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NATURALHY

"Preparing for the Hydrogen Economy by Using the Existing Natural Gas System as a Catalyst"
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Assessing the Durability of Natural Gas Infrastructures for Transporting and Distributing Mixtures of Hydrogen and Natural Gas

Using the existing natural gas grids for delivering hydrogen represents an opportunity for paving the way for the forthcoming hydrogen economy, in preparation for expanded pure H_2 grids. But the crucial question is: how much H_2 can be added in the existing natural gas infrastructure (grids of transmission, distribution and indoors delivery and auxiliaries) without damaging those facilities? To answer this question, the Work Package "Durability" states the following main objectives:

- Establish allowable hydrogen percentage limits for several grid elements,
- Estimate the lifetime for the different networks and components,
- Identify bottlenecks and solutions to remove them,
- Construct a Lifetime Assessment tool and provide operational guidelines to end-users.

What are the changes induced by injecting H_2 in the natural gas supply on the durability of the materials on the existing infrastructure? This question will be answered by means of survey of literature, experimental testing and numerical simulation. Experiments involving several parts of the existing infrastructure will re-examine the major risks previously studied for natural gas, like the effect of H_2 on fatigue behaviour and corrosion of steels used for the transmission pipes and their burst resistance, on permeability and ageing of polymer pipes on the low pressure distribution grids, on reliability and ageing of domestic gas meters, on tightness to H_2 of domestic appliances and their connections. Information exchange on those subjects will take place with the Dutch programme "Greening gas" and the "H_2 Delivery Programme" launched by Department of Energy (DOE, US).

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EDITORIAL

It is a pleasure for the consortium to present the second newsletter on our project NATURALHY that aims to define the conditions under which the existing natural gas system (transmission and distribution system, the end user infrastructure and appliances) can be used for the delivery of hydrogen.

These aims are being addressed in order to take as much as possible advantage as possible of existing assets in the transition towards the hydrogen economy. The basic vision of the project is that mixtures of hydrogen and natural gas will be transmitted and distributed by the natural gas system and that hydrogen will be separated downstream as well as using mixtures in the existing appliances.

However, the physical and chemical properties of hydrogen differ significantly from natural gas. Further to this, the properties of mixtures differ from those of "pure" natural gas, and this will have consequences for safety, the integrity of the system and for end use. In this second newsletter we will give special attention to the impact of hydrogen added to natural gas on the integrity aspects of the system.

We hope that this newsletter will be interesting and informative for you and would like to invite you to react to it through our website www.naturalhy.net.

Onno Florisson & Rolinda Huizing
(The Project coordinator team)

News

First NATURALHY Workshop

NATURALHY will be organising a workshop, dedicated exclusively to the promotion of the project, during the 2nd European Hydrogen Energy Conference EHEC 2005 (Zaragoza - November, 22nd -25th, 2005). EHEC is a forum for all latest developments and advances in the field of hydrogen and is devoted to the exchange of scientific and technical information. Attendance at the workshop will be free for all registered EHEC 2005 participants. Furthermore, a limited number of tickets will be available for non-EHEC attendants free of charge. Additional information and the detailed workshop agenda will soon be posted on the NATURALHY website.

NATURALHY 2nd Annual Meeting

The 2nd annual meeting of the full consortium of the NATURALHY-project was held in Istanbul, Turkey on the 9th and 10th of June, 2005 during which the progress, state of affairs and outlook of the project were discussed. All partners agreed that the project has successfully met and overcome various first year issues and that it steadily on track to meet future project expectations.

Developments in the Strategic Advisory Committee

NATURALHY welcomes CONTINUON (http://www.continuon.nl/), as a new member of its Strategic Advisory Committee (SAC). The SAC addresses the strategic aspects of the NATURALHY-project and establishes a platform for dissemination and for promoting public understanding and acceptance of hydrogen. Participation is open, under certain conditions, to new third parties who show interest and organisations willing to join should contact Mr. Onno Florisson, Project Co-ordinator.

NATURALHY in the Global Hydrogen Arena

In March this year, with the support of the European Commission, a Collaborative Project Pre-proposal on the NATURALHY-project was submitted in the framework of the International Partnership for the Hydrogen Economy, IPHE (www.IPHE.net). The IPHE aims at serving as a mechanism to organize and implement effective, efficient, and focused international research, development, demonstration and commercial utilization activities related to hydrogen and fuel cell technologies. It also provides a forum for advancing policies, and common codes and standards that can accelerate the cost-effective transition to a global hydrogen economy to enhance energy security and environmental protection. Recently, the proposal submitted was selected by the IPHE Evaluation Team for "formal consideration", and further to this, a "formal project proposal for IPHE recognition" was submitted. Participation of the NATURALHY-project in the Partnership will put the project in the global hydrogen arena and offers interesting dissemination and collaboration perspectives.

Assessing the Durability of Natural Gas Infrastructures for Transporting and Distributing Mixtures of Hydrogen and Natural Gas

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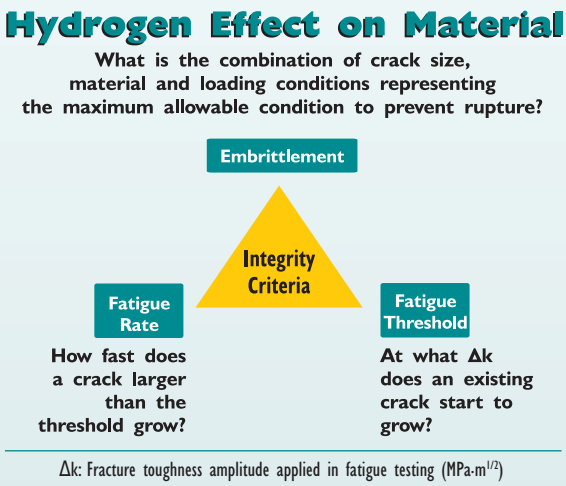
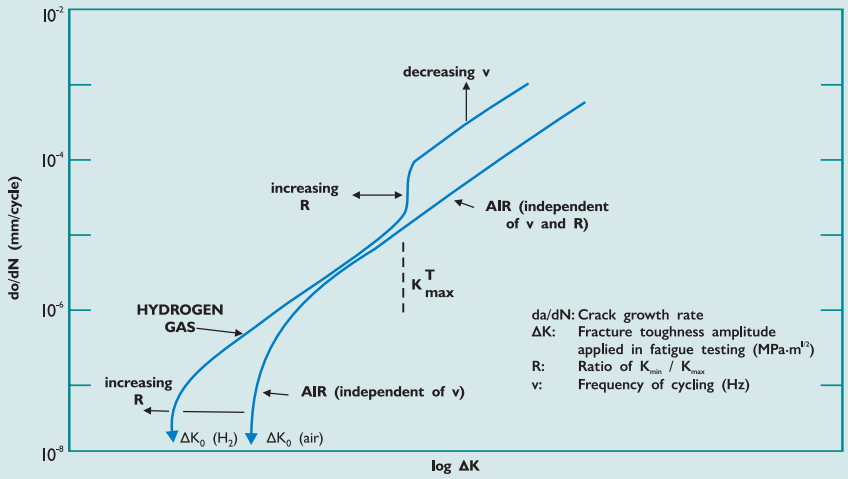
Durability of Steel for Transmission Pipes with H_2

Transmission pipes in the existing natural gas grids operate under high pressures, for example from 40 bar up to 100 bar. The steels (low carbon steels) used for building the transmission grids have been developed with higher and higher mechanical strength; the steel X42 is one of the oldest, used in the 60's and today operators have started to use the X80. But the higher the yield strength, the lower the resistance to crack growth. This risk is well managed for natural gas and should be assessed for hydrogen. Although the interaction of hydrogen with steels has been largely studied, the aim of using the steel grids designed for natural gas for transport of H_2 requires extended studies about the effect of hydrogen on the properties of these steels and understanding of the mechanisms. The various effects of H_2 on the steel materials behaviour are depicted in the figure below.



Hydrogen Embrittlement and its Effect on Toughness and Fatigue Behaviour

It is well known that hydrogen might initiate brittleness of steel pipes, which affects the failure resistance of the pipe and has consequences for the safety and the lifetime of the pipeline. The effect of pressurized gaseous hydrogen on the integrity of a pipeline is very complex. Preliminary experiments showed that the sensitivity of a pipeline for degradation by hydrogen is affected by, amongst others, the operational conditions of the pipeline. It was proven that a pipeline operated under fluctuating pressures, introducing fatigue cycles in the system, is more sensitive to degradation than a pipeline operated under more or less constant pressure. Pressurized gaseous hydrogen can affect the fatigue resistance of the material: it can reduce the threshold value for fatigue cracking and it can also result in an acceleration of the crack growth rate. The assumed effect of gaseous hydrogen on fatigue behavior is graphically presented in the figure below.



Effect of gaseous hydrogen on resistance of pipe steel to crack growth in fatigue loading

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Impact of Hydrogen Added to Natural Gas on the Performance of Natural Gas Appliances

Just admitting, say, 20 or 30 percent hydrogen to an existing natural gas network could threaten personal safety and cause equipment damage for end users.

The combustion phenomena causing these effects upon hydrogen addition are flashback and spontaneous (undesired) ignition. Domestic appliances and lean-premixed gas turbines are particularly sensitive to flashback, that is, unstable combustion and the escape of fuel gas, while the flame tends to enter the burner causing overheating and damage.

Thus a thorough consideration of these phenomena is needed in order to understand the extent to which all existing appliances, which are set up to work with the present range of pipeline natural gases, can cope with the admixture of hydrogen.

In order to fully understand the combustion properties of hydrogen natural gas mixtures, we should, in addition to the Wobbe index (gross calorific value divide by the square root of the relative density), also take into account the burning velocity of the mixture.

By using existing knowledge and new developments in the fundamental understanding of hydrogen/natural gas combustion, the impact of the hydrogen addition on the performance of existing natural gas appliances will be evaluated and predicted in the framework of the NATURALHY project. ❖

UPCOMING EVENTS

The 1st NATURALHY workshop will take place during the following event:

22-25 November 2005
2nd European Hydrogen Energy Conference (EHEC 2005) Zaragoza, Spain
www.ehec.info

NATURALHY will also participate in the events below:

8-10 September 2005
International Conference on Hydrogen Safety (ICHS) Pisa, Italy
http://hysafe.org

5-9 June 2006
23rd World Gas Conference (WGC) Amsterdam, the Netherlands
www.wgc2006.nl

13-16 June 2006
16th World Hydrogen Energy Conference (WHEC) Lyon, France
www.whec2006.com

1-5 June 2008
17th World Hydrogen Energy Conference (WHEC) Brisbane, Australia

16-21 May 2010
18th World Hydrogen Energy Conference (WHEC 18) Essen, Germany
www.18whec2010.de

From Another Point of View

Adding Hydrogen to Natural Gas

A view from the IEA greenhouse gas R&D programme

The International Energy Agency Greenhouse Gas Research and Development Programme (IEAGHG) is an international collaborative activity, investigating technologies for reducing greenhouse gas emissions. It was set up in 1991 and is supported by 16 countries, the EU and 10 industrial sponsors.

The IEAGHG is interested in hydrogen addition to natural gas as a possible method of reducing CO_2 emissions from the burning of fossil fuel. In the short to medium term the hydrogen would be produced from fossil fuels with capture of the carbon content as CO_2. The option is attractive as a route to a future hydrogen economy because it would make use of the investment in existing gas infrastructure. IEAGHG studies focus on the potential and cost of alternative technologies and particularly those which involve carbon dioxide capture and storage because this seems to have very large potential for emission reduction, could be implemented quickly and at affordable cost.

IEAGHG has completed one study on the addition of hydrogen to natural gas as a CO_2 emission abatement measure and is contemplating studies to explore possibilities further. The initial study looked at modest additions to up to 25% of molecular content and revealed a number of quite serious barriers. The costs of abatement were also rather high and the net reduction in CO_2 emissions was far less than might be expected from a maximum 25% addition. Average addition would be half this maximum figure unless a lot of spare hydrogen capacity was built because of the variation in gas demand over the year.

Also the calorific value of hydrogen is about one third that of natural gas so that more of the blend is required to supply the same amount of energy. Finally the conversion and capture processes suffer unavoidable inefficiencies. The actual CO_2 emission reductions were calculated to be in the range of 4-6% rather than the nameplate 25% which the maximum H_2 percentage might at first sight suggest. From the GHG emission viewpoint much higher average hydrogen additions would be required for the technology to have a significant effect.

Also more study needs to be done on gas quality bands to determine what is practical and whether there is a real case for moving to hydrogen gas mixtures rather than establishment of a separate 100% hydrogen grid.

Abatement cost estimates and comparisons should be a key element of future studies which need to determine whether the hydrogen in natural gas option could compete with CO_2 capture from fossil fueled electric power generating plants. ❖

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Durability of Polymer for Distribution Pipes with H_2

The polyethylene (PE) is the mostly used material for local distribution of natural gas at low pressures, from 16 bar down to few mbar. The main concern about pipes made of polymer like the PE is its permeability to H_2 which may induce leakage of gaseous H_2 and, therefore, a dangerous situation. Measurements were done on PE80 material samples in various conditions of pressure, H_2 content and temperature. Results showed that H_2 diffuses quicker than CH_4 and in larger quantities. Results will be used for calculating the potential leakages on distribution network and these data will be exchanged with the Work Package on Safety.

Literature is quite limited on ageing of PE in a H_2 gas atmosphere. Reduction of the role of anti-oxidant was reported. This subject will be studied under H_2 pressure with different H_2 content in CH_4 (up to 100%). The ageing tests will be accelerated by means of temperature increases. Tests at 10°C will simulate the actual thermal conditions. Mechanical and physical-chemical techniques will be used for investigating the evolution of the PE properties and micro-structure with ageing conditions.

Durability of domestic gas meters

The most common domestic gas meters are membranes meters, made with a polymeric membrane which is sensitive to H_2 permeation. Several potential effects of H_2 are expected:

- Potential influence on metering accuracy; the fact that hydrogen particles are smaller than natural gas ones may cause leakages through the membrane. In such a case, the measuring accuracy would be impaired,
- Potential influence on safety; the dimensions of hydrogen particles may lead to a leakage into the atmosphere through connection sealing,
- Potential influence on durability; Hydrogen's physical characteristics may damage the internal parts of the meter.

Then, the meters will be tested regarding their reliability for H_2 metering and ageing behaviour of the membrane in presence of hydrogen.

Durability Assessment Tool

All results obtained within the Work Package on Durability will be used for providing lifetime estimation for the different parts of the gas networks (transmission, distribution and inner grids) and adjusting the existing lifetime models for pipelines designed for natural gas. The results will be synthesized with the aim at developing sufficient knowledge in order to produce the assessment tool; new software tool for predicting damage impact on pipeline strength, verification of software simulation, and guidelines for end-users. It will be useful for simulating the most risky situations (severe defects, weak material pieces or joints, H_2 release, etc.), so that the safety resulting from the handling of mixtures of hydrogen and natural gas can be determined. Furthermore, the results are an essential input for the Work Package on Integrity.

Partners in the WP3 Durability

The WP3 "Durability" is led by Gaz de France. The partners involved are Gaz de France (F), BP Gas Marketing Limited (UK), Commissariat à l'Energie Atomique (F), Computational Mechanics International Ltd (UK), Centro Sviluppo Materiali SPA (I), DBI Gas- und Umwelttechnik GmbH (D), Public Gas Corporation S.A. (GR), N.V. Nederlandse Gasunie (NL), GE PII Limited (UK), Istanbul Gaz Dagitim Sanayi ve Ticaret A.S. (TR), Institut Français du Pétrole (F), Instituto de Soldadura e Qualidade (P), Türkiye Bilimsel ve Teknik Arastirma Kurumu (TR), National Technical University of Athens (GR), Ecole Nationale d'Ingénieurs de Metz (F), Statoil ASA (N), Total S.A. (F), Netherlands Organisation for Applied Scientific Research (NL).

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