Natural gas pipelines for hydrogen transportation

Laurent BEDEL[a], Michel JUNKER[b]

ALPHEA HYDROGENE
European Network and Center of Expertise on Hydrogen and its Applications
Parc d'Activités FORBACH Ouest - Rue Jacques CALLOT - 57600 FORBACH, FRANCE
Phone: +33 (0)3 87 84 76 55 – Fax: +33 (0)3 87 84 76 47
http://www.alphea.com
[a]laurent.bedel@alphea.com
[b]michel.junker@alphea.com

ABSTRACT:

Hydrogen transportation is a corner stone for settling up a hydrogen based economy. Using the existing natural gas pipeline network for hydrogen transportation could be a way to match hydrogen economy needs and today possibilities.

This paper presents some results from a study carried out by ALPHEA Hydrogène. Natural gas lines material compatibility with hydrogen service was studied, as well as the separation techniques allowing hydrogen recovery and economical aspects.

KEYWORDS: *hydrogen pipeline, natural gas grid.*

1. Introduction

Using the existing natural gas (NG) grid for the hydrogen service has been being considered over the past decades. Having a well developed H2-transmission grid is of major concern for building an extended hydrogen economy.

Even if some hydrogen pipelines networks exist, such as the northern Europe network owned by Air Liquide, there are currently no large and widespread national hydrogen grids. Building such a grid would require huge investments that can only be motivated by large hydrogen demand. In order to initiate this demand, supplying hydrogen by mixing it with natural gas and using the NG existing grid could be considered.

The aim of the first part of our study is to settle down the technical conditions to be fulfilled by the NG grid to be hydrogen compatible (materials susceptibility to hydrogen embrittlement or induced cracking, welds compatibility…).

In order to point out the pros and cons of the joint H2-NG route compared to other hydrogen dedicated methods, separation of hydrogen from natural gas has to be considered. In the second part of the study, separation techniques for large scale hydrogen separation from natural gas are discussed according to economics and NG service constraints.

Study end up with economical aspects related to hydrogen transportation as a mix with natural gas.

This paper does only present some of the results from our study. The full report is available at ALPHEA Hydrogène.

2. Material compatibility

Existing hydrogen pipelines networks are reviewed and their main characteristics are detailed (Table 1) and compared to those of the natural gas pipelines.

Location	Pipe material	Years of operation	Diameter (mm)	Length (km)	Service pressure (MPa) and hydrogen purity (%)	Satus
AGEC, Alberta, Canada	Gr.290 (5LX X42)	Since1987	273 (Thickness: 4.8)	3.7	3.8 (99.9%)	Operational
Air Liquide, Texas/Louisiana, USA	API 5LX42, X52, X60 and other	?	76 - 356	390	5.1	Operational
Air Liquide, France, Belgium, Netherlands	Seamless Carbon steel	Since1966	Up to 304.8	879	6.5-10 (pure and raw H2)	Operational
Air Products, Houston, USA	-	Since1969	114.3 – 324	100	0.345 – 5.516 (pure H2)	Operational
Air Products, Louisiana	ASTM 106	?	101.3 – 304.8	48.3	3.447	Operational
Air Products, Sarnia	-	-	-	~3	-	Operational
Air Products, Texas	Standard natural gas line pipe (steel)	>10	114.3	8	5.5 (pure H2)	Operational
Air Products, Texas	steel, Schedule 40	>8	219	19	1.4 (pure H2)	Operational
Air Products, Netherlands	-	-	-	45	(flow rate : 50 t/day)	Operational
South Africa	-	-	-	80	-	-
Chemische Werke Huis AG, Ruhr, Germany	Seamless equipment to SAE 1016 steel	Since1938	168-273	215	Up to 2.5 (pure H2)	Operational
Cominco B.C., Canada	Carbon Steel (ASTM 210 seamless)	Since1964	5 (Thickness: 0.8)	6	>30 (62-100 %)	Stand-by
Gulf Petroleum Cnd, Petromont – Varrnes	Carbon Steel, seamless, Schedule 40	-	168	16	93.5% H2-7.5% CH4	Operational
Hawkeye Chemical, Iowa	ASTM A53 Gr. B	3	152.4	3.2	2.8	Operational
ICI Billingham, UK	Carbon Steel	-	-	15	30 (pure H2)	-
LASL, New Mexico	ASME A357 Gr. 5	-	25.4	6.4	13.8	Abandoned
Los Alamos, New Mexico	5Cr-Mo (ASME A357 Gr. 5)	>8	30	6	13.8 (pure H2)	Abandoned
Linde, Germany	-	-	-	1.6 – 3.2	-	-
NASA-KSC, Florida	Stainless steel 316 (austenitic)	>16	50	1.6-2	42	Operational
NSA-MSFC, Alabama	ASTM A106-B	-	76.2	0.091	34.5	Abandoned
Philips Petroleum	ASTM A524	4	203.2	20.9	12.1 – 12.8	Operational
Praxair, Golf Coast, Texas, Indiana, California, Alabama, Louisiana, Michigan	Carbon Steel	-	-	450	H2 commercial grade (14 M Nm3/day)	Operational
Rockwell International S.	Stainless steel -116	>10	250	-	>100 (ultra pure H2)	-

Table 1 : Main features of hydrogen pipeline around the world[i]

It results from this analysis that transporting hydrogen as a mixture with natural gas is technically feasible. Nevertheless, natural gas transportation lines have been built over many decades, so, as a consequence, made of lots of different steel grades more or less sensitive to hydrogen embrittlement. Highest strength steels used (such as X70 or superior) are highly alloyed with materials inclined to hydrogen attack. Furthermore, their weldability require very high temperature processes which lead to hard spot formation if severe precaution are not taken into account such as post welding annealing. Most preferred steels for hydrogen use are austenitic steels, unfortunately also the most expensive. An alternative is given by the development of composite reinforced line pipes (CRLPtm) actually in test scale in northern America (Figure 1).

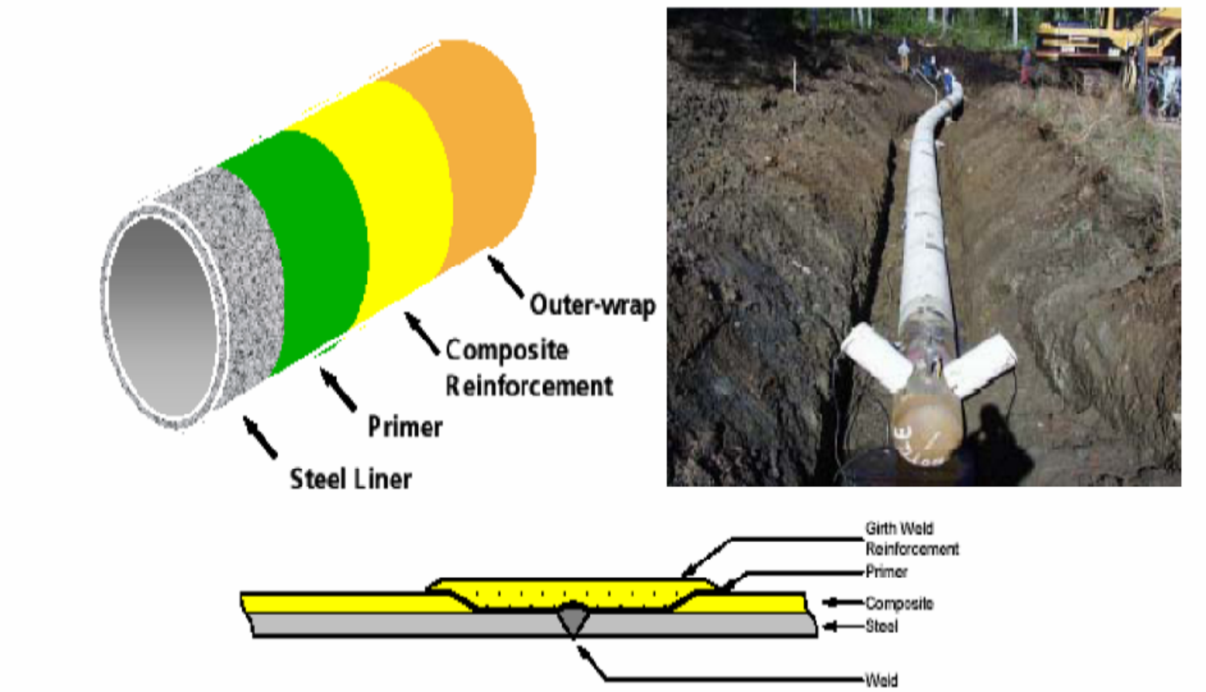

Figure 1 : Composite Reinforced Line Pipe (CRLP^{TM})[ii]

Problems of hydrogen embrittlement generally occur at pressure of more than 7 MPa i.e. the NG transportation lines service pressure. No generalisation can be done, but, as NG transportation lines pressure is below critical pressure for hydrogen embrittlement, a large number of NG pipeline sections could be compatible for hydrogen-enriched natural gas transmission even if their construction materials are not the best suited for a pure hydrogen use. Realisation depends more on economics than on technical challenges.

3. Separation process

Among cryogenic separation, pressure swing adsorption (PSA) and membrane technology, membranes seem to be the most promising separation technique for this special application. For example, recovering hydrogen from a PSA unit should involve the recovery of the main constituent (i.e. NG) at pressure as low as few bars, thus huge recompression costs for further transportation, while membrane use would lead to the recovery of valuable natural gas at high pressure.

Typical features of PSA, cryogenic units and permeation process are listed in Table 2.

	Typical features for		
	PSA	**Cryogenic separation**	**Membranes (organic)**
Produced Hydrogen			
Purity (% vol.)	Up to 99,9999 %	Up to 99 %	Up to 99,9 %
Hydrogen flow rate ($Nm^3.h^{-1}$)	100-100.000	5000-110.000	100-100.000
Possibility to increase capacity	possible	possible	**Easy**
Feed gas			
Min. H2 content (% vol.)	**50**	15	15
Process operating pressure (bar)	5-45	10-80 (max. : 120)	Up to 150
Performances			
H2 recovery yield (%)	50-95	Up to 98	Up to 98
Yield dependance to tail gas pressure	High	Some	**No**
Pressure drop between feed and H2	< 1bar	~2 bar	High

Table 2 : Typical values for PSA, cryogenic units and membrane separators[iii]

Organic membranes are currently used in industry. Inorganic porous membranes are still at the lab scale. These new permeation materials are very promising for large scale hydrogen purification.

4. Conclusion

Transporting hydrogen using the existing natural gas grid is technically feasible. According to our results, it seems to be a hardly economically viable way of hydrogen transportation, mainly due to separation costs.

Development of large scale hydrogen purification techniques, useful in large scale hydrogen production facilities such as considered in some clean coal technologies, should be facilitating hydrogen transportation as a mixture with natural gas.

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[i] *M. Mohitpour, H. Solanky and G. Vinjamuri "Materials Selection and Performance Criteria for Hydrogen Pipeline Transmission" proceedings of PVP 2004 Conference: 2004 ASME/JSME Pressure Vessel & Piping, San Diego, CA (2004)*
[ii] *TransCanada technical booklet "Composite Reinforced Line Pipe (CRLPTM)"*
[iii] *Air Liquide technical booklet "Hydrogen purification units"*