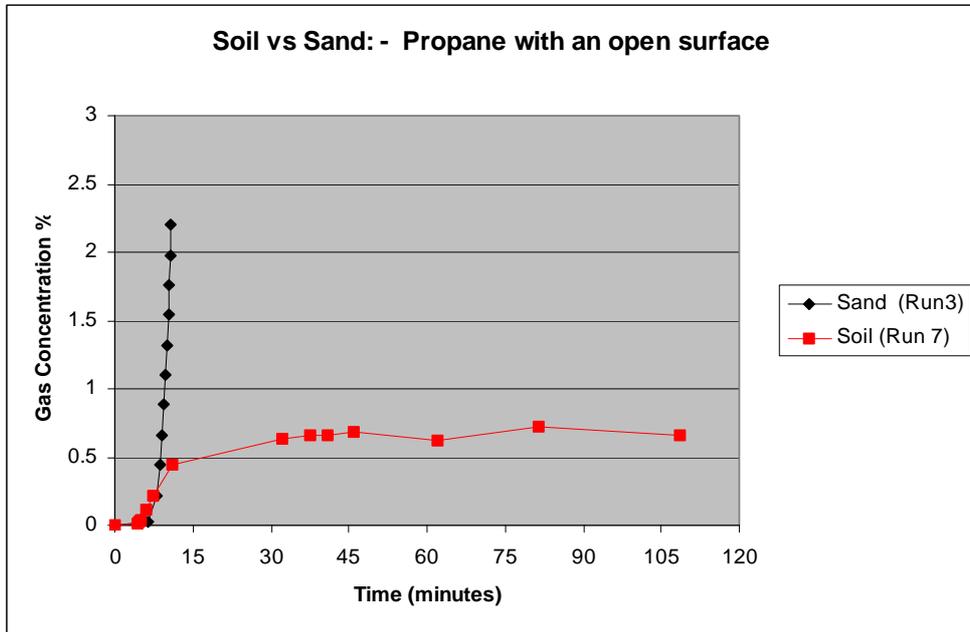
The final task achieved in the preliminary tests was to make an initial assessment of any differences in behaviour between gas released into the sand container and into the container of top soil.

The sand forms very uniform ground, with consistent porosity formed from a myriad of small voids. By comparison the top soil forms a much more uneven ground. The soil clumps into relatively large lumps with very small internal voids (if any at all) and large voids between them. These voids are not uniformly distributed and can lead to 'channels' where a number of larger voids run into one another. As well as channelling allowing gas to move more quickly in some directions than others, the presence of larger voids could allow the effects of gas density to become more significant.

This would have particular significance in this case, as the methane and propane being compared are, respectively, lighter than air and heavier than air.

Figure 8 shows a preliminary comparison of propane releases in both soil and sand, with the ground uncovered. In this graph the data is taken from sample points 300 mm from the release point and again at the same depth (250 mm below the surface).

It is clear that the behaviour is different, with the concentration in the soil peaking at a much lower level at this particular depth.



**Figure 8: Initial Comparison of gas movement in soil and sandy ground.**

The preliminary testing, despite the instrumentation problems, showed that:

- The level of repeatability between similar tests was high.
- Gas propagation rates at the release depth were much higher if the surface was covered over.
- The behaviour in different types of ground could differ markedly.
- The propagation rates of propane were significantly higher than those of methane

Once alternative instruments had been sourced, the main test programme could then concentrate on obtaining reliable data of gas movement in the vertical direction as well as at the two basic points sampled in these preliminary tests.

### 3.2 MAIN TESTING

The majority of tests were carried out with the instrumentation as shown in Figure 1. Each test was given a code at the time it was carried out. Table 2 shows the test codes against the matrix of conditions covered in the test programme (i.e. Propane or methane, open or covered surface, sand or top soil substrate and, for topsoil with an open surface, whether the readings were from the main measurement points or at the alternative locations - shown as 'alt.loc').

*Table 2: Basic test programme ID codes*

	<i>Propane</i>		<i>Methane</i>	
	<i>Sand</i>	<i>Soil</i>	<i>Sand</i>	<i>Soil</i>
<i>Open surface</i>	S1	T5, T7 (alt.loc)	S2	T4, T8 (alt.loc)
<i>Covered surface</i>	S3	T6	J1	T1

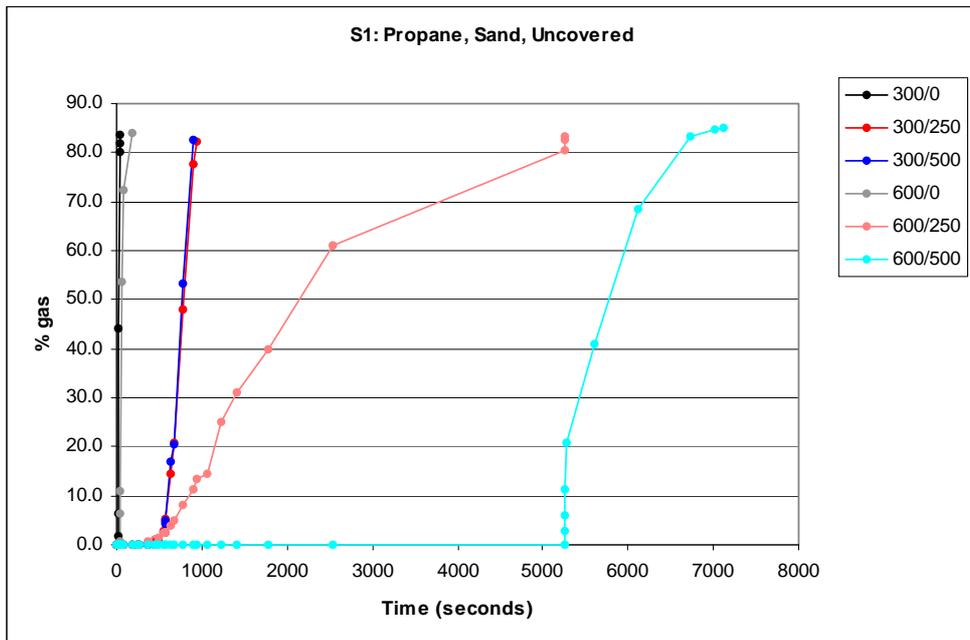
Figures 9 to 18 show the results from each of these tests.

As indicated by the key, each graph shows time histories of the samples from each test point. The darker shades show the samples at 300 mm along from the release point, while the lighter shades show samples at 600 mm. The black/grey traces are near the surface, red/pink at the release depth and blue/cyan at twice the depth of the release.

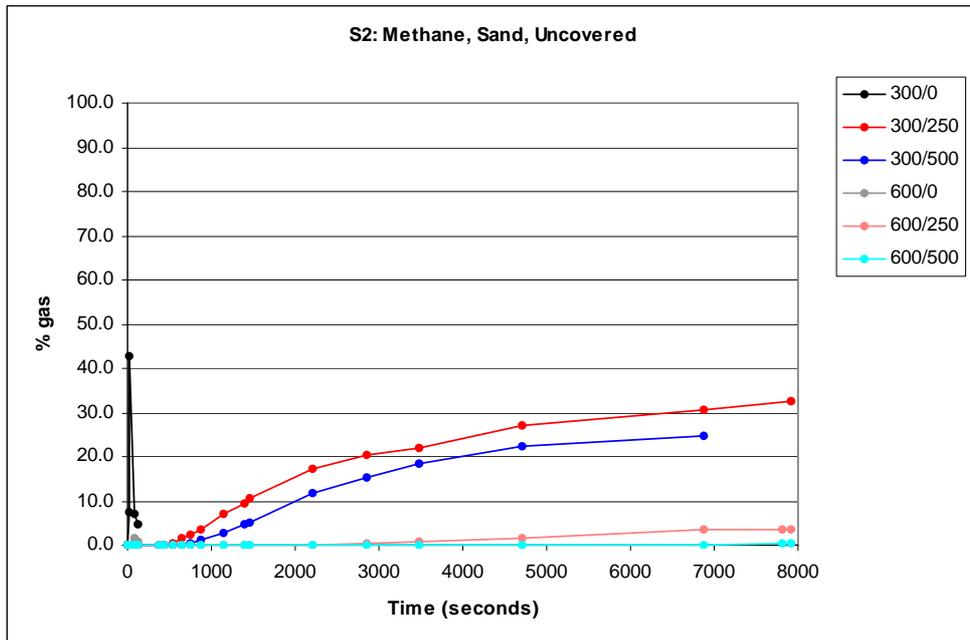
These are shown in the legends. For example, in Figure 9 the legend 300/250 indicates the sample point at a distance of 300 mm from the release point and at the nominal release depth of 250 mm.

All the results are shown as a volume percentage concentration of gas. In interpreting the graphs with respect to a hazardous situation, it should be recalled that the lower flammable limits are 5% for methane and 2.2% for propane.

Where practical, the comparative tests between methane and propane have been shown on the same vertical scale. However, there are cases where this would lose almost all the detail in the readings – in these cases the vertical scale has been adjusted to show the detail. Consequently, some care needs to be taken when comparing these results.

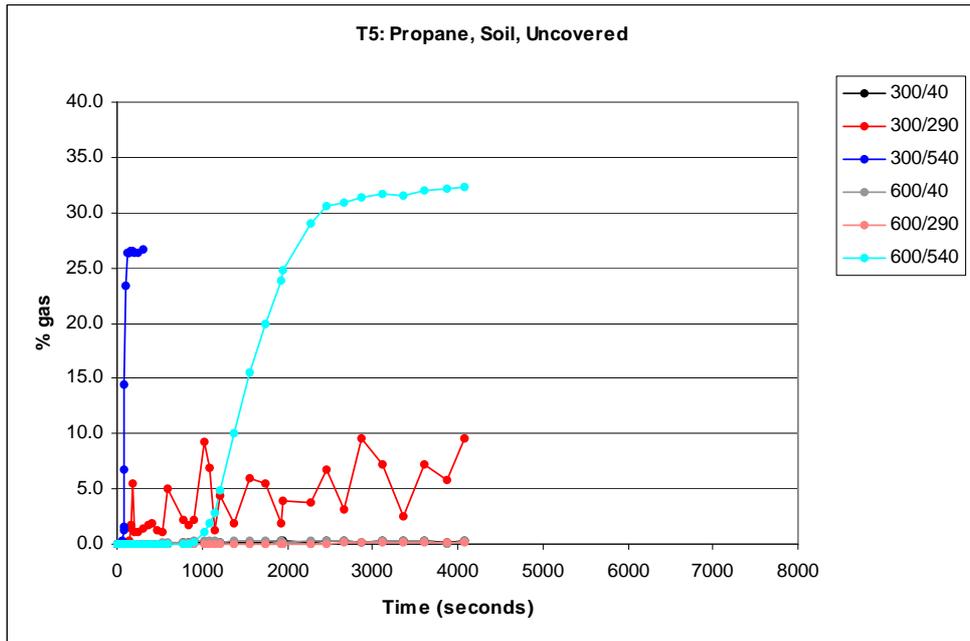


**Figure 9: Results from Test S1**

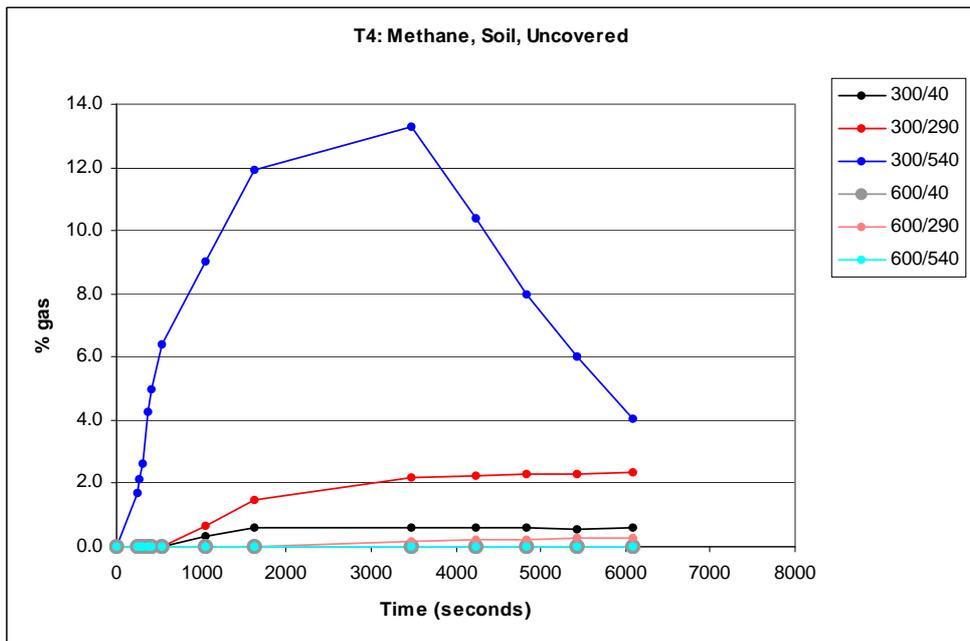


**Figure 10: Results from Test S2**

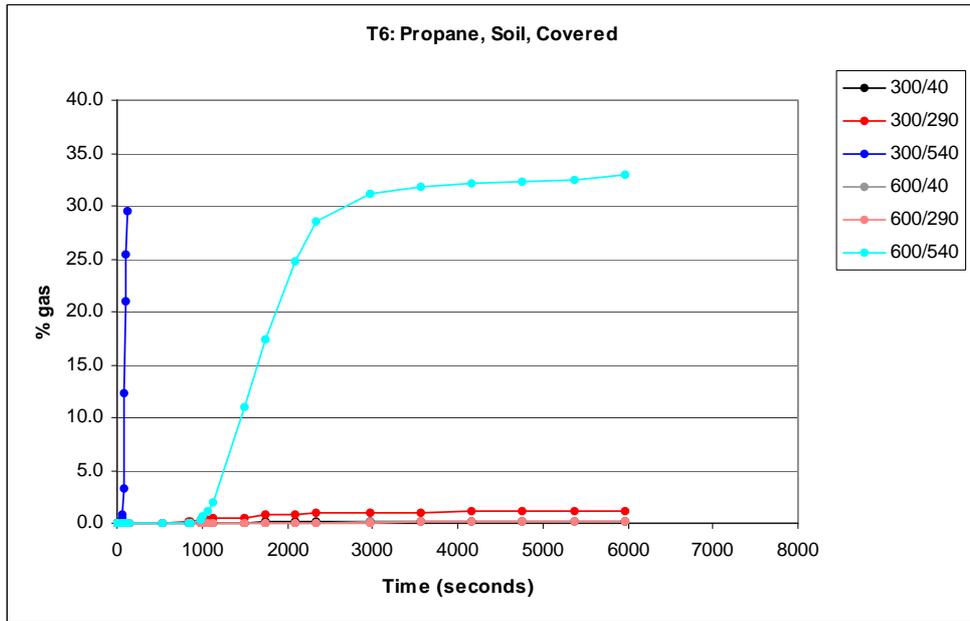




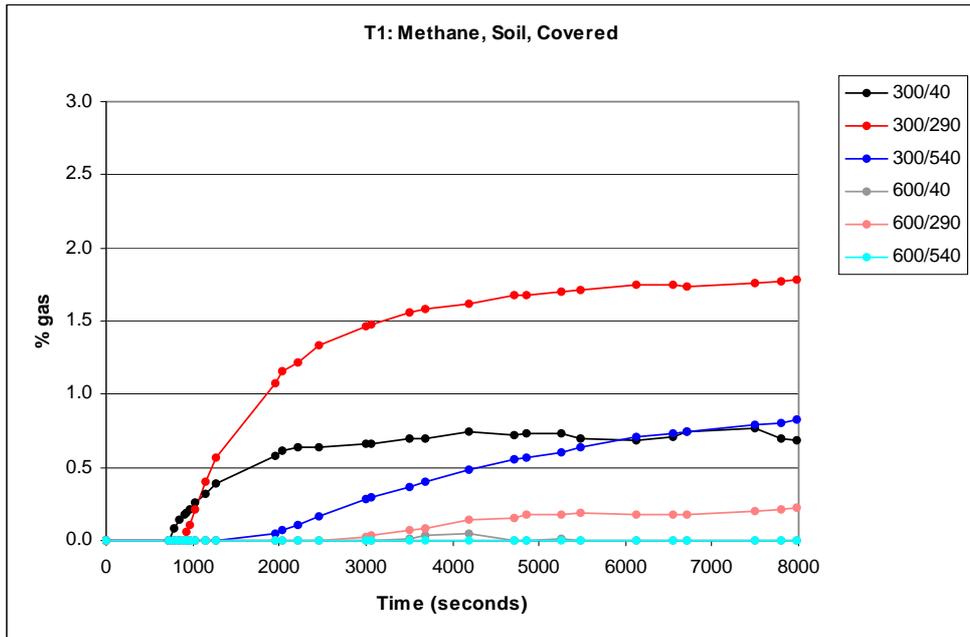
**Figure 13: Results from Test T5**



**Figure 14: Results from Test T4**



**Figure 15: Results from Test T6**



**Figure 16: Results from Test T1**



The results have been summarised in table 3, which gives a general overview of the behaviour in each test condition:

**Table 3: Summary of test results**

Ground Type	Covering	Distance from Release	Comments on behaviour
Sand	Covered	300 mm	Propane concentration high at all depths. Methane only rose to 25% max.
		600 mm	Propane concentrations high towards surface. Methane only at 5% after 2h 15m
	Open Surface	300 mm	Propane high at all levels. Methane only rose to 15% max.
		600 mm	Propane rose to high levels but slowly (1h 30m at 500mm depth) Methane only 5% after 2h 15m (i.e. as covered)
Soil	Covered	300 mm	Propane high below release depth, low elsewhere Methane only rose to 1.5% at release depth
		600 mm	Propane rose to 30% at lower depth after 20 min. Methane below 1% even after 2h 15m.
	Open	300 mm	Propane high below release depth, low elsewhere. Methane peaked at ~45 min (13% at lower depth) then concentrations fell again.
		600 mm	Propane rose to 30% at lower depth after 45 min. Methane below 1% even after 2h 15m.
	Open (alternate location)	300 mm	Propane 25% below release depth, low elsewhere. Methane peaked at ~45 min (3% at lower depth) then concentrations fell slightly.
		600 mm	Propane rose to 30% at lower depth after 45 min. Methane rose to 1% after 2h 15m.

A number of other observations were made during the tests:

- In all the propane tests there was a noticeable smell of gas within a short time of the release starting. (The methane used was not stencched and so had no detectable smell).
- A single test was carried out with sampling at several points across the surface of the soil filled box. This showed that the concentration rose to the highest levels close to the edges of the box.

## 4 DISCUSSION

### 4.1 TIME TO REACH LOWER FLAMMABLE LIMIT

As well as any difference in migration rates through the ground, the consequences of a given amount of gas reaching an area containing an ignition source are also affected by the gas itself. The lower flammable limit (LFL) is the lowest concentration of gas at which an ignition source can start the gas burning. For an explosion to occur, the gas must be present at a concentration above the limit. For methane this limit is 5% concentration of gas in air, while for propane it is lower at 2.2%. This means that a smaller volume of gas is required to reach a dangerous concentration.

Tables 4, 5 and 6 show the time at which LFL was reached at three depths at the near location (300 mm from the release point). The time to LFL is shown in seconds, with “<LFL” indicating that concentrations did not rise to LFL at that point at any time during that experiment.

*Table 4 – Time to LFL at surface (seconds)*

	<i>Propane</i>		<i>Methane</i>	
	<i>Sand</i>	<i>Soil</i>	<i>Sand</i>	<i>Soil</i>
<i>Open surface</i>	25	<LFL, <LFL (alt.loc)	14	<LFL, 375 (alt.loc)
<i>Covered surface</i>	30	<LFL	55	<LFL

*Table 5 – Time to LFL at release depth (seconds)*

	<i>Propane</i>		<i>Methane</i>	
	<i>Sand</i>	<i>Soil</i>	<i>Sand</i>	<i>Soil</i>
<i>Open surface</i>	510	180, <LFL (alt.loc)	1300	<LFL, 1000 (alt.loc)
<i>Covered surface</i>	185	<LFL	1170	<LFL

*Table 6 – Time to LFL at twice release depth (seconds)*

	<i>Propane</i>		<i>Methane</i>	
	<i>Sand</i>	<i>Soil</i>	<i>Sand</i>	<i>Soil</i>
<i>Open surface</i>	540	73, 128 (alt.loc)	2650	419, <LFL (alt.loc)
<i>Covered surface</i>	635	70	1700	<LFL

These results show that, with the exception of the time needed to reach an uncovered sand surface, LFL is reached very much faster for propane than methane. In the worst case, looking at gas travelling down through sand, it took nearly five times longer to reach LFL with methane compared to propane.

## **4.2 DIFFERENCES IN SOIL TYPE**

The physical differences in the two substrates used are that the sand forms a very evenly packed bed with many small voids distributed uniformly throughout the bed in all directions, while the topsoil contains many larger tightly packed clumps of soil with larger voids between them. This means that the soil will contain areas where relatively large voids allow gas to be significantly affected by buoyancy, and may also contain 'chains' of voids where the overall resistance to flow is much lower in one direction than others.

Given this, it would be expected that the sand flows would be more uniform and repeatable, while the soil flows are more likely to be different between different points.

This is reflected in the results, and in particular in the tests carried out at a second release point in the soil bed. The results given in tables 4 to 6 show that the two values for soil with an open surface– which were the two otherwise similar tests with alternative release locations - differ significantly from each other.

This could well be a significant issue for buried pipes, which will be located at the bottom of refilled trenches. The ground along the length of the pipe and above it is likely to be less compacted than the ground to either side and below. Gas is therefore likely to track preferentially along the pipe run and to the surface. Easier flow to the surface may be advantageous, as the gas may be detected more quickly. Easier flow along the length of the pipe may be more problematic, as it will carry gas back towards the source (such as an LPG tank) and towards the point of use - which is likely to be a building that may be put at risk.

## **4.3 IMPLICATIONS FOR MODELLING FLOWS**

The Advantica model presumes that there are two drivers for gas flow through porous ground: pressure differences and buoyancy.

If both effects are important, then a number of things should be observed.

Firstly, if pressure difference drives some of the flow then the buoyancy effects should be overcome to some extent. This would be reflected in methane, which is lighter than air, being driven downward to some extent while propane, which is heavier than air, should be partly driven upwards. In this context, the sand tests will give the most useful results, as they are least likely to be affected by non-uniformity and channelling in the substrate.

This behaviour is reflected, at least qualitatively, in the results from the tests. Propane was detected at the surface in the sand tests and while surface propane was only detected at low concentrations in the topsoil tests there was always sufficient escape from the surface for the stenching agent to be obvious. Similarly, methane was detected at levels below the release point in almost all the tests.

Secondly, if buoyancy drives some of the flow then above the release point the concentration of methane should be higher than that of propane in the equivalent test and conversely the concentration of propane should be higher below the release point.

Qualitatively, this is what is seen. The results clearly show that there is a difference in behaviour between methane and propane, and that this difference is more pronounced in the topsoil where there are larger, less uniform voids. In the tests at the second release position, the propane concentration never rose to LFL near the surface while the methane concentration did not reach LFL at the lowest position.

The results clearly indicate that both pressure and density effects have a role in the migration of gas through the ground. This needs to be reflected in any predictive model of behaviour.

It is also clear that the practical results will be more variable in more broken ground. Any modelling also needs to reflect this and either err on the side of caution or clearly indicate a lower level of confidence in the margin of error around an “average” result. Where results are used to predict the likelihood of flammable gas entering a building through the ground, the conservative assumption is for the fastest movement of gas.

## 5 RECOMMENDATIONS

Any modelling of gas movement where LPG may be compared with Natural Gas should recognise the differences in behaviour and physical properties.

For the existing natural gas data to be useful for LPG, care needs to be taken to include appropriate factors for the faster LPG movement through the ground.

Modelling also needs to include the difference in lower flammable limit, as LPG will reach an explosive mixture more quickly than the same volumetric flow of Natural Gas.

The Advantica model includes the appropriate processes, but would need to be carefully modified to account for the differences in LPG and natural gas behaviour.

In broken ground or where other spaces exist which might channel gas, it should be recognised that is likely that gas movement (whether LPG or natural gas) will be dominated by flow along such channels.

In such soils, prediction of an average speed will provide an accurate input into prediction of average risk, but to predict the highest risk then the highest migration rate needs to be calculated.



# Comparing subsurface migration of LPG with natural gas

A programme of experiments assessed differences in behaviour between leaks of natural gas and Liquefied Petroleum Gas (LPG) from buried pipes, to inform opinion on whether an existing (Advantica) model of the risks from buried natural gas pipework could be useful in assessing the risks associated with buried metallic LPG pipes.

In experiments with two different soil types, LPG or natural gas was injected at a fixed position and samples were then taken from a number of points below and at the surface. The effect of covering the surface was also assessed. Both LPG and natural gas migrated away from the leak into the surrounding soil, gas being detected both above and below the release point and reaching the surface quite quickly. This showed the importance of pressure differences in driving the flow.

In sand, with uniform porosity, LPG was seen to migrate more quickly than natural gas, needing a substantially shorter time to reach a hazardous concentration. In soil with larger, less regular pores, differences in buoyancy were more apparent, and the results showed much more variability.

It was concluded that the Advantica model included the appropriate processes, but that the model would need to be carefully modified to account for the differences in LPG and natural gas behaviour before being used in any prioritisation of LPG pipe replacement.

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