



The Impact of Adding Hydrogen to Natural Gas on the Hazard Posed by Gas Escapes in the Home

The concept of the Naturalhy project is to introduce hydrogen into the gas transmission and distribution network. Whether or not some of the hydrogen is subsequently removed for use by hydrogen fuelled equipment or vehicles, some of the hydrogen that is mixed with natural gas will reach the gas consumer at the end of the pipeline network. In particular, domestic gas customers will be receiving a natural gas/hydrogen mixture, through their meters and into their gas fuelled appliances. As mentioned in Naturalhy Newsletter No 2, the effect of this mixture on appliance performance is being assessed by the project (within Work Package 5) and the effect on meters is being studied in Work Package 3 (see also Newsletter No 2).



Figure 1: The test rig representing a domestic room

However, the use of flammable gases in the home has never been risk free and we all know that every year there are a small number of explosions in residential properties, sometimes with serious consequences for the occupants; although not all escapes of gas lead to explosions as many are safely isolated and dispersed. Indeed, the overall risk to a domestic gas customer is extremely low and at a level that society finds acceptable compared to the benefits of using gas in our homes for heating and cooking. The question that the Safety Work Package of Naturalhy must ask is: Will adding hydrogen to the natural gas change the level of risk to the domestic customer, and if so, is that still an acceptable risk?

To answer this question, several issues need to be addressed, such as the likelihood of a gas escape in the first place, whether a flammable mixture will accumulate, how easily will it be ignited and what will be the severity of the resulting explosion? All of these issues are being considered by the Safety Work Package. In particular, large scale experiments have been performed to study the behaviour of gas escapes and the nature and concentration of the gas accumulation formed. The 10 experiments involved releases of natural gas/hydrogen mixtures (up to 50% hydrogen) into an enclosure representing a domestic room and measuring 3m by 3m by 2.3m high, fitted with a door in one wall and small ventilation openings in two other walls (Figure 1). The room was made of steel rather than the materials normally expected in the home as, in some cases, the gas accumulation formed during an experiment was ignited and the explosion severity measured. The gas was released at pressures typical of that found in a domestic environment upstream and downstream of a meter (20-30mbar) and from small leaks (2mm diameter) to pipework failures (10mm diameter). In all cases the gas was released vertically upwards and openings each side of the room allowed ventilation air to flow through, entering at low level and leaving at high level. By this arrangement, an upward air flow through the room was established. (This situation was chosen as this regime promotes the formation of a

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EDITORIAL

In our programme on defining the conditions under which hydrogen can be added to natural gas in the existing infrastructure, one of the main issues is the potential impact on the safety risks associated with the transmission, distribution and end use of gas. As the physical and chemical properties of hydrogen differ from natural gas, it is expected that the addition of hydrogen to natural gas will also affect amongst others the combustion characteristics of the gas and, as a consequence, the safety risks.

In the third issue of the NATURALHY newsletter we reported on the investigations concerning burning velocity of hydrogen/methane mixtures. Further to this work, the present Newsletter focuses on the examination of the impact of added hydrogen on the hazard posed by gas escapes in domestic situations.

As hydrogen added to natural gas might also effect the pipeline material properties (see Newsletter 2), the management of durability aspects of pipelines is an essential part of the NATURALHY-programme. In this issue, a short overview of the work on pipeline integrity is included: This subject will be further addressed in the next Newsletter.

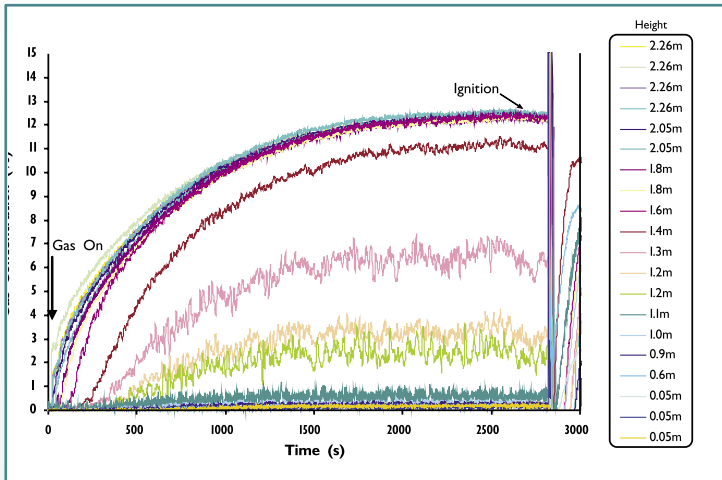
Furthermore, we are pleased to address in this newsletter the International Association for Hydrogen Energy, an initiative with which NATURALHY has strong connection.

We kindly invite you to visit our website www.naturalhy.net for further information on our project or for any questions or remarks.

The project coordination team
Onno Florisson, Gjalt Tiekstra,
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Figure 2: Gas Concentration Measured During a Test by Oxygen Cells Throughout the Room Showing Dependence only on Height



layer within the upper part of an enclosure. In such a situation, if the gas accumulation occupies only part of the room then it will reach a flammable level more quickly than if it had been distributed throughout the entire room.)

During the experiments gas concentrations were measured using 20 oxygen cells distributed throughout the room. These provided a continuous measure of the oxygen level (and hence, by inference, the gas concentration) with time throughout the experiments. An on-line analyser was also used to measure the hydrogen and methane levels directly from one of three sample positions within the room. This provided the opportunity to assess whether or not the hydrogen might separate from the natural gas/hydrogen mixture and accumulate preferentially near the ceiling.

It was found that the gas concentrations measured at the same height but at different locations within the room were the same, indicating that the gas accumulation was uniform in the horizontal plane and only varied with height above the floor (see **Figure 2**). Further, the gas accumulation formed a layer of essentially uniform concentration above the height of the release point. This layer formed quickly after the onset of a gas release and then increased in concentration until a steady state concentration was reached. This is illustrated in **Figure 3**, where gas was released vertically upwards from a position at about half-height within the enclosure. **Figure 4** shows the methane/hydrogen ratio measured within the gas accumulation at high, mid and low level throughout an

Figure 3: Formation of a Gas Layer of Uniform Concentration in Upper Part of Room

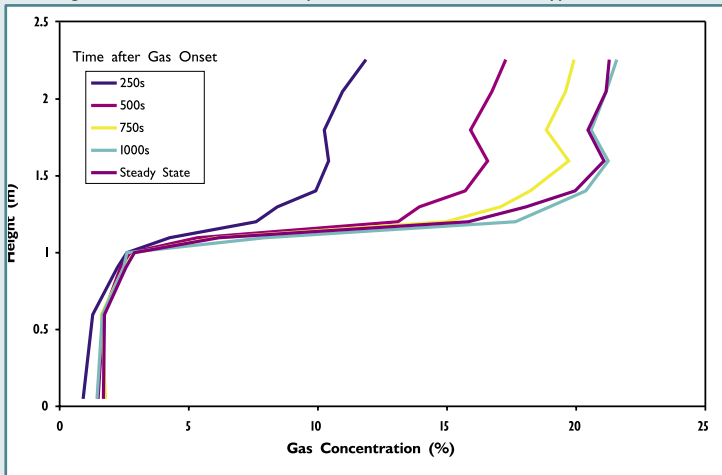
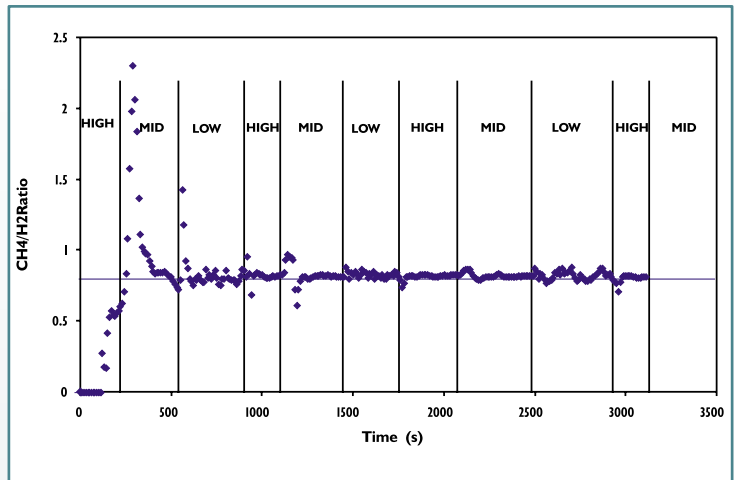


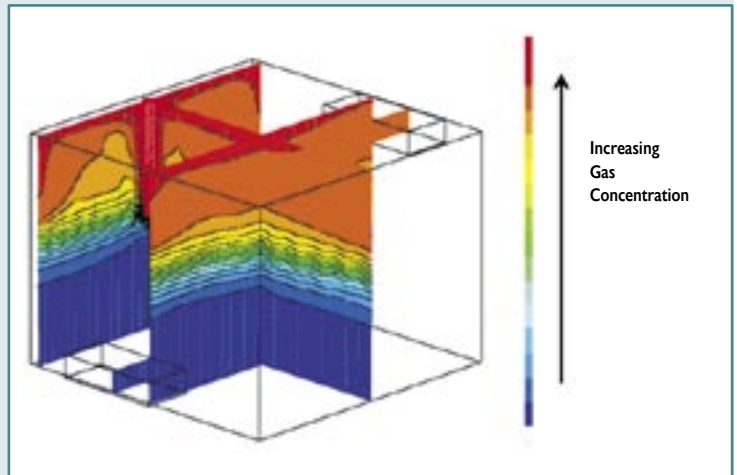
Figure 4: Methane/Hydrogen Ratio at High, Mid and Low Level During a Test Showing no Evidence of Separation of the Mixture



experiment. This shows that the ratio remained constant, regardless of the height of the sample. This implies that hydrogen separation from the mixture does not occur.

However, the sort of results shown in **Figure 3** is exactly the same as would be expected for releases of natural gas, so how can we tell if the addition of hydrogen has made a difference? The answer really requires use of a mathematical model capable of predicting gas build up behaviour for natural gas and for natural gas/hydrogen mixtures. The development and validation of such models using this experimental data is also part of the Safety Work Package and is now ongoing. CEA are developing a CFD approach and Loughborough University are developing a simplified model. Both approaches are showing promising results. For example, the CEA model exhibits the same layering behaviour and uniformity of concentration in the horizontal plane (**Figure 5**). However, an important observation that has been made directly from the experimental results is that the nature of the gas released also influences the degree of ventilation experienced. This is because buoyancy forces are generated by an accumulation of a lighter-than-air gas within the upper part of a room. These buoyancy forces cause air to be entrained through the low level opening which is additional to the air passing through as a result of the prevailing wind conditions. The more hydrogen that is added to the natural gas, the stronger this effect. Therefore, it will be important for the mathematical models to take account of this factor in order to predict the gas concentrations accurately. ❖

Figure 5: CFD Prediction of Gas Accumulation Showing Characteristic Layering



Hydrogen Energy and its Technologies - A Stroll through the IAHE Activities

by Carl-Jochen Winter, Ueberlingen, Germany

Like electricity, the other secondary energy carrier, hydrogen is being generated from almost any thinkable primary energy (raw material); like electricity, once generated, hydrogen is environmentally and climatically clean over the entire length of its energy conversion chain; and like electricity, hydrogen is grid delivered (with exceptions) and strengthens the secondary energy realm. Hydrogen's major and foremost characteristic, however, is its ability to exergize the energy system (energy=exergy+energy, with exergy making available technical work and being converted into any other energy form, energy not); it makes more technical work (exergy) out of less primary energy. Hydrogen fuelled fuel cells decentralize the system; with the help of IT-controlled virtual hydrogen power stations it activates dormant energy potentials, so far un-operational.

The International Association for Hydrogen Energy (IAHE) devotes its activities to the promotion and furtherance of hydrogen energy and its technologies in the up and coming hydrogen energy economy. The Association was founded in 1974; in even years it organizes biennial World Hydrogen Energy Conferences (WHECs); so far 16 WHECs have accomplished with great successes, the more recent ones each had 1,000 to 1,500 attendees. The WHEC 2006 was held in LYON, France, the one thereafter for 2008 will be in Brisbane, Australia, and the next for 2010 in Essen, Germany. In odd years, World Hydrogen Technologies Conventions (WHTCs) gather hydrogen engineers from almost all over the world; the next WHTC will be in 2007 in Montecatini Terme, Italy, and the 2009 WHTC in New Delhi, India. Clearly, hydrogen energy's approach to the market place shows a positive gradient. Every major auto maker, power generating company, portable electronics manufacturer in the world with significant operational R, D & D programs are working to commercialise hydrogen energy technologies. Altogether billions of US dollars of private or tax money are being spent.

Today, the bulk of hydrogen comes from fossil fuels - natural gas, heavy oil fractions or coal. On the longer run, say, in decades to come, hydrogen, clean from cradle to grave over its entire length of the conversion chain, will be generated still from fossil fuels, now including capture and storage

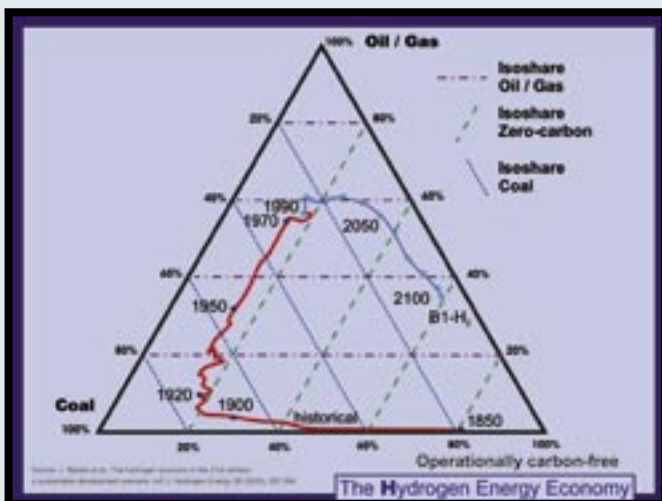


With hydrogen, the vast renewable sources of the world, so far limited to local or, at most, regional services, get a storable and transportable chemical energy carrier, which enables them to play their role in the global energy trade system: e.g. Patagonian wind, Canadian hydro, Australian solar will be serving the world's big energy user regions! With hydrogen, materially closed cycle coal fired power plants may become a reality in due time, literally, with no CO₂ emission into the atmosphere. With on-board hydrogen under the hood of ICE- or fuel cell automobiles or buses, zero-pollution inner city transport ceases to be an illusion; a thousand of demonstration vehicles are already on the road. With hydrogen, airlines stop polluting the atmosphere when flying in or underneath the tropopause where water vapour is a natural constituency. Truly, a real "zoo" of technologies are under development.

of co-produced carbon dioxide, or from renewable energies. Moving the hydrogen from the generation sites to the end user will be not too different than moving today's fluid fossil fuels - via pipeline networks or tanker trucks or ships; with the liquefied hydrogen temperature of -250°C, of course, the transport temperature will be decisively different! Certain amounts of hydrogen from decentralized reformers or electrolyzers may be added locally, the latter particularly where non-carbon inexpensive electricity sources are available. In the transition phase which in some industry countries (e.g. California, Germany) is already on the verge, gaseous or liquefied hydrogen will be delivered via the well established commercial gas traders' network, as is done for the time being for c. 50 million tonnes of hydrogen p.a. for other than energetic purposes in safe, reliable and appropriately marketed ways. If - a thought experiment - the number of natural gas fuelled stationary or mobile fuel cell systems in the end use sector will be increasing, hydrogen pick-a-back on natural gas delivery may be of advantage, because the reforming effort gets handier. Here, all what can be learned from the NATURALHY project will be beneficial. And not at all least, the investment already in place represents an enormous advantage, not only money-wise but also with respect to handling and experience gathered so far!

"Abundant clean energy for mankind" is the motto of the Association, and truly, it increasingly materializes. Hydrogen energy will not be available for a shoestring, and in macroeconomic terms it will only be operational in decades up to half a century. Energy needs time! The consequence: It's HYtime to start and see it through!

For more information or membership application, please, write to IAHE, 5783 SW 40 St. #303, Miami, FL 33155, USA or visit www.IAHE.org or take a look into Elsevier's hydrogen standard monthly periodical, International Journal of Hydrogen Energy (including Fuel Cells), ISSN 0360-3199. ❖



Delivers the energy history of mankind in the 19th and 20th centuries (red line) and one prospective development into the 21st century (blue dotted line). Since the 21st century potentially expects an increase in operationally carbon-free renewable and/or nuclear energy, a chemical storable and transportable energy carrier is needed in order to let renewable and nuclear primary sources contribute to the global energy trade system: this is why a certain unavoidability of hydrogen becomes reasonable.

NATURALHY activities on the management of pipeline integrity

The currently applied integrity management for natural gas pipelines ensures that the gas transportation is safe, stable and cost effective. When thinking about transportation of other gases (e.g. hydrogen) in the existing pipelines it is necessary to prove whether the applied integrity management procedures are fit for this new purpose.

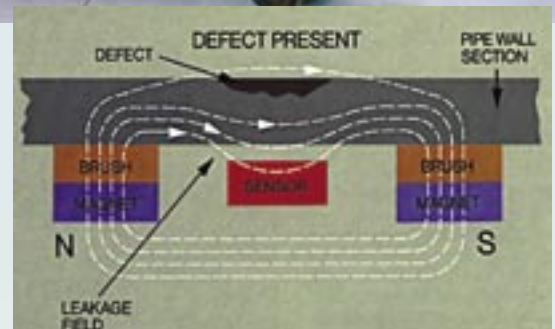
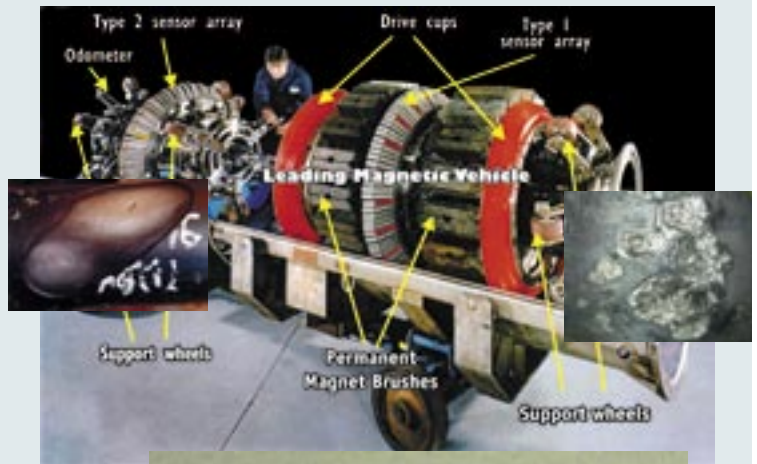
The first step on this way is to establish a clear picture of the defects that are known today. This concerns the number, the type and the shape of defects. As a second step it is necessary to evaluate, which of the defects are more prone to failure and which less.

The most important criterion for the evaluation of the defect criticality is the amount of stress a defect can put on the material. Blunt defects like dents cause only low stresses but sharp defects like cracks can cause significant stresses. Beyond this, certain cracks can reach a state in which they grow unstable, what makes them more critical than corrosion defects. It is essential to distinguish the critical defects from the less critical defects, to determine the growth rates and the critical defect sizes.

Having acquired this information it is possible to define detection requirements for inspection technologies and to calculate inspection intervals. The next link in the chain of the hydrogen service integrity management is to develop suitable measures / procedures to mitigate the risk of failure. That means that in addition to the definition of detection limits and intervals, one has to prove whether the current repair technologies are fit for the new purpose of the hydrogen transportation.

In fact one has to identify, which technologies are more suitable than others from a technical and economical point of view. The various parts of the integrity management, such as the requirements on the inspection tools, the definition of the maximum allowable defect sizes / types and the corresponding inspection intervals as well as the repair technologies, all have an impact on the cost for integrity management.

It is necessary to optimize the technical specifications with respect to the required financial effort. One example is the specification of the required detection limit of the inspection technologies. A higher probability of detection of small defects will increase the costs for one inspection run but will prolong the intervals between the inspection runs, which will



reduce costs. Another subject for optimisation is repair: there are several answers to the question: "When to repair defects?"

The repair can be done batch wise (repair all defects that are detected) or only when a defect-size exceeds a predefined threshold.

To develop a functional specification of an integrity management tool suitable for the hydrogen service is the aim of the integrity work package (WP4). All the aspects mentioned above, from the definition of the critical defect to the cost-optimisation, are being studied in this work package. A more detailed overview of the tasks, the progress, the opportunities and the partners contributing to WP4 will be given in the next (5th) newsletter. ❖

UPCOMING EVENTS

Second NATURALHY-workshop: 30 May 2007 (Amsterdam, please see the project website www.naturalhy.net)

18-22 June 2007 3rd European Hydrogen Energy Conference, Maastricht, The Netherlands
Theme: HYDROGEN IN ACTION – Bridging the Gap between Science and Market

11-13 September, 2007 International Conference on Hydrogen Safety (ICHS), San Sebastian, (Spain).
Theme: "Safety of Hydrogen as an Energy Carrier".

To be corrected: The 17th WHEC will take place **15-19 June 2008**

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