3

HYDROGEN COMPRESSED NATURAL GAS AND LIQUEFIED COMPRESSED NATURAL GAS: FUELS FOR FUTURE

Kriti Yadav and Anirbid Sircar

ABSTRACT: Due to the increasing demand of fuels natural gas is used not only in its original form but also as a mixture of several gases. Hydrogen Compressed Natural Gas (HCNG) and Liquefied Compressed Natural Gas (LCNG) are examples of such fuels. The paper narrates about two technologies:

(1) one in which the compressed natural gas is blended with the various proportions of hydrogen,

(2) while in case of Liquefied compressed natural gas (LCNG), Liquefied Natural Gas (LNG) is compressed to about 200 bar pressure to produce LCNG.

The paper also talks about the components necessary for LCNG and HCNG stations. In addition, the advantages and challenges related to these fuels are also described.

KEYWORDS

Natural Gas, Hydrogen, HCNG, LCNG

1. INTRODUCTION

Natural gas is considered as the most widely used alternative fuel for substitution of hydrocarbons (Bechtold, 1997). Natural gas is not only used in the form of LPG, CNG and LNG but also as Liquefied Compressed Natural Gas (LCNG) and Hydrogen Compressed Natural Gas (HCNG) (Shrestha et al., 1999). LCNG and HCNG are the two new trends in natural gas sector which are seen as the futuristic fuels of the world. In case of LCNG the liquefied natural gas is compressed up to a significant pressure and converted into compressed natural gas. It leads to the fueling of both CNG and LNG type vehicles at the same station point. While in case of HCNG a proportionate amount of hydrogen is blended to the compressed natural gas. At this type of station hydrogen as well as HCNG vehicles can be refuelled. These two fuels seem to be the future fuels which are also eco-friendly in nature. In case of India these are the developing technology which needs to be adapted.

2. HCNG

Since 1983 the mixture of natural gas and hydrogen have been used for test engine dating (Nagalimet al., 1983). In 1983 Nigalim B., Duebel F. and Schmillen K. conducted an experiment on AVL (Austrian based automotive consulting firm) engine fueled with 100/0, 80/20, 50/50 and 0/100 varying ratio of hydrogen and CNG. In year 1989, HCI (Hydrogen Components Inc.) started blending the various proportions of hydrogen to natural gas for testing the engine efficiency at Colorado State University (Hythane Company, LLC, 2007). The lean burn characteristic and the lower tail pipe emission is anticipated to be improved by the blending of hydrogen and CNG (Tunestal et al., 2002). Two types of fuels are formed by blending the various proportions of hydrogen to natural gas: one is HANG and another one is HYTHANE which is formed when 20% of hydrogen is added to 80% of CNG by volume. Typically the proportion of hydrogen, by volume for blending the natural gas varies from 8-50% (Table 2). Studies indicate that HCNG mixtures with 20-30% hydrogen by volume are optimal for vehicle performance and emission reduction (Del Toro et al., 2005). Refueling stations of HCNG requires a source for hydrogen and natural gas, which are pressurized and blended on-site for vehicle fueling. The supply of gas is through the natural gas infrastructure while the hydrogen is provided through electrolysis of natural gas reformation. By using the on-site electricity from local grid the phenomena of electrolysis is performed. Hydrogen from reformation of natural gas is supplied to sites by truck or produced on-site using low commercial reformers.

Figure 1 represents the integrated model of CNG and HCNG station where hydrogen as well as HCNG vehicles are fueled at same station. There are six major components which are required at combined CNG and HCNG stations, which are as follows:

1. Electrolyser
2. Source of Natural Gas
3. Source of Hydrogen
4. CNG/ Hydrogen Blender
5. CNG storage tanks
6. CNG and HCNG dispensers

Table 1 gives the comparative analysis of Hydrogen, CNG, 5% HCNG blend shows the characteristic values of HCNG with different hydrogen proportions. These properties confirm that the properties of HCNG lie between Hydrogen and CNG.

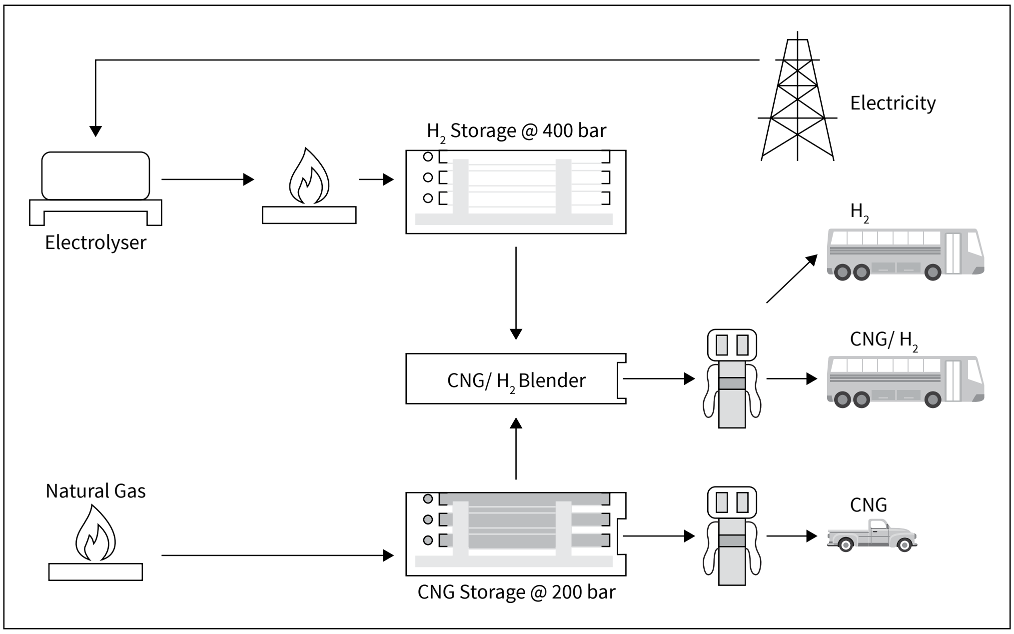

FIGURE 1. Integrated Model of CNG and HCNG Station *Source: modified after Pal, 2009*

Properties	Hydrogen	HCNG 5	Ch_4	Gasoline
Limits of flammability in air, [vol.%]	4-75	5-35	5-15	1.0-7.6
Stoichiometric composition in air, [vol.%]	29.53	22.8	9.48	1.76
Minimum energy for ignition in air, [mJ]	0.02	0.21	0.29	0.24
Auto ignition temperature, [K]	858	825	813	501-744
Flame temperature in air, [K]	2318	2210	2148	2470
Burning velocity in NTP (Normal Temp. & Press.) air, [cms^{-1}]	325	110	45	37-43
Quenching gap in NTP air, [cm]	0.064	0.152	0.203	0.2
Normalized flame emissivity	1.0	1.5	1.7	1.7
Equivalent ration flammability limit in NTP air	0.1-7.1	0.5-5.4	0.7-4	0.7-3.8
Methane Number	0	76	80	-

TABLE 1. Composition of Properties of Hydrogen, CNG and HCNG 5 with Gasoline

Properties	CNG	HCNG 10	HCNG 20	HCNG 30
H2 [% vol.]	0	10	20	30
H2 [% mass]	0	1.21	2.69	4.52
H2 [% energy]	0	3.09	6.68	10.94
LHV [$MJkg^{-1}$]	46.28	47.17	48.26	49.61
LHV [$MJNm^{-3}$]	37.16	34.50	31.85	29.20
LHV stoich. Mixture [$MJNm^{-3}$]	3.376	3.368	3.359	3.349
LHV - Lower Heating Value				

TABLE 2. Properties of CNG and HCNG Blends with different hydrogen content

Source: Xu et al., 2010

2.1 ADVANTAGES OF HCNG:

• It requires only a small hydrogen storage and a column for the mixing of hydrogen with natural gas at existing CNG stations.

• Safety components are similar to the CNG. HCNG is easy and safe to use than hydrogen as it contains very low energy content from hydrogen i.e., up to 30% by volume.

• HCNG reduces the engines unburned hydrocarbon emissions and speed up the process of combustion.

• The engines fuel efficiency is improved by blending the CNG from hydrogen which lowers the fuel consumption of vehicle.

• The thermal efficiency and fuel economy is also increased by HCNG.

2.2 DISADVANTAGES

• HCNG storage and supply infrastructure is a big challenge.

• System performance and material compatibility needs to be taken in account.

• Emission testing of HCNG blends needs to be done with various ranges of hydrogen.

3. LCNG

LCNG stations are the type of stations which make LNG gasified to become CNG and fuel both LNG and CNG vehicles. The source of natural gas at LCNG stations are through LNG storage tanks, where the dispenser for both LNG and CNG vehicles are available. Cryogenic pumps are used at LCNG stations for moving the LNG from an insulated storage vessel through dispenser into the vehicle. To produce CNG from LNG the gas is compressed up to 300 bar pressure in a controlled manner so that it can be dispensed at the right pressure as CNG. The LCNG stations use LCNG skid to pump the LNG liquid through high-pressure piston pump into the vaporizer, to make it become gas and save it into the cylinder or well, then it uses CNG and LNG dispensers to refuel the vehicles. An LCNG station has cryogenic LNG pumps and LNG storage tanks. The LCNG stations generally have high capital but low operating costs in comparison to CNG and LNG stations. LCNG stations mainly consist of:

• Storage vessel – tanker truck delivers LNG to storage vessel

• Cryogenic pump – moves LNG from storage to dispenser and vaporizer

• Vaporizer – converts LNG to gas and controls pressure to dispense it as CNG

• Dispenser – both LNG and CNG dispensers

Figure 2 represents the combined LNG and CNG stations which can fuel both LNG and CNG vehicles at the same station points. There are generally two basic types of LCNG stations one uses the cryogenic centrifugal pump whereas the other uses the boil off recovery system to convert LNG to CNG.

3.1 ADVANTAGES

• It has low capital cost than LNG and CNG stations.

• High refueling capacity for LNG vehicles.

• It can serve to both LNG as well as CNG vehicles both.

• It has flexibility to refuel heavy and light commercial vehicles.

• Low space requirement.

3.2 DISADVANTAGES

• High operational cost.

• Not capable to fuel the high pressure trucks.

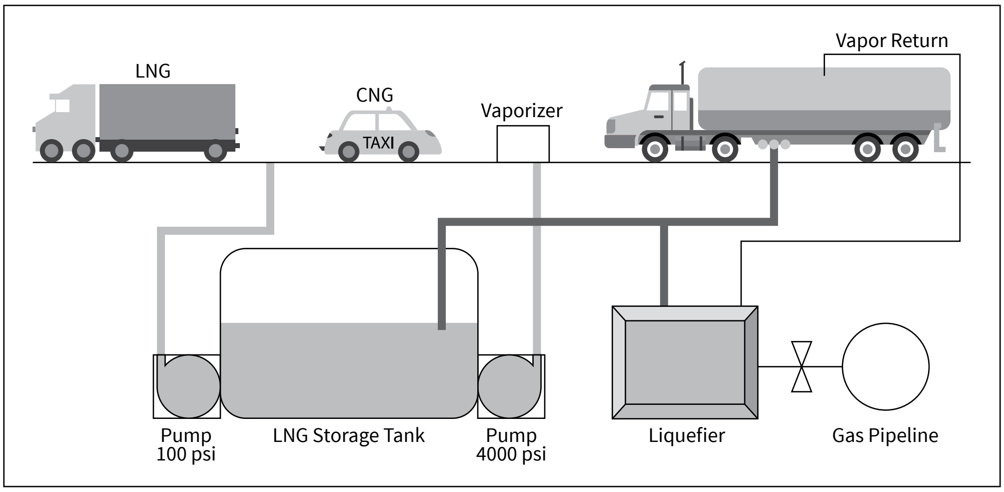

FIGURE 2. Liquefied Compressed Natural Gas (LCNG) Station *Source: Wegrzyn and Litzke, 1999*

4. CONCLUSION

The paper gives an overview about the two futuristic fuels LCNG and HCNG. It talks about the types of fuels formed due to the blending of hydrogen at different proportions. The paper articulates the six major components present at HCNG stations along with the comparative analysis of various properties of Hydrogen, HCNG5, CNG and Gasoline. The paper also emphasises on the advantages and disadvantages of HCNG and LCNG. Along with HCNG it talks about the four major components of LCNG which are storage vessels, cryogenic pump, vaporizer and dispenser. It also depicts the integrated model for LCNG and HCNG stations. It is found from various literature that the storage and supply infrastructure is a big challenge in terms of HCNG vehicles. The LCNG techniques is still in a need to be adapted in India while HCNG pilot projects are going on in two states of India. The initiative is taken by Indian oil, the first HCNG dispensing system was set up at Faridabad in 2005 where the HCNG @ 250bar pressure is served. While another station is established in Dwarka, Delhi in 2009 where HCNG @ 250bar pressure is served. The technology of LCNG is significantly adapted in Europe, Brazil, etc.

REFERENCES

Bechtold, R. L. (1997). Alternative fuels guidebook: properties, storage, dispensing, and vehicle facility modifications.

Del Toro, A., Frailey, M., Lynch, F., Munshi, S., & Wayne, S. (2005). Development and demonstration of hydrogen and compressed natural gas (H/CNG) blend transit buses. National Renewable Energy Laboratory Technical Report NREL/TP-540-38707 for Contract No. DEAC36-99-GO10337.

Hythane Company, LLC. (2007). Hythane: Blue Sky Clean Air http://www.hythane.com

Kavathekar, K. P., Rairikar, S. D., &Thipse, S. S. (2007). Development of a CNG injection engine compliant to Euro-IV norms and development strategy for HCNG operation (No. 2007-26-029). SAE Technical Paper.

Nagalingam, B., Duebel, F., & Schmillen, K. (1983). Performance study using natural gas, hydrogen-supplemented natural gas and hydrogen in AVL research engine. International Journal of Hydrogen Energy, 8(9), 715-720.

Pal N.K. (2009). "Successful Adoption of CNG and Emerging CNG-H2 Program in India" Proceedings to US DOT and DOE Workshop Compressed Natural gas and Hydrogen Fuels: Lesson Learned for the Safe Development of Vehicles, Washington DC, December, 10-11, 2009.

Shrestha, S. B., & Karim, G. A. (1999). Hydrogen as an additive to methane for spark ignition engine applications. International Journal of Hydrogen Energy, 24(6), 577-586.

Tunestål, P., Christensen, M., Einewall, P., Andersson, T., Johansson, B., &Jönsson, O. (2002). Hydrogen addition for improved lean burn capability of slow and fast burning natural gas combustion chambers (No. 2002-01-2686). SAE Technical Paper.

Xu, J., Zhang, X., Liu, J., & Fan, L. (2010). Experimental study of a single-cylinder engine fueled with natural gas–hydrogen mixtures. International journal of hydrogen energy, 35(7), 2909-2914.

Wegrzyn, J. E., Litzke, W. L., &Gurevich, M. (1999). Natural gas as a fuel option for heavy vehicles (No. 1999-01-2248). SAE Technical Paper.

Kriti Yadav
School of Petroleum Technology,
Pandit Deendayal Petroleum University,
Gandhinagar, Gujarat, India

Anirbid Sircar
School of Petroleum Technology,
Pandit Deendayal Petroleum University,
Gandhinagar, Gujarat, India

Email: *kriti.yphd15@spt.pdpu.ac.in*