

NATURALHY

"Preparing for the Hydrogen Economy by Using
the Existing Natural Gas System as a Catalyst"
Project Contract No.: SES6/CT/2004/502661

NATURALHY is an Integrated Project funded by the European Commission's Sixth Framework Programme (2002-2006) for research, technological development and demonstration (RTD)



DST - The Naturalhy Decision Support Tool

The ultimate goal of the Naturalhy programme is to identify, according to a number of different analyses, what can be expected to happen when a specific gas transport network or network section is carrying a mixture of hydrogen and natural gas, also called hythane.

Being an extremely complex and lengthy programme, Naturalhy delivers a massive amount of information on the economics, societal and environmental aspects of transporting hydrogen over a natural gas transmission network. Research also comprised a wide range of materials' properties and behaviour when in presence of several pressurised hydrogen concentrations, on separation membranes performance and costs for several end user applications, such as industries, filling stations, etc., on pipeline integrity and on gas transport network safety performance when carrying hythane.

It becomes quite difficult for a gas company to assess, under these different views, the set of potentially conflicting options and contradictory consequences of transmitting hydrogen over a pipeline system; to name just a few, consider the hydrogen lower calorific power or intrinsic gas properties that demand additional compressor station loads, energy expenditure, pipeline crack behaviour inspection and repair demands.

These and similar issues are addressed by the Naturalhy programme. In order to enable a Natural Gas Company research staff to actually perform a what-if analysis, an integrating mechanism, conveying, under a single and coherent interface, what happens to a specific gas transport network when hydrogen percentages are loaded, carried and extracted was devised: the Naturalhy DST – Decision Support Tool. The DST is a PC based software tool enabling a company to introduce a configuration layout of a specific gas transport network system or section and evaluate the consequences of carrying hydrogen over a number of active years.

It must be stressed that, under the presently available knowledge conditions and DST usability balance, only an overall and raw analysis is possible; therefore, the DST is focused on this type of analysis and not on replacing, for instance, commercially available pipeline integrity management systems which carry integrity analysis to a much more detailed level. In addition, the massive amount of detailed information on actual pipeline conditions and behaviour that is required in order to enable a thorough analysis is either simply not available at gas company level or requires a data collection cost that is not acceptable for the obtainable increase in accuracy.

The DST has two main uses: to inform, through its Information Repository, what is expected in material and device behaviour when certain hydrogen loads/percentages are applied and to simulate, using its what-if analysis capabilities, the actual pipeline degradation behaviour over certain periods of time being also able to apply, on the pipeline model, mitigation measures. Thus, the Naturalhy-DST key goals are to (i) enable editing, analysis and annotation of a pipeline network, so relevant information may be found and extracted at later stages, (ii) to allow comparison of parameters and measures amongst several pipeline network trunks and terminal points and (iii) to compute, from the information included by the operational Work Packages, a parameter set which will yield a comprehensive what-if analysis of applying different loads of hydrogen and natural gas in different subsections of the network;

The above-mentioned analysis comprises risk assessment, cost assessment, evaluation, and proposal of rules, guidelines and procedures that will mitigate the expected increase of risk when applying the gas mixture to the pipeline network.

The GTN layout form

The GTN sub-form is provided to enable the user to lay out a complete GTN. As previously stated, it is very important to keep in mind that the DST is not a PIM replacement tool. In spite that the user is

▶▶ PAGE 2

TABLE OF
CONTENTS

Page 1: DST - The Naturalhy Decision Support Tool

Page 2: Improved corrosion integrity management of pipelines using remote monitoring and modelling

Page 3: LURAP: A risk assessment methodology for transmission pipelines conveying natural gas/hydrogen mixtures

On 13th March 2009, we received the shocking news that Gjal Tiekstra had passed away after a very short illness of only three months. His wife and daughters were with him until the very end. He was only 58 years old.

Gjal led the NATURALHY project coordination team during the last two years.

With his passing, we have lost a dear and much appreciated colleague and friend. He will be missed by all that worked with or knew him.

We deeply sympathize with his wife and daughters.



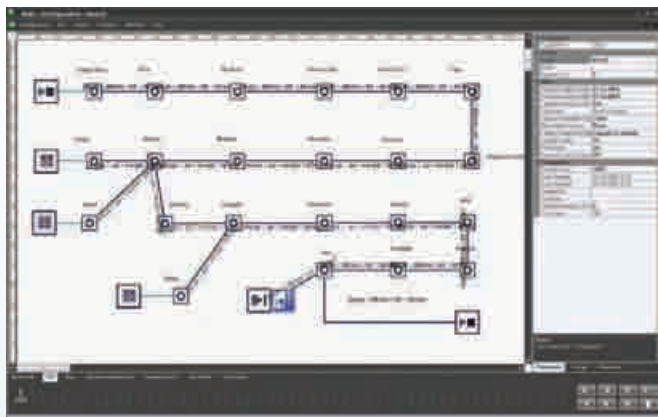
EDITORIAL

This is the ninth and final newsletter of the NATURALHY project, which aimed to define the conditions under which the existing natural gas infrastructure could be used for hydrogen delivery. Since the previous newsletter, the NATURALHY project has suffered a serious loss; on 13th March 2009, Gjal Tiekstra, the overall project coordinator, passed away after a very short illness of less than 4 months. This has of course been a tragedy for Gjal and his family, and has deeply shocked all who knew Gjal. In view of the importance of Gjal and his contribution to the NATURALHY project, the NATURALHY consortium dedicates this final Newsletter as homage to Gjal.

In this final newsletter, we tie up the loose ends of the project by focussing on the main final result, the so-called Decision Support Tool. In fact, this is a software tool which combines and integrates the outcomes obtained from within the NATURALHY project during the last 5.5 years. This means that it can support pipeline companies to determine the possibilities to accommodate hydrogen in their own grids. Crucial inputs into this tool are generated by improved corrosion integrity management using remote monitoring and modelling and by the associated 'LURAP', the newly developed safety risk assessment tool. These two subjects are explained in detail elsewhere in this newsletter.

Finally, we kindly invite you to the NATURALHY Final Public Presentation which will take place in Groningen on 19th November 2009. (Registration is via the NATURALHY website).

NATURALHY coordination team, Onno Florisson,
Folkert Koopman, Loraine Ho-A-Hing



(continued from page 1)

allowed to adopt whichever scale he or she wants, it does not make real sense to lay out a few meters pipe sections and define all types of joints, valves, compressors, active and passive elements. The goal is to quickly generate a raw what-if analysis.

GTN form main working areas

The GTN form comprises two principal areas: a drawing area, to the left, that can be seen in the figure, as a white dotted area, and a tool and control tabbed area, with 3 tabs: Parameters, Design and Overview.

The layout synoptic is laid on the GTN working area using a set of design tools. Elements and their specific properties are shown and can be edited in the Parameter tab.

If there is no selected GTN element, as in the pictured situation where there are no elements at all, the Parameters show the overall Configuration attributes and, on top to key Operating Expenses – the overall network cost for the time period and H₂ level, maintaining the risk at user selected levels.

The DST provides a comprehensive toolbox that enables the user to completely lay out a GTN. Access to the toolbox is provided through the Design tab on the tabbed work area.

The Toolbox contains four sets of buttons: a first set, on top, contains the four buttons that permit the insertion of pipelines, one button per accepted pipeline type; just below, there are the 10 buttons for the 10 possible types of GTN elements, described below.

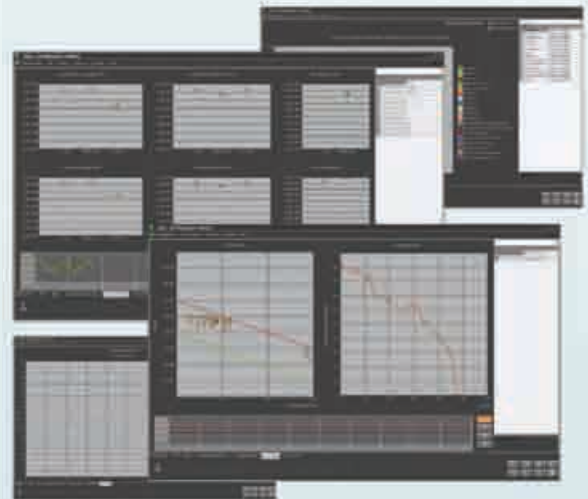
Then, separated, a button for inserting commenting text in the layout, followed by 6 aligning buttons and, finally, two key active buttons: one for validation of the GTN and one for calculating all simulated information for the Safety and Integrity analysis

In order to activate any function, the user just clicks on the button and clicks again, in the GTN work area where he or she wants to lay out the element or text. As per the aligning buttons, the user must first select a set of elements in the work area and then apply the aligning

function to it. Finally, but most importantly, the user uses the pipeline buttons to link any other GTN elements.

The DST is able to actually draw a map of the GTN so the user may actually see in the layout where sections cross population areas and establish more accurate risk distances (e.g. proximity to population densities). The DST presents several Dashboards, for Economic and Social analysis, for Safety, for Integrity and for Cost. With the exception of the Economic and Social analysis, all analyses are time dependent and show the evolution of the GTN properties over time.

Each of the dashboards evidences a specific analysis that is carried out by the Naturalhy DST. It is through the dashboards that comparisons between a GTN with or without hydrogen can be performed. The DST is extremely flexible and is able to carry out GTN simulation and comparison of any two configurations over a period of up to 50 years, yielding cost, safety and integrity calculations for all selected sections. The DST draws the standard technical charts on Safety and is able to plot all relevant defect information on a pipeline for integrity assessment.



Partners in WP6 Decision Support Tool

The WP6 “Decision Support Tool” is led by Instituto de Soldadura e Qualidade (P). The following partners are involved in WP6: The Open Group (UK), University of Borås (SE), National Technical University of Athens (EL), SQS Portugal (P), N.V. Nederlandse Gasunie (NL), GDF Suez (F), University of Oxford (UK), and DESFA (EL). ❖

Peter Bartlam and João Serras Pereira, ISQ

Improved corrosion integrity management of pipelines using remote monitoring and modelling

As part of the work on Integrity Management investigations have been performed into the possible needs in the improvements of inspection tools if Hydrogen was added to the Gas network. At the outset of the project it was considered a possibility that more frequent and more accurate inspections would be required in order to maintain the level of integrity. One approach investigated was to use a combination of remote monitoring and computer simulation of the cathodic protection system to provide real time data on the protection provided to the pipeline and identify defects in the protection system.

Corrosion in pipelines is normally controlled by two main different mechanisms: Coating and Cathodic Protection (CP) systems. Both systems need to be combined with a monitoring system in order to have an efficient solution for corrosion control. The monitoring approach needs to be cost efficient and accurate in order to detect anomalies and potential failures in real time for aiding pipeline operators in their maintenance and decision making policies. Monitoring is traditionally done by surveys (such as DCVG, or CIS), which do not provide systematic continuous quality assessment of the grid or real time reports. In addition they are costly and time consuming. Existing modelling and monitoring techniques can be combined in order to avoid the aforementioned drawbacks.

The benefits of an intelligent remote monitoring system are multiple. Firstly, it enables pipeline operators to assess the level of protection of their structures against corrosion avoiding the need of costly field surveys. Secondly, it helps to predict the remaining lifetime of sacrificial/perishable components in advance, such as for example organic coatings and protective paints, or sacrificial anodes. The data collected from the system can be employed to detect anomalies, such as the introduction of foreign metallic structures, stray currents, localised damage in the coatings, etc.

The prototype remote system is divided into a monitoring system, and a modelling system. The former consists of the set of hardware and software required to collect, transmit and store information from the CP system associated with the pipeline, such as voltages and currents read from the sensors distributed along the infrastructure. This monitoring system makes it possible to collect remotely real time potentials at test stations along the pipeline and becomes particularly useful for detecting anomaly behaviours.

The modelling system consists of a suite of simulation tools for the analysis of the collected data, in order to evaluate and predict the level of protection against corrosion, not only at the test stations but also along the pipeline by model prediction. The modelling software can also predict future levels of protection and identify defects in the protection system. It allows the quantitative assessment of different remedial strategies and eventually optimal design in case of contemplating modifications in the existing system.

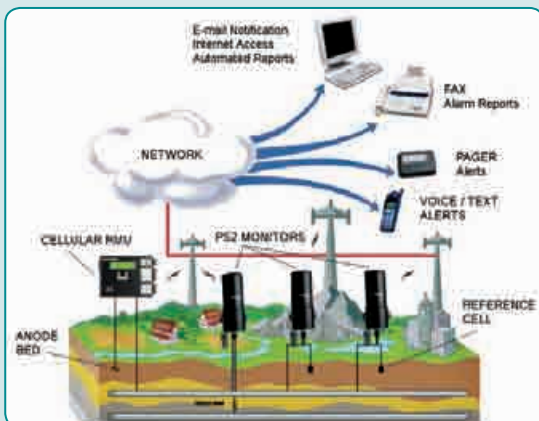
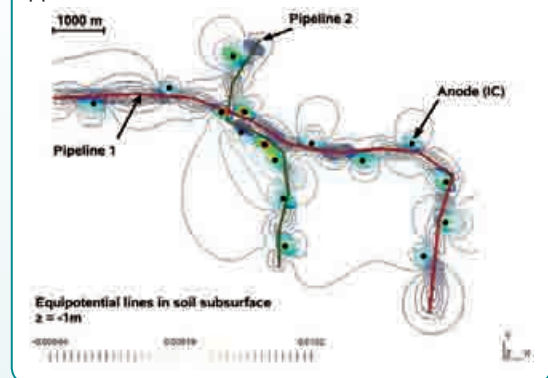


Figure 1 shows an example of a remote monitoring system deployed along a pipeline. The information (potential measurements among others) collected from the sensors is transmitted wirelessly to different clients throughout a network.

A test system was developed and implemented on a pipeline in Portugal to prove the concept and test the hardware and software. Data was successfully collected for assessing the potentials on the pipeline but there was insufficient time and data to fully integrate the modelling software to make predictions in real time. However historical data from surveys on the pipeline was also used and good initial results were obtained thus demonstrating the concept.

In summary the work has demonstrated the feasibility of improving Pipeline Integrity by using a remote monitoring system combined with a

Figure 2 shows the predicted potentials on the pipeline and at the ground surface by the modelling software in the case of two crossing pipelines.



reverse modelling simulation tool to obtain the following advantages:

- This system allows pipeline operators to quantitatively know the levels of protection on their pipelines without the need for personnel displacement for field surveys;
- The system provides a real time display of the protection levels of all their test posts. This system would have the advantage of allowing the following functions: On-line monitoring of relevant data including potential and current data.
- In addition, the system allows for immediate detection of troubleshooting; for example after a thunderstorm, theft of the test post, interference with other structures installed in the same corridor, etc.
- With this system, the operator has the possibility to call the CP station at any time in order to read the data and to predict the status of the pipeline and identify defects in the protection system using the computer model
- Incomplete data can be recomposed by means of the reverse modelling tool. ❖

*Dr Robert Adey & Dr Andres Peratta
CMI/BEASY Ltd, Gervasio F. Pimenta, ISQ*

LURAP: A Risk Assessment Methodology for Transmission Pipelines Conveying Natural Gas/Hydrogen Mixtures

The concept of the Naturally project is to introduce hydrogen into the gas network. However, the transmission pipelines were designed on the basis that natural gas would be transported. The addition of hydrogen may change the safety of the system and hence the risk posed to the public. Therefore, as part of the safety Work Package of Naturally, a risk assessment methodology (called LURAP) has been developed by Loughborough University which can assess the risk posed to the public by a network conveying a natural gas/hydrogen mixture and compare it with that currently expected for natural gas.

'Risk' is a measure of the number of fatalities per year. Risk is evaluated from the likelihood of an adverse event occurring and the consequences of that event. The 'consequences' are an assessment of the number of fatalities, based on a consideration of the hazard posed.

(continued from page 3)

In relation to transmission pipelines the hazard is the thermal radiation from a fire. Risk to the public is usually measured in two ways: 'Individual Risk', that is, the likelihood of an individual at a particular location relative to the pipeline becoming a fatality per year; and 'Societal Risk' which provides an overall assessment of the risk presented to the population living near a pipeline network.

LURAP Use and Capabilities LURAP is intended to be an easy-to-use screening tool with which pipeline operators can assess the change in risk of adding different levels of hydrogen to part or all of their network. It allows risk assessments to be performed for different years over a period of up to 50 years and allows hydrogen to be added to individual pipeline at different times. It is integrated within the DST which provides a User interface for all the input data required. In particular, LURAP requires information about the pipelines which form the network, such as the steel grade, diameter, wall thickness, operating pressure, depth of cover and year of construction etc. Other information includes the amount of hydrogen added to the natural gas in each pipeline and the year it is added.

Failure Frequency and Ignition Probability LURAP includes data on the failure frequency of natural gas pipelines based on historical data from two well-known natural gas pipeline incident databases provided by EGIG and UKOPA. This enables failure frequencies to be determined for each pipeline of the network as a result of failure mechanism such as Third Party Damage (TPD), Corrosion, Manufacturing/Construction Defects (Crack-like defects), Ground Movement and Hot-tap Errors. In addition, an empirical method of calculating the failure frequency from TPD has been included which provides a good approximation to a method based on structural reliability. The advantage of this approach for determining failure frequency from TPD is that the benefits of mitigation measures such as marking or slabbing over the pipeline, increasing the depth of cover, reducing operating pressure, or increasing the wall thickness can be realised in terms of a lower failure frequency.

The work by the Durability and Integrity Work Packages of Naturalhy has shown that the only failure mechanism likely to be affected by the presence of hydrogen is Manufacturing/Construction Defects as the presence of hydrogen can increase the rate of crack growth from fatigue. However, providing that an appropriate integrity management system is adopted the change in failure frequency is expected to be negligible for hydrogen concentrations up to 50% by volume. Nevertheless, LURAP enables the User to introduce factors by which the failure frequency from crack-like defects increases with time for the years after hydrogen is added should this be necessary.

Three methods for determining the ignition probability of natural gas pipeline failures are also available within LURAP. Conservative estimates of the ignition probability of hydrogen have been made and a method of determining the ignition probability of the mixture is incorporated within LURAP.

Hazard Posed by the Fire LURAP includes a model of the fire event itself, determining the length of the fire and thermal radiation field. This model was developed based on data from large scale experiments conducted within Naturalhy and from other data involving hydrogen provided confidentially to Loughborough University. This enables the thermal characteristics to be determined as a function of hydrogen concentration. Due to the lower density of natural gas/hydrogen mixtures, the mass outflow following a failure is reduced compared to natural gas and the pipeline depressurises more quickly. The overall result is that the thermal radiation hazard is slightly reduced for the mixture.

Determining Risk The effect of thermal radiation on people is a function of both the level of radiation and the time of exposure – termed the 'thermal dose' measured in thermal dose units ($\text{tdu} = (\text{kW m}^{-2})^{4/3} \text{ s}$). Typically a level of 1800 tdu would result in 50% fatalities and 1050 tdu corresponds to a 1% chance of becoming a fatality. It is also assumed that persons in the vicinity will attempt to escape and are likely to find shelter within 30 seconds. To provide a conservative approach, LURAP determines the distance to 1050 tdu over a 30 second period and uses this as a criteria for fatalities. In reality the outflow and fire event following rupture of a pipeline is a highly transient event and so the radiation will vary with time and distance following the rupture. However, prediction of the outflow is complex, so the approach taken by LURAP is to approximate the transient event by a steady outflow. The determination of the steady outflow level includes factors which are a function of the gas composition and so take into account the different mass outflow and more rapid depressurisation expected for pipelines which include some hydrogen.

Validation and Application In order to validate the LURAP, the methodology was applied to some benchmark exercises for 4 natural gas pipelines, which ranged in diameter from 273 mm to 914 mm with operating pressures of either 38 or 70 bar. The predicted distance to 1050 tdu by LURAP was compared with the results of a well established risk assessment package for natural gas pipelines and found to be within $\pm 10\%$.

Using the same 4 benchmark pipelines, the effect of risk of the addition of 25% by volume hydrogen can be seen on Figure 1 which shows the resulting individual risk with distance from the pipeline. As can be seen, the individual risk has increased at locations close to the pipeline but reduced at more distant locations, reflecting the reduced extent of the hazardous region for the natural gas/hydrogen mixture. ❖

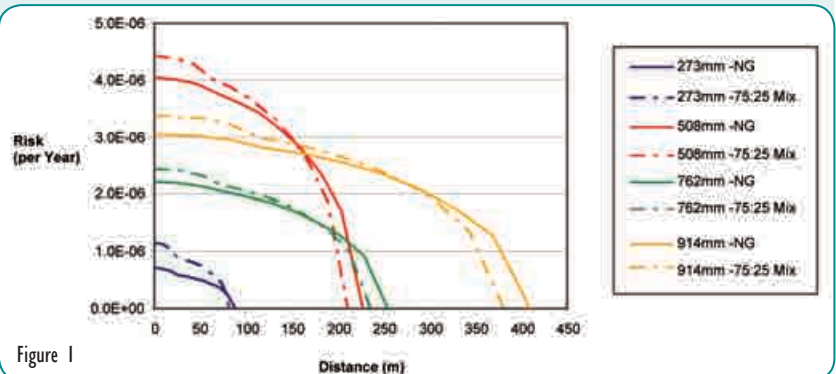


Figure 1

Prof G. Hankinson and Dr B. J. Lowesmith, Loughborough University

UPCOMING EVENTS

November 19, 2009 Final Public Presentation of Naturalhy, Gasunie Headquarters, Groningen, The Netherlands.

Registration via www.naturalhy.net or by email: naturalhy@gasunie.nl

CONTACT US

For more information on the NATURALHY Project, please contact:
 Onno Florisson Gasunie Engineering & Technology N.V. Nederlandse Gasunie // P.O.Box 19 // NL-9700 MA Groningen // The Netherlands // email: naturalhy@gasunie.nl
 OR Visit the NATURALHY website: www.naturalhy.net