WHITE PAPER

HDPE PIPE IS HYDROGEN READY

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– Find out how modern HDPE pipe networks support the safe and efficient distribution of hydrogen. –

Hydrogen derived from renewable energy is a highly promising low carbon fuel. Whilst the hydrogen economy has been slow to emerge, it is starting to attract significant interest due to its capacity to store and transport renewable energy. Existing natural gas distribution networks in Australia made from HDPE piping are a practical way to distribute hydrogen. Recent research supports safe and efficient hydrogen distribution through HDPE pipe networks with operating risks comparable to natural gas.

RENEWABLE ENERGY SOURCES SUCH AS WIND AND SOLAR ARE PROGRESSIVELY INCREASING THEIR SHARE IN THE ENERGY MIX. ADVANCES IN TECHNOLOGY ARE DRIVING DOWN THE COST CURVE, MAKING RENEWABLE ENERGY INCREASINGLY COMPETITIVE COMPARED TO TRADITIONAL (FOSSIL) ALTERNATIVES. ONE OF THE KEY CHALLENGES IS THE INTRINSIC INTERMITTENT NATURE OF WIND AND SOLAR. STORAGE OF EXCESS RENEWABLE ENERGY HARVESTED DURING SUNNY AND WINDY DAYS IS A KEY REQUIREMENT TO DECREASE THE DEPENDENCE ON FOSSIL RESOURCES AND TACKLE GLOBAL CLIMATE CHALLENGES. EXISTING HDPE GAS PIPE NETWORKS MAY PROVIDE A VIABLE OPTION AS STORAGE AND TRANSPORT CAPACITY FOR RENEWABLE ENERGY.

HDPE PIPE IS HYDROGEN READY

Renewable electricity may be used to produce hydrogen from water by electrolysis with pure oxygen as the only by product. Hydrogen may be used in fuel cells to power electric vehicles but can also be used as alternative to natural gas in power plants, homes and businesses. Importantly, natural gas distribution networks may act as a storage for excess hydrogen, similar to a battery. Trials are currently ongoing in NSW, SA, ACT, and WA to test whether networks and appliances are able to cope with natural gas containing hydrogen at 10% or more. This requires existing gas networks to be compatible with hydrogen. As the majority of natural gas networks in Australia rely on HDPE piping today, the latest research focuses on the suitability of HDPE piping for the transport of hydrogen gas.

Kiwa Technology, one of the world's leading laboratories for plastic pipe testing and research, in collaboration with Groningen Seaports in the Netherlands investigated the suitability of the latest generation HDPE pipe (PE100 HSCR) for the transport of pure hydrogen gas and published their findings in a paper presented at the 2018 Plastic Pipe Conference.[1] The study focused on the chemical resistance of HDPE to hydrogen, the permeation rate of hydrogen through HDPE and the electrofusion coupling of HDPE pipe segments exposed to hydrogen.

The chemical resistance of HDPE to hydrogen was tested by exposure of ring shaped specimens cut from a DN90 SDR11 PE100 HSCR pipe to hydrogen at a pressure of 2 bar for 1,000 hours whilst subjected to constant deformation at room temperature. The ring specimens were subsequently weighed and a tensile test was performed to investigate any change in mass or strength as a result of chemical attack. The results indicated no significant change in mass or tensile strength thus supporting the case that HDPE is inert to hydrogen.

Figure 1. Peel test setup as per ISO 13954

One of the strengths of HDPE piping is its ability to be repaired via electrofusion jointing. To ensure that HDPE pipe networks containing hydrogen maintain this ability, pipe sections of the same type described above were exposed to hydrogen at a pressure of 2 bar for 1,000 hours at room temperature. Subsequently, these sections were fused via an electrofusion coupler in accordance with the Dutch welding standard NTA 8828:2016. Tensile specimens were cut from the joints and then examined by visual inspection and using the peel test in accordance with ISO 13954 (Figure 1). No cavities were found in any of the test bars and the peel test resulted in ductile failure of the pipe itself rather than across the joint, indicating no detrimental effect of hydrogen on the ability of HDPE piping to be repaired after exposure to hydrogen.

Figure 2. Permeation experimental setup in which the PE pipe (black with yellow stripes) is capped and pressurised whilst permeation is measured by gas chromatography in a stainless steel jacket pipe.

Concerns have been raised about the ability of hydrogen to permeate through piping materials as hydrogen molecules are very small. Small molecules are able to permeate through any solid membrane, including pipe walls whether made from metal, concrete or plastic. The rate of permeation is determined by many factors including the size of the permeating molecule. Molecular hydrogen H_2 has a kinetic diameter of 2.89 Å whereas methane CH_4 has a kinetic diameter of 3.8 Å.

> IT WAS SHOWN THROUGH PROLONGED EXPOSURE AND SUBSEQUENT MECHANICAL TESTING THAT HYDROGEN DOES NOT AFFECT THE INTEGRITY OF THE HDPE PIPE OR ITS ABILITY TO BE REPAIRED OR MAINTAINED THROUGH ELECTROFUSION JOINTING.

The Kiwa study revealed a permeation coefficient of 127 ml mm m^{-2} $bara^{-1}$ day^{-1} for hydrogen through HDPE at room temperature, which is roughly two times higher compared to methane at 56 ml mm m^{-2} $bara^{-1}$ day^{-1} (Figure 2). A DN90 mm SDR11 pipe operated at a hydrogen pressure of 2 bar would emit 4,360 litres of hydrogen per km per year. In comparison, the same pipeline transporting methane would emit 1,930 litres of methane per km per year (Figure 3). Gas loss through permeation for natural gas networks made form HDPE is considered negligible in comparison to the amount of gas that is being transported. This property does not differ significantly in the case of hydrogen.

In this context it is useful to take into account the lower energy density in terms of net heating value of hydrogen (10.81 MJ/m^3) compared to natural gas (36.65 MJ/m^3).[2] Considering also the lower operating temperature relative to research work, which is typically below 20°C for buried pipes, it is estimated that energy losses through hydrogen permeation are actually 30% lower for hydrogen compared to natural gas at equivalent network pressure (Figure 3).

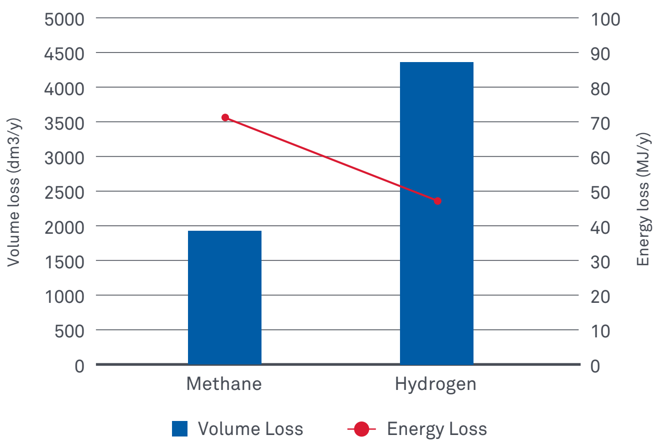

Figure 3. Volume and energy loss per year through permeation for a 1km long DN90mm SDR11 pipeline operated at 2 bar transporting either methane (natural gas) or hydrogen at room temperature.

The study concludes that when taking into account the different characteristics of methane and hydrogen, the operating risks relating to material integrity, network repair and maintenance, and gas permeability of HDPE networks are comparable.

The study indicates that modern HDPE pipe networks are fit for purpose for the transport of pure hydrogen at pressures up to at least 200 kPa, taking into account the specific characteristics of hydrogen such as its different chemical compatibility, higher rate of permeation and lower energy density that distinguish it from natural gas when adapting work procedures and safety instructions. This research strongly supports the ongoing trials in Australia where renewable hydrogen is injected to complement methane in HDPE natural gas networks.

References

1. R.J.M. Hermkens, H. Colmer, H.A. Ophoff, *Modern PE Pipe Enables The Transport of Hydrogen,* Proceedings of the 19th Plastic Pipe Conference PPXIX, Las Vegas, September 2018
2. Source: www.EngineeringToolBox.com

HOW THE RESIN MANUFACTURER CAN HELP

Transport of combustible gases and fluids remains a high risk application for polyethylene pipes, which is addressed through prescribed conservative design factors. Nonetheless, added robustness of the pipe may be required in trenchless installations, high risk areas or where squeeze-off is extensively used. This may be achieved through the selection of a polyethylene material with high stress crack resistance. Research and field performance identified resistance to Slow Crack Growth as the primary mechanism controlling service life in gas piping applications.

QENOS has developed Alkadyne® HCR193B – a new class of PE100 grade resin with stress crack resistance many times greater than standard PE100 resin. Developed in partnership with Australian pipe manufacturers, Alkadyne HCR193B has increased resistance to slow crack growth initiation caused by the presence of stress concentrators. The exceptional resistance to slow crack growth of Alkadyne HCR193B provides asset owners with greater confidence and a greater safety margin in trenchless installations and when utilising squeeze-off.

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