Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 07, July - 2025

Conversion of CNG Fuel System to H2IC Fuel System for Commercial Vehicles

Rajat Srivastava, Mukesh Kumar Sharma, Gaurav Kumar Singh,
Shoaib Mustafa, Sunil Hemachandran

Abstract
The conversion of CNG fuel systems to H2IC fuel systems in commercial vehicles is an encouraging step towards affective cleaner transportation. Hydrogen, as a zero-emission fuel, which offers significant environmental advantage in comparison to CNG, emits CO2 upon combustion. This involves critical changes in design, including the replacement of storage cylinders with high-pressure hydrogen-compatible cylinders and its affiliated parts, improvement in the fuel delivery system, and recalibrating the engine for hydrogen's distinct combustion property. Advanced material and safety for the user and surroundings are essential to address hydrogen's unique characteristics, i.e. high flammability and risk for metal embrittlement. To enhance operational safety, hydrogen leak detection systems and safety valves have been incorporated. Although the infrastructure constraints and cost for conversion provide us significant challenges, this transition will support the global sustainability objectives which is top most priority for the world. This study outlines the technical and regulatory aspect of such conversions, which is aiming to support the acceptance of hydrogen fuel system in commercial transportation. Additional adjustment involve recalibrating the air-fuel mixture and ignition timing to achieve high performance and efficiency higher in comparison to CNG fuel system. Moreover, the refuelling infrastructure must be able to support hydrogen, including compatible nozzles and pressure regulators. While the introductory costs and limited hydrogen refuelling chain poses a great challenge, this conversion helps encounter with global efforts to reduce greenhouse gas emissions and dependency on fossil fuels. By knowing these technical and regulatory considerations, hydrogen-powered commercial vehicles will play a crucial and decisive role in decarbonizing the transportation sector for commercial vehicles. This research paper intent to provide a detailed changes required for the H2IC fuel system, which includes engineering modifications, emissions performance, and techno-economic feasibility with all safety requirements, and regulatory compliance required and necessary for strong and successful implementation, aiming to hype hydrogen as a viable fuel for future commercial vehicle fleets and future zero-emission technologies.

INTRODUCTION

As we all know that the global automotive sector advances its evolution towards sustainable and low-emission propulsion technologies, hydrogen is emerging as a viable alternative fuel owing to its high energy content per unit mass and zero-carbon emissions which we can use. While hydrogen fuel cell systems have attracted traction, the H2IC fuel system gives an enticing transitional solution by taking advantage of conventional engine platforms while significantly reducing exhaust emissions.

An H2IC system works by compressed gaseous hydrogen into a modified SI or CI engine, where it will get combusted with air in the combustion chamber. Key requirement typically include changes in fuel injection systems, changes in ignition timing, strengthen engine components, and specially designed materials to encounter hydrogen's high flame speed and lower ignition energy. The stoichiometric air-fuel ratio for hydrogen 34:1 is far greater than gasoline 14.7:1, which will lead to empower lean burn operation, improving thermal efficiency and reducing NOx emissions which will come in affect when controlled effectively.

Hydrogen has special combustion characteristics, such as broad flammability limits (4-75% in air) and a high flame velocity and can be burned quickly, which could have the effect of increasing engine efficiency. Yet such properties suffer the problem of pre-ignition, backfiring, and high cylinder temperature, which must be mitigated with highly precise engine calibration and advanced control. Furthermore, hydrogen storage and transfer, traditionally through high-pressure (350–700 bar) tanks, necessitate strong safety features and thermal control.

When compared with FCEVs, H2IC-fueled engines result in faster deployment, as they are compatible with current manufacturing, which requires lower capital investment and simpler powertrain integration. They are consequently especially well adapted to commercial vehicle applications, including buses and trucks and for off-road equipment such as earth moving vehicles, where range, refuelling time and payload are important considerations.

Principle of operation The H2IC works on the basic principles of thermodynamics with a conventional SI engine, meaning that it works on the Otto- or the Atkinson cycle. But instead of hydrocarbons like gas or CNG, it burns hydrogen gas mixed with air in the combustion chamber to produce power.

PERFORMANCE METRIC COMPARISON

Metric	H2IC Engine	CNG Engine
Fuel Energy Density (MJ/kg)	~120 (very high)	~50
Thermal Efficiency	38–45% (lean burn possible)	30–38%
CO_2 Emissions	~0 g/km (no carbon in fuel)	~130–180 g/km (lower than gasoline)
NOx Emissions	Low–Moderate (can be minimized)	Moderate
Combustion Speed	Very High (fast flame propagation)	Moderate
Engine Noise	Lower due to smooth combustion	Comparable
Backfire Sensitivity	Higher (requires careful timing)	Lower
Range (on full tank)	Moderate (due to low volumetric density)	High
Chemical Formula	H_2	CH_4 (Methane dominant)
Stoichiometric Air-Fuel Ratio	34:1	17.2:1

Table 1

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 07, July - 2025

COMPARISON WITH CNG FUEL SYSTEM

Parameter	H2IC System	CNG System
Fuel Type	Hydrogen gas (H_2)	Compressed Natural Gas (methane-based)
Carbon Emissions	Zero tailpipe CO_2	Low, but non-zero
Flammability Range	Wide (4–75%)	Narrower (5–15%)
Auto-ignition Temperature	~585°C	~540°C
Ignition Energy	~0.02 mJ (very low)	~0.29 mJ
Storage Pressure	350–700 bar	200–250 bar
Combustion Temperature	Higher (produces more NOx)	Moderate
Fuel Infrastructure	Emerging	Well-established in many countries
Cost of Retrofit	Higher due to specialized components	Lower
Environmental Impact	Near-zero emissions	Lower impact than petrol/diesel, but not zero

Table 2

OVERVIEW OF THE CONVERSION OF CNG FUEL SYSTEM TO H2IC FUEL SYSTEM FOR COMMERCIAL VEHICLES

Designing a commercial vehicle which can run by H2IC versus CNG involves major differences in packaging, safety, and vehicle system integration. An H2IC vehicle requires high-pressure cylinders, often operating between 350 to 700 bar, which must be securely mounted within the chassis using advanced composite materials and placed in well-ventilated zones to prevent accumulation of leaked gas. Design for H2IC should accommodate hydrogen-specific fuel lines, sensors, and electronic control systems which results in a more complex layout of vehicle design. Additional thermal shielding and leak detection systems are integrated throughout the vehicle. In contrast, CNG vehicle design is relatively simpler, as CNG tanks operate at lower pressures (typically 200–250 bar) and are more compact. Standard-grade steel or composite cylinders are used, and integration into existing commercial vehicles should be more straightforward. CNG systems gets advantage from sophisticated infrastructure and well established safety regulations from the respective governments which eases design constraints for the vehicle. Overall, H2IC vehicle design demands more advanced engineering to meet hydrogen's unique storage and safety requirements, whereas CNG vehicles offer a more conventional and cost-effective design pathway with easier adaptation to current platforms.

MAJOR AFFECTED AGGREGATES FOR THE CONVERSION –ENGINE

The basic engine architecture in H2IC and CNG engines are very similar, as both of them use spark-ignition designs which comes from traditional petrol engines. However, due to the unique combustion characteristics of hydrogen, so many internal modifications are required in H2IC engines. Hydrogen has a broader flammability and higher flame speed range, which demands careful control of ignition timing and air-fuel mixing to prevent pre-ignition or knock. H2IC engines often use specially coated valves, hardened valve seats, and modified spark plugs to withstand higher combustion temperatures. In addition, due to hydrogen's low lubricity, engine parts materials and oils are selected to decrease the
wear in engine components. In comparison, CNG engines work under conditions closer to conventional spark-ignition systems and require very few internal changes in engine. CNG combustion is kind of slower and stabilized which results in lower peak temperatures and easy in operation. Therefore both engines are using similar architecture, H2IC engines need more advanced thermal management with specialized materials and more control strategies for safely handling hydrogen's reactive nature.

The Engine Block and Internal Components in H2IC and CNG engines are totally working on conventional spark-ignition designs but varying in material selection, component reinforcement, and thermal handling due to the difference in combustion properties of both the fuels. H2IC engines are getting operated at higher combustion temperatures and faster flame speeds which require the engine block to be made from heat-resistant alloys or reinforced aluminium. Engine components such as pistons, valves, and cylinder heads are generally coated with thermal barrier coatings and valve seats are typically hardened to abide increased wear. Hydrogen's dry combustion also demands better lubrication oil to minimize friction-generated damage. In comparison, CNG engines produce slightly lower combustion temperatures and pressure spikes, which allows for the use of standard engine blocks with only slight adjustments. Pistons and valve trains in CNG engines are usually similar to gasoline counterparts, requiring less thermal or wear resistance. While the base design remains comparable, H2IC engines need high grade materials and precision engineering to ensure longevity and durability under hard operating conditions.

The air-fuel mixing systems in engines of H2IC and CNG vehicles are designed in a way to suit the combustion characteristics of their respective fuels. In H2IC engines, air-fuel mixing need very precise control because of hydrogen's wide flammability range and low ignition energy. Hydrogen can ignite prematurely if not handled with care, so direct injection into the combustion chamber is often preferred to avoid backfiring which improves in combustion timings. This is a way which helps us in achieving lean burn operation, enhancing thermal efficiency and decreases NOx emissions. In comparison, CNG engines generally use port fuel injection in which natural gas is mixed with air before entering the

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 07, July - 2025

combustion chamber. This way it works effectively due to methane's relatively stable combustion nature and narrow down the flammability limits. This ratio controlled in CNG engines are less complex which allows for smoother integration with traditional engine control systems. Overall, with both fuel systems are aiming for optimal combustion, H2IC engines need more advanced air-fuel mixing strategies to achieve the safety and affectively handle the unique characteristics and combustion properties of hydrogen

FUEL SYSTEM

The Fuel Systems in H2IC and CNG engines differ typically in overall design, storage and handling requirements. H2IC systems are designed to handle hydrogen's low energy density and high diffusivity requires in high-pressure tanks in between 350–700 bar which is made of high composite materials to meet the safety and containment. Hydrogen injectors and fuel lines must be specially designed for preventing leakage and resist metal embrittlement. In comparison, CNG systems are getting operated at lower pressures which is somewhere around 180-200 bar and use of steel or composite cylinders, with conventional injectors adapted for methane's properties. While both systems demand gaseous fuel injection technology, hydrogen's smaller molecular size necessitates more stringent sealing and materials compatibility. In addition, due to hydrogen's flammability range and ignition characteristics, H2IC systems are designed with more robust safety sensors and ventilation in accidental cases. Overall, while both fuel systems share a same foundation in gaseous fuel handling, hydrogen's physical and chemical characteristics require higher advanced and customized system components in comparison to CNG.

The Fuel Delivery Systems in H2IC and CNG engines has primarily change due to the difference in physical and chemical properties of the two fuels. In H2IC systems, hydrogen is basically stored at very high pressures and passed through specifically designed fuel lines and injectors which prevents leakage and can withstand hydrogen embrittlement. The fuel delivery system should also account for hydrogen's low density and high diffusivity which requires precise measuring and advanced control systems to ensure proper safety and effective combustion. On the other hand, CNG fuel delivery systems are relatively simpler which operating at lower pressures and using the materials which are already well-designed and well-established for methane handling. CNG injectors and regulators are designed for stable flow and pressure control, with less stringent requirements for sealing compared to hydrogen systems. In addition, hydrogen's fast flame speed and wide flammability range required more complex fuel-air mixing strategies in the delivery system to avoid pre-ignition or backfiring. In summary, while both systems deliver gaseous fuel to the engine, the hydrogen fuel delivery system needs high advanced engineering solutions to meet its unique challenges, whereas the CNG system get benefit from well-established, comparatively less complex technology and if we work on the H2IC like we once worked on CNG we can achieve the same feat again and say the same for H2IC that it is well-designed and well-established, we only just need to think in the same direction.

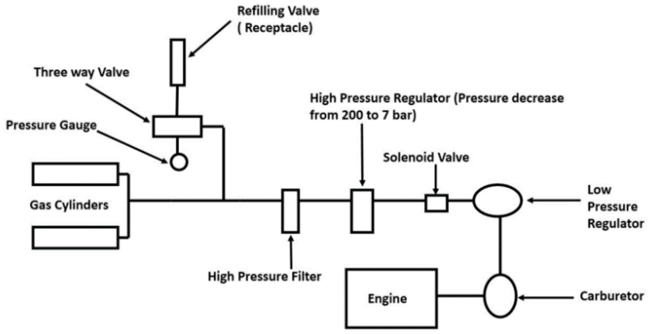

Figure -1 CNG fuel system line diagram

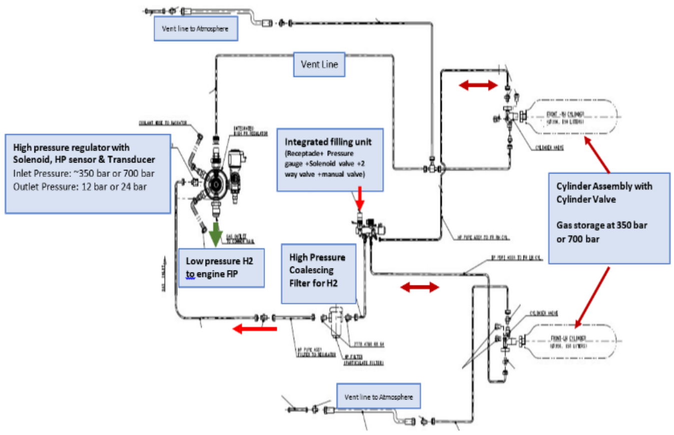

Figure – 2 Hydrogen fuel system line diagram

ELECTRICAL SYSTEM

The Electrical Systems in H2IC and CNG vehicles share so many fundamental components, such as the battery, alternator, ignition system and control units but they differ in terms of system complexity and sensor integration. In H2IC engines, the electrical system is more advanced due to the need for precise monitoring and control of hydrogen's reactive combustion behaviour. This includes of additional sensors for detecting hydrogen leak, higher-resolution of advanced air-fuel ratio monitoring and need of more advancement in ignition control circuitry. The wiring harness and connectors in H2IC vehicles are often upgraded for high-speed data communication between sensors and the ECU, specifically designed for real-time adjustments which prevents backfire and manage NOx emissions. In comparison, CNG electrical systems are more conventional, resembling those used in gasoline vehicles. They include standard sensors for pressure, temperature, and oxygen levels, along with traditional spark ignition control. Since methane has a more stable combustion profile, fewer specialized sensors and real-time safety mechanisms are needed. Overall, the electrical system in H2IC engines is more sensor-rich and electronics-intensive, reflecting the stricter demands of hydrogen handling and combustion management.

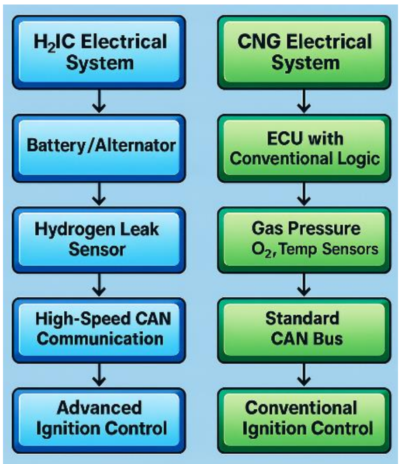

Figure – 3

The Electronic Systems in H2IC and CNG engines are majorly liable for managing engine functions, sensor inputs and fuel system controls but they vary typically in complexity and requirements. In H2IC vehicles, the electronic system is more significantly advanced and sensor-intensive which leads to hydrogen's reactive nature and high combustion sensitivity. It included specialized highly advanced: hydrogen leak detectors, NOx sensors, high-resolution oxygen sensors and engine control units (ECUs) with real-time processing capabilities results in smoother function of the vehicle. These systems continuously monitor fuel flow, combustion conditions and emissions which enables precise adjustments for safety and efficiency. In comparison, CNG electronic systems are more conventional which are relying on standard temperature, pressure and lambda sensors to support combustion control. The ECU in CNG engines is typically based on gasoline engine logic which requires only moderate and simple adaptation for gas injection and spark timing. While both systems use CAN bus architecture for communication, H2IC electronics demand precise and faster data handling, feedback loops which in terms enhanced diagnostic capabilities to maintain operational safety and performance.

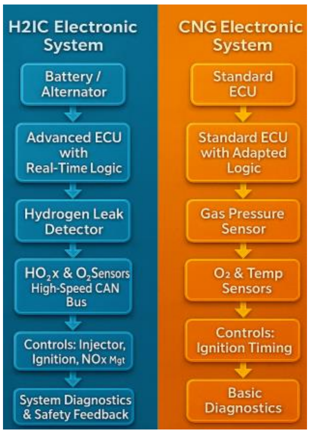

Figure – 4

The Sensor Systems in H2IC and CNG engines are way more critical and should be precise for engine control, safety and emissions monitoring, but very much different in complexity and functionality because of the unique characteristics of hydrogen and methane fuels. H2IC engines required highly précised and extensive sensor network which includes hydrogen leak detectors, high-precision NOx sensors, high-resolution oxygen (lambda) sensors, and cylinder pressure sensors for real-time monitoring of combustion conditions. These are the sensors which helps the ECU regulate hydrogen injection, prevent backfire, and ensure safe operation under lean-burn conditions. In addition, temperature and flow sensors are used to manage cooling and airflow, given hydrogen's higher combustion temperatures. In comparison, CNG engines typically based and design on basic pressure sensors, oxygen sensors, temperature sensors, and knock sensors to manage combustion efficiency and emissions. As we all know methane is more stable and less reactive in comparison to hydrogen, CNG systems do not require real-time leak detection or high-speed gas monitoring because of the lower pressure. Overall, H2IC sensor systems are more safety-driven and required precision in higher-speed communication and diagnostics, whereas CNG systems are simpler which rely on proven, conventional sensors for engine control.

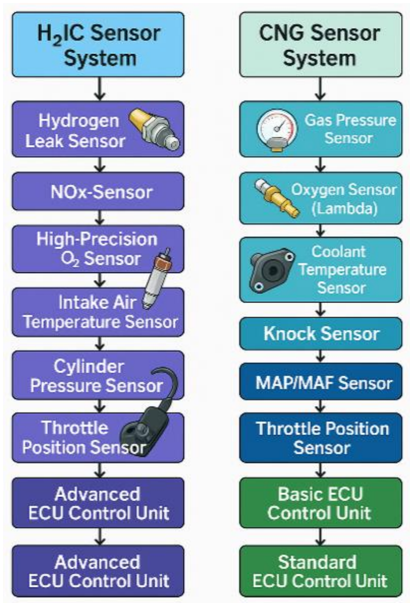

Figure – 5

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 07, July - 2025

The Engine Control Unit (ECU) plays a major role in managing all vehicles operation for both H2IC and CNG engines, but it is design and functions changes to suit the specific fuel properties. In H2IC engines, the ECU should handle the highly sensitive parameters i.e. precise fuel injection timing, lean-burn strategies and advanced ignition control because of hydrogen's high flammability range and fast flame speed. In addition, it needs to continuously monitor for pre-ignition, backfiring and NOx emissions which often requiring integration with exhaust after-treatment systems. This comes with need of more complex software algorithms and lightening data processing. Conversely, in CNG engines, the ECU operates in more conventional ways which is controlling injection duration, ignition timing and air-fuel ratios which results in less complexity. While still responsible for emissions control and fuel efficiency, the CNG ECU benefits from the fuel's stable combustion characteristics, making it easier to calibrate. Overall, the H2IC ECU requires more advanced logic and real-time adaptability, whereas the CNG ECU relies on established combustion models and control strategies.

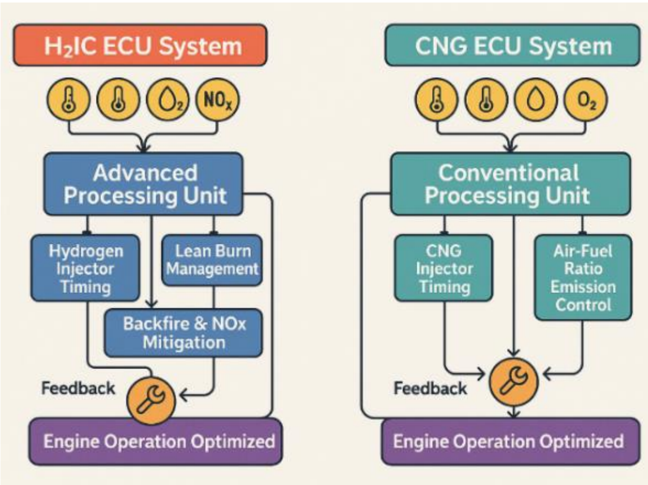

Figure – 6

ENGINE PERIPHERALS

The Air Intake Systems in H2IC and CNG engines are responsible for providing cleaner air to the combustion chamber, but they are different in configuration due to the fuel characteristics and combustion behaviour. In H2IC engines precise control of the air intake is far critical because of hydrogen has a wide flammability range which tends to pre-ignite under high pressures and temperatures. With reference to this, H2IC air intake systems are often incorporated with advanced sensors, air throttling mechanisms and tuned intake manifolds which ensure lean-burn operation and decrease the risk of backfiring. In many designs, hydrogen is directly injected into the combustion chamber, so the intake system only carries air, helping improve volumetric efficiency. In comparison, CNG engines do the mixing of air and fuel in the intake manifold using port injection. The intake system must ensures homogeneous mixing of air and methane for proper combustion. The overall design of a CNG intake system is very simple with standard filters, air throttles and very few real-time control requirement. While both of the system manages airflow to simplify the combustion, H2IC needs more precision and safety-focused design because of hydrogen's reactive nature.

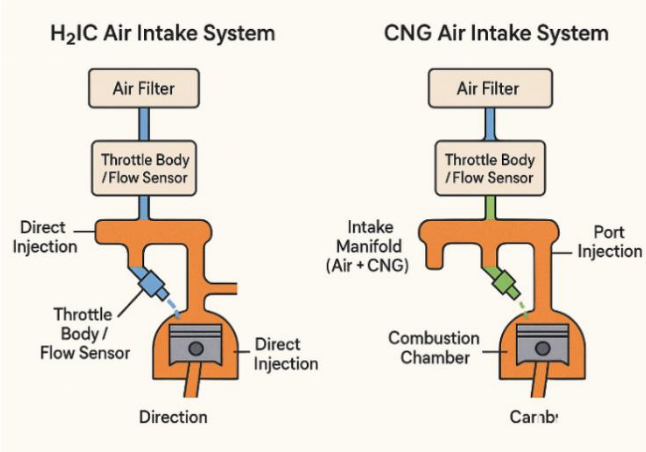

Figure – 7

The Cooling Systems in H2IC and CNG engines are designed to meet the optimal operating temperatures, but the need to place the cooling system on them vary due to the combustion characteristics of each fuel. H2IC engines primarily generate higher peak combustion temperatures because of hydrogen's rapid flame speed and high adiabatic flame temperature. This need to enhanced cooling strategies i.e. high-capacity radiators, increased coolant flow rates and advanced heat-resistant components around the combustion chamber to manage all the thermal stresses. The cooling system also required for local hot spots that are the reason which can contribute to NOx formation. In comparison, CNG engines works with slightly more moderate combustion temperatures which in terms reducing the thermal load on the system. As a result, this lead to rely on conventional radiators and coolant circuits more similar to those in gasoline engines. Overall while the fundamental components are similar i.e. radiator, water pump, thermostat. The H2IC cooling system must be specifically more robust and thermally efficient to ensure engine longevity and emission control.

The Fuel Injectors in H2IC and CNG engines plays the similar fundamental purpose i.e. delivering the right amount of fuel into the engine but their design and operational requirements are significantly different due to the nature of the fuels. H2IC injectors needs to be engineered in a way to handle extremely low-density, high-pressure hydrogen gas which is in between 350 to 700 bar. These injectors needs precision sealing for preventing leakage and must be made from component resistant to hydrogen embrittlement. In addition, H2IC systems regularly employ direct injection to decrease the pre-ignition, backfiring risks and to improve volumetric efficiency. In comparison, CNG injectors specifically operate at lower pressures in between 180–200 bar and are less demanding in terms of sealing and component strength. CNG systems usually use port fuel injection with

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 07, July - 2025

introducing the fuel into the intake manifold where it mixes with air before entering the combustion chamber. As such, while both injectors manage gaseous fuels, H2IC injectors are more advanced and require tighter control and specialized design to ensure safety and performance.

The Lubrication Systems in H2IC and CNG engines perform the same fundamental role—reducing friction, cooling components, and preventing wear—but differ in specific requirements due to fuel characteristics. H2IC engines require specialized attention in lubrication because hydrogen combustion tends to produce very high temperatures and does not contribute to oil dilution, unlike hydrocarbon fuels. Additionally, hydrogen lacks lubricity and may cause increased valve seat and piston ring wear. Therefore, the lubrication system in H2IC engines often incorporates high-performance synthetic oils with superior thermal stability and additives to minimize oxidation and wear. These systems may also include improved oil cooling circuits to manage localized thermal loads. On the other hand, CNG engines experience lower combustion temperatures and cleaner burning, resulting in less carbon build up and slower oil degradation. Conventional or mildly upgraded lubricants are generally sufficient for CNG engines, and standard oil circulation systems meet performance requirements. Thus, while both engines use a pressurized oil circuit, H2IC engines demand higher-grade lubricants and enhanced thermal management to maintain long-term durability.

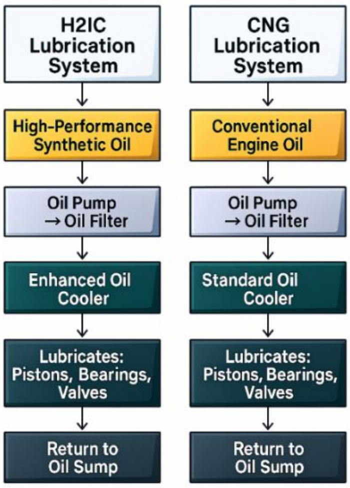

Figure – 8

The Safety Components in H2IC and CNG fuel systems are very crucial for managing high-pressure gases and preventing hazardous incidents. However, due to the difference in physical and chemical properties of hydrogen, H2IC systems needs more precise safety measures. Hydrogen is highly flammable which has a wide ignition range and diffuses quickly through small leaks. Therefore, H2IC systems are highly integrated with advanced hydrogen sensors, leak detection systems, automatic shut-off valves, flame arrestors, and high-pressure relief devices. Venting systems are also designed in a way to provide safely direct leaked hydrogen away from enclosed spaces. Storage cylinders for H2IC are made of carbon fibre composites with multilayer linings to avoid component embrittlement which ensures architectural integrity under the high pressure. In comparison, CNG systems are also worked under pressure but it involve less reactive fuel. Safety components in CNG consists of pressure relief valves, gas shutoff solenoids, temperature sensors etc. While both systems majorly focus on safe gas handling, H2IC requires additional layers of precise protection and real-time monitoring to mitigate hydrogen-specific risks.

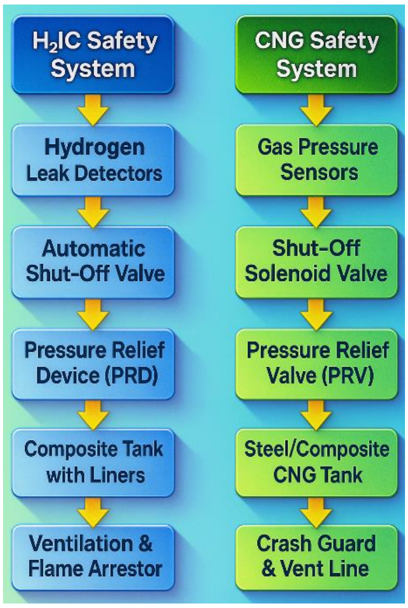

Figure – 9

The Ignition Systems in H2IC and CNG engines are basically different due to the distinct ignition characteristics of the two fuels. Hydrogen has a lower ignition energy and a broader flammability range compared to CNG, making it more prone to pre-ignition and backfiring. As a result, H2IC engines need of highly precise ignition timing and majorly incorporate advanced spark ignition systems with the high-energy coils for proper controlled combustion. In addition, due to hydrogen's high flame speed it must be carefully calibrated to prevent knock and enhance efficiency. In comparison, CNG engines are using conventional spark ignition systems which are similar to those found in gasoline engines because of methane's higher ignition energy and narrower flammability range makes combustion more manageable. The ignition timing in CNG engines are generally less sensitive which allow us for more straightforward engine control. Overall, while both systems rely on spark-based ignition, hydrogen engines demand more precise and high responsive ignition systems to take care of their more reactive combustion behaviour.

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 07, July - 2025

EXHAUST SYSTEM

The exhaust systems in H2IC and CNG engines are designed to cater the different emissions profiles of their respective fuels. H2IC engines produces zero carbon-based emissions since hydrogen combustion results in water vapour, with minimum amount of nitrogen oxides (NOx) because of high combustion temperatures. Therefore, the exhaust system in H2IC engines focuses on controlling NOx emissions which often using EGR or SCR systems to minimize their formation. In comparison, CNG engines emit CO_2, CO, unburned hydrocarbons, and NOx although at lower levels compared to conventional gasoline or diesel engines. As a result, CNG exhaust systems are designed with three-way catalytic converters which majorly focuses on all three major pollutants—CO, HC, and NOx. While both systems aims to minimize pollution on environment, H2IC exhaust systems are more simpler in terms of carbon-related emission treatment but requires specialized strategies to handle NOx effectively, whereas CNG systems must manage a broader range of exhaust pollutants.

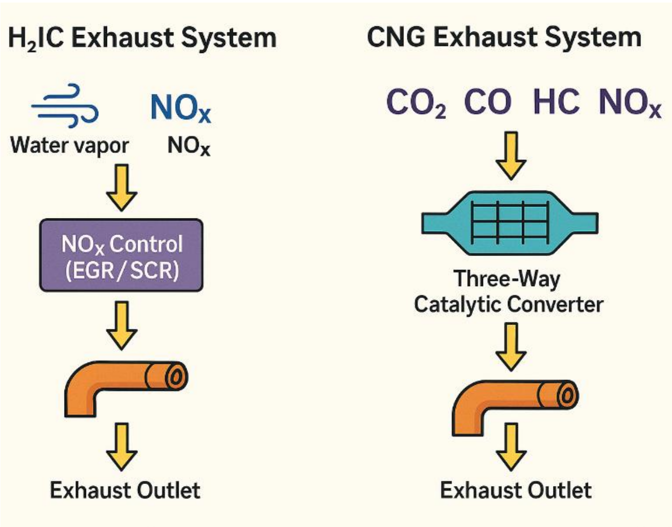

Figure – 10 Exhaust System line diagram

MAJOR CHALLENGES

While hydrogen is toxic free and clean-burning, its physical and chemical properties gives us unique major challenges:

•Infrastructure Limitations: Hydrogen fuelling infrastructure is in starting phase in most of the countries which decreases widespread deployment for the H2IC sooner.

•Hydrogen Storage: Due to hydrogen's low volumetric density, high-pressure tanks or cryogenic storage is needed will be adding cost, weight, and safety measures.

•Hydrogen Embrittlement: Prolonged exposure can weak the metal components, especially in valves and pipelines; which makes material selection very critical.

•Backfire and Pre-Ignition: Hydrogen's low ignition energy and wide flammability range boost the risk of backfire and knock which demands accurate control systems for the H2IC.

•NOx Emissions: While CO_2 is totally eliminated from exhaust, high combustion temperatures are still producing NOx which require after-treatment systems in exhaust system.

•Flammability and Ignition Risk: Hydrogen has a wide flammability range lies between 4–75% and very low ignition energy, which lead us to unintentional spark if leaks occur.

•Leak Detection: Hydrogen is colourless and odourless, so specialized sensors (e.g., TCD or electrochemical sensors) are mandatory for leak detection.

•Ventilation and Purge Systems: Engines and storage areas should be having proper ventilation to avoid accumulation of leaked gas and prevent explosion risks.

•Cost of Retrofit or Design: Modifying existing ICEs or building new engines optimized for hydrogen involves substantial initial investment.

•Training Requirement: Hydrogen-specific safety protocols, driver/operator training, and integrated fire suppression systems are essential components of a comprehensive H2IC deployment.

APPLICATION AREAS

•Heavy-Duty Trucks and Buses: Ideal for long-range, high-utilization vehicles that require quick refuelling and high torque.

•Off-Highway and Agricultural Equipment: Where charging infrastructure is unavailable and high durability is needed.

•Rail and Marine Applications: Engines can be adapted to use hydrogen as a zero-carbon propulsion source.

•Backup Power Generators: Stationary H2IC engines can be used for clean, reliable emergency power.

SUMMARY/CONCLUSIONS

The H2IC fuel system provides a promising and compelling blend of environmental benefit, technical feasibility, and economic viability in coming future. By permissive use of hydrogen fuel in familiar ICE design architectures, it serves as a transitional technology which bridges the gap between traditional fossil-fuel engines and advanced zero-emission alternatives like fuel cells and battery-electric systems.

Regardless of technical and infrastructural challenges in current situation especially around storage, NOx emissions, and safety advancements in materials science, control systems and hydrogen distribution pumps are improving the practicality of H2IC implementation. With its potential to decarbonize sectors which are difficult to electrify, the H2IC system stands as a critical component in the diversified pathway toward a low-carbon future for the world.

Hydrogen ICEs are attaining high renewed interest, especially in the sectors where electrification faces practical limitations. OEMs like Toyota, Cummins, and Kawasaki are actively developing H2IC engines and there are regulatory

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 07, July - 2025

frameworks in countries like Japan, Germany and India are beginning to support hydrogen mobility in the coming years. Future improvements in hydrogen production (green hydrogen), storage (solid-state or liquid organic carriers), and distribution could make H2IC systems more economically viable and environmentally beneficial.

REFERENCES

1. https://www.statista.com/statistics/715241/india-consumption-volume-of-petroleum-products/
2. file:///D:/PERSONAL%20DOCUMENTS/DOCS/RE/MANUSCRIPT/d2c/conversion-of-gasoline-vehicles-to-cng-hybrid-vehicles-cng-electric-vehicles.pdf
3. file:///D:/PERSONAL%20DOCUMENTS/DOCS/RE/MANUSCRIPT/d2c/v6-2332-2338.pdf
4. https://www.unescap.org/sites/default/files/pub_1361_fulltext.pdf
5. AIS-028: Code of Practice for Use of Gaseous Fuels in Internal Combustion Engine Vehicles.
6. https://www.bharatpetroleum.in/our-businesses/gas/compressed-natural-gas.aspx.
7. https://www.ctc-n.org/technology-library/vehicle-and-fuel-technologies/compressed-natural-gas-cng-fuel
8. https://energyeducation.ca/encyclopedia/Four_stroke_engine
9. https://afdc.energy.gov/vehicles/how-do-natural-gas-cars-work
10. https://www.energy.gov/eere/fuelcells/safe-use-hydrogen
11. https://www.cngwire.com/can-regular-cars-be-converted-to-cng/
12. https://www.sciencedirect.com/topics/engineering/hydrogen-storage

DEFINITIONS/ABBREVIATIONS

CNG	Compressed Natural Gas
UHC	Unburned Hydrocarbons
CO	Carbon Monoxide
NOx	Nitrogen Oxide
SOx	Sulfur Oxide
PM	Particulate Matter
HC	Hydrocarbons
CO2	Carbon dioxide
DEF	Diesel Exhaust Fluid
DOC	Diesel Oxidation Catalyst
SCR	Selective Catalyst Reduction
DPF	Diesel Particulate Filter
EGP	Exhaust Gas Processor
TWC	Three-way catalytic converter
EGR	Exhaust Gas Recirculation
H2IC	Hydrogen Internal Combustion
ICE	Internal Combustion Engine
OEMs	Original Equipment Manufacturer
ECUs	Engine Control Units
FCEVs	Fuel Cell Electric Vehicles
CI	Compression-Ignition
SI	Spark-Ignition

ACKNOWLEDGMENTS

I'm overwhelmed in all humbleness and gratefulness to acknowledge my deepest gratitude to all those who have helped me to put this paper, well above the level of simplicity & into something concrete. It provided me an opportunity to upgrade my skills as well as sharpen my professional knowledge. I am indebted to my family and deem it a proud privilege to express my sincerest regards and gratitude to my colleagues for their invaluable guidance and vital suggestions throughout the paper.