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Design and Fabrication on Hydrogen engine (Water fuel)

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ABSTRACT

A hydrogen vehicle is an alternative fuel vehicle that uses hydrogen as its onboard fuel for motive power. The term may refer to a personal transportation vehicle, such as an automobile, or any other vehicle that uses hydrogen in a similar fashion, such as an aircraft. The power plants of such vehicles convert the chemical energy of hydrogen to mechanical energy either by burning hydrogen in an internal combustion engine, or by reacting hydrogen with oxygen in a fuel cell to run electric motors. The widespread use of hydrogen for fueling transportation is a key element of a proposed economy. Hydrogen fuel does not occur naturally on Earth, and thus is not an energy source, but is an energy carrier. Currently it is most frequently made from methane or other fossil fuels. However, it can be produced from a wide range of sources (such as wind, solar, or nuclear) that are intermittent, too diffuse or too cumbersome to directly propel vehicles. Integrated wind-to-hydrogen plants, using electrolysis of water, are exploring technologies to deliver cost low enough, and quantities great enough, to compete with traditional energy sources.

Keywords

Hydrogen vehicle, low emission, Electron Grid Extractor Circuit, isolation valves, Equivalence ratio.

1. INTRODUCTION

Many companies are working to develop technologies that might efficiently exploit the potential of hydrogen energy for mobile users. The attraction of using hydrogen as an energy currency is that, if hydrogen is prepared without using fossil fuel inputs, vehicle propulsion would not contribute to carbon dioxide emissions. The drawbacks of hydrogen use are low energy content per unit volume, high tank age weights, the storage, transportation and filling of gaseous or liquid hydrogen in vehicles, the large investment in infrastructure that would be required to fuel vehicles and the inefficiency of production processes. Buses, trains, PHB bicycles, canal boats, cargo bikes, golf carts, motorcycles, wheelchairs, ships, airplanes, submarines, and rockets can already run on hydrogen, in various forms. NASA uses hydrogen to launch Space Shuttles into space. There is even a working toy model car that runs on solar power, using a regenerative fuel cell to store energy in the form of hydrogen and oxygen gas. It can then convert the fuel back into water to release the solar energy. The current land speed record for a hydrogen-powered vehicle is 286.476 mph (461.038 km/h) set by Ohio State University's Buckeye Bullet 2, which achieved a "flying-mile" speed of 280.007 mph (450.628 km/h) at the Bonneville Salt Flats in August 2008. For production-style vehicles, the current record for a hydrogen-powered vehicle is 333.38 km/h (207.2 mph) set by a prototype Ford Fusion Hydrogen 999 Fuel Cell Race Car at Bonneville Salt Flats in Wend over, Utah in August 2007. It was accompanied by a large compressed oxygen tank to increase power. Honda has also created a concept called the FC Sport, which may be able to beat that record if put into production.

1.1 Hydrogen fuel

In a flame of pure hydrogen gas, burning in air, the hydrogen (H_2) reacts with oxygen (O_2) to form water (H_2O) and heat. It does not produce other chemical by-products, except for a small amount of nitrogen oxides. Hence a key feature of hydrogen as a fuel is that it is relatively non-polluting (since water is not a pollutant). Pure hydrogen does not occur naturally; it takes energy to manufacture it. Once manufactured it is an energy carrier (i.e. a store for energy first generated by other means). The energy is eventually delivered as heat when the hydrogen is burned. The heat in a hydrogen flame is a radiant emission from the newly formed water molecules. The water molecules are in an excited state of initial formation and then transition to a ground state, the transition unleashing thermal radiation. When burning in air, the temperature is roughly 2000°C. Hydrogen fuel can provide motive power for cars, boats and aero planes, portable fuel cell applications or stationary fuel cell applications, which can power an electric motor.

The current leading technology for producing hydrogen in large quantities is steam reforming of methane gas (CH4). Other methods are discussed in the Hydrogen Production article. Primarily because hydrogen fuel can be environmentally friendly, there are advocates for its more widespread use. At present, however, there is not a sufficient technical and economic infrastructure to support widespread use. The proposed creation of such an infrastructure is referred to as the hydrogen economy.

At the gas pressure that hydrogen is typically stored, hydrogen requires four times more storage volume than the volume of gasoline that produces the equivalent energy, but the weight of this hydrogen is nearly one third that of the gasoline. With regard to safety from unwanted explosions, hydrogen fuel in automotive vehicles is at least as safe as gasoline. The advantages and disadvantages of hydrogen fuel compared to its competitors are discussed at hydrogen economy.

1.2 Hydrogen internal combustion engine vehicle

A hydrogen internal combustion engine vehicle (HICEV) is a type of hydrogen vehicle using an internal combustion engine. Hydrogen internal combustion engine vehicles are different from hydrogen fuel cell vehicles (which use hydrogen + oxygen rather than hydrogen + air); the hydrogen internal combustion engine is simply a modified version of the traditional gasoline-powered internal combustion engine.

1.3 Low Emissions

The combustion of hydrogen with oxygen produces water as its only product:

$$2H_2 + O_2 \rightarrow 2H_2O$$

The combustion of hydrogen with air can also produce oxides of nitrogen, though at negligibly small amounts. Tuning a hydrogen engine to create the most amounts of emissions as possible results in emissions compared with consumer operated gasoline engines since 1976.

$$H_2 + O_2 + N_2 \rightarrow H_2O + N_2 + NOx$$

1.4 Adaptation of Existing Engines

The difference between a hydrogen ICE from a traditional gasoline engine could include hardened valves and valve seats, stronger connecting rods, non-platinum tipped spark plugs, higher voltage ignition coil, fuel injectors designed for a gas instead of a liquid, larger crankshaft damper, stronger head gasket material, modified (for supercharger) intake manifold, positive pressure supercharger, and a high temperature engine oil. All modifications would amount to about one point five times (1.5) the current cost of a gasoline engine. These hydrogen engines burn fuel in the same manner that gasoline engines do. The power output of a direct injected hydrogen engine vehicle is 20% more than in a gasoline engine vehicle and 42% more than a hydrogen engine vehicle using a carburetor. Hydrogen internal combustion engine cars are different from hydrogen fuel cell cars. The hydrogen internal combustion car is a slightly modified version of the traditional gasoline internal combustion engine car. These hydrogen engines burn fuel in the same manner that gasoline engines do.

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Mazda has developed Wankel engines burning hydrogen. The advantage of using ICE (internal combustion engine) like Wankel and piston engines is the cost of retooling for production is much lower. Existing-technology, ICE can still be applied for solving those problems where fuel cells are not a viable solution insofar, for example in cold-weather applications. ICE has been demonstrated based on converting diesel internal combustion engines with direct injection.

1.5 Hydrogen vehicle

A hydrogen vehicle is an alternative fuel vehicle that uses hydrogen as its on-board fuel for motive power. The term may refer to a personal transportation vehicle, such as an automobile, or any other vehicle that uses hydrogen in a similar fashion, such as an aircraft. The power plants of such vehicles convert the chemical energy of hydrogen to mechanical energy either by burning hydrogen in an internal combustion engine, or by reacting hydrogen with oxygen in a fuel cell to run electric motors. The widespread use of hydrogen for fueling transportation is a key element of a proposed hydrogen economy.

Hydrogen fuel does not occur naturally on Earth, and thus is not an energy source, but is an energy carrier. Currently it is most frequently made from methane or other fossil fuels. However, it can be produced from a wide range of sources (such as wind, solar, or nuclear) that are intermittent, too diffuse or too cumbersome to directly propel vehicles. Integrated wind-to-hydrogen plants, using electrolysis of water, are exploring technologies to deliver cost low enough, and quantities great enough, to compete with traditional energy sources. Many companies are working to develop technologies that might efficiently exploit the potential of hydrogen energy for mobile users. The attraction of using hydrogen as an energy currency is that, if hydrogen is prepared without using fossil fuel inputs, vehicle propulsion would not contribute to carbon dioxide emissions.

2. HYDROGEN PROPERTIES

2.1 Introduction

Although hydrogen is a component of gasoline, hydrogen alone has unique characteristics compared to gasoline. Understanding these properties will aid in engine design and the development of control algorithms to avoid pre-ignition. Pre-ignition is the ignition of the fresh charge after the intake valve closes and before the spark plug fires

2.2 Physical Properties of Hydrogen

Table 2.1 shows a comparison of hydrogen properties to gasoline properties. Ignition limits and ignition energy are important properties. The necessary conditions for the ignition of hydrogen and air are a critical mixture ratio, and an ignition source with sufficient energy. There is a lower and a higher ignition limit. Self-sustained flame propagation in the mixture is impossible beyond these limits. Besides the mixture composition, ignition limits depend on the ignition energy, initial pressure, initial temperature, and relative humidity. The ignitable concentration range is widened by a strong increase in ignition energy. This effect is minimal, especially in terms of self-sustained flame propagation. Initial pressure in the mixture before ignition also affects the range of flammability. The upper ignition limit is disconcerted by an increase in the initial pressure.

Table 2.1 Physical Properties of Hydrogen and Gasoline

Property	Hydrogen	Gasoline
Specific Gravity at STP relative to air	0.07	-4.0
Normal Boiling Point (K)	20.3	310-478
Critical Pressure (atm)	12.8	24.5-27
Density of Liquid at STP (kg/L)	0.0708	-0.70
Density of Gas at STP (kg/m^3)	0.838	-4.40

Density Ratio, STP	845	-150
Octane Rating	130+	86-110
Thermal Diffusivity in STP air (cm^2/s)	0.61	-0.05
Diffusion Velocity in STP air (cm/s)	-2	-0.34
Quenching Gap in STP air (mm)	0.64	2
Limits of Flammability in air Vol. (%)	4-75	1-7.6
Limits of Detonation in air Vol. (%)	18.3-59	1.1-3.3
Minimum Energy for Ignition in air (mJ)	0.02	0.24
Auto ignition Temperature (K)	858	501-744
Maximum Burning Velocity in STP air	278	37-43
Flame Temperature in air (K)	2318	2470

The flame temperatures of hydrogen and gasoline differ very little in stoichiometries mixtures with air, see Table 2.2. Flame temperatures for a hydrogen-air mixture have a high dependence on the initial temperature of the unburned mixture. If back flashing or pre-ignition occur then the initial temperature for the following hydrogen-air mixture will be increased and increase flame temperatures. If the flame temperatures are increased then there will be a greater chance of back flashing and/or pre ignition to keep occurring. Based on current information, traffic accidents with liquid hydrogen fuel involve notably lower risks for drivers, passengers, and pedestrians due to hydrogen's very short evaporation and burning times in comparison to conventional fuels such as gasoline and diesel fuel, when released in equivalent amounts, because of the extremely fast distribution and dilution of evaporating hydrogen in the open. Complete and total proof of this has yet to be demonstrated.

Table 2.2 Comparison of properties of hydrogen and gasoline

Property	Hydrogen	Gasoline
Lean equivalence ratio	0.1	0L6
Max. flame speed (m/s)	2.91	0.38
Quenching distance, mm (stoich)	0.64	2.84
Flame temp, at stoich K (1 atm)	2380	2300
Flame temp, at stoich K (100 atm)	2490	2405
Min. ignition energy (J)	0.00002	0.00055
Energy content (MJ kg"^{1})	24.5	***9.2*** (gas)

2.3 Hydrogen production

- Current technologies for manufacturing hydrogen use energy in various forms, totaling between 25 and 50 percent of the higher heating value of the hydrogen fuel, used to produce, compress or liquefy, and transmit the hydrogen by pipeline or truck.

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- Environmental consequences of the production of hydrogen from fossil energy resources include the emission of greenhouse gases, a consequence that would also result from the on-board reforming of methanol into hydrogen.
- Studies comparing the environmental consequences of hydrogen production and use in fuel-cell vehicles to the refining of petroleum and combustion in conventional automobile engines find a net reduction of ozone and greenhouse gases in favour of hydrogen.

2.4 Hydrogen Distribution

- The hydrogen infrastructure consists mainly of industrial hydrogen pipeline transport and hydrogen-equipped filling stations like those found on a hydrogen highway. Hydrogen stations which are not situated near a hydrogen pipeline get supply via hydrogen tanks, compressed hydrogen trailers, liquid hydrogen trucks, or dedicated onsite production.
- Hydrogen use would require the alteration of industry and transport on a scale never seen before in history. The distribution of hydrogen fuel for vehicles would require new hydrogen stations costing billions of currency in each country.

3. HYDROGEN FRACTURING

Meyer discovered that it was also possible to spilt molecules of gases using the same method he illustrated when separating water molecules, which would produce a huge amount of energy in the form of heat and explosions. This way it was calculated that the power from a single gallon of water would be the equivalent of something between 44,000 to 108,000 barrels of oil! It’s also an environment-safe process as the nucleus of the atom is always intact. The aim of hydrogen fracturing technology (HFP) is the development of a system which uses the energy from atoms to make a system which can be later on made on a mass production scale. Meyer was working on integrating an Electrical Polarization Generator (EPG) – a gas-based fuel cell that generates energy without the involvement of any chemical reactions – into the HFP. The important aspect of this output voltage is it be used economically and efficiently to separate the water molecules in a very controlled manner. This is considered as a new innovation, as it consumes very low amounts of power to generate oxygen and hydrogen ions which can be used to trigger the HFP, allowing the atoms to release their energy. A new system called Electron Grid Extractor Circuit (EGEC) has been developed to enhance the use of what’s called a Hydrogen Gas Gun (HGG), which can as well work as a trigger for the HPF. The development of what’s known as a Voltage Intensifier Circuit (VIC), which can generate the voltage phenomena mentioned earlier while consuming very little energy in the process, and its integration with the EGEC can use even less energy to achieve the same results. Meyer also worked on the introduction of the EPG system as a part of his WFC and enhancing its performance in a way that would allow them to integrate into a single unit that can be mass produced keeping in mind the importance of the economic approval of the system to help reduce the production cost. Figure 3.1shows the schematic diagram of Hydrogen Gas Gun

It was discovered that to maximize the performance of the EPG, different types of magnetized gases were developed and tester as Meyer developed a new technology to optimize the EPG by enhancing the electromagnetic deflection of these magnetized gases. Thus making his system would be more economic and efficient. While the HFP us used to destabilize the electric balance of the gas atoms, making them reach the critical point for energy utilization. The HFP consist of an electronic control system which can trigger the system and control its efficiency and establishes the interfacing possibility. This system compiles with patent requirements both in and outside the US, and would be mass produced in the form of a small, simple and easily-used electronic component. Another system called the Hydrogen Gas Injector Fuel Cell (HGIFC) consists of a vertical array of resonance cavities in its lower section, which would split the water molecules into hydrogen and oxygen ions using a high volt pulse train causing the resonance action. This ionized mixture then enter the HGG, mounted on top of the resonance cavities, and on to the HFP.The thrust nozzle on top of the system is an optical thermal lens connected to the control system of the HPF itself. The final form of this product would be small and light weight allowing mass production at a low. Figure 3.2shows the schematic diagram of water fuel cell.

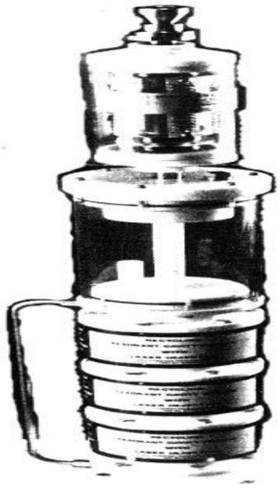

Fig 3.1: Hydrogen Gas Gun

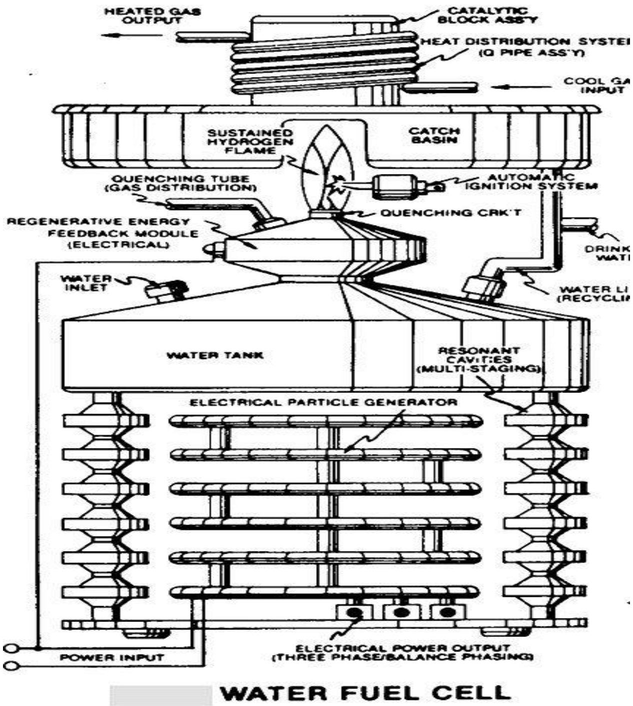

Figure 3.2 Water fuel cell

4. WORKING PRINCIPLE

The hydrogen gas is produced by mixing the KOH and water with the help of cathode and anode terminals. This is called Fuel cell arrangement. A fuel cell is an electrochemical cell that converts a source fuel into an electrical current. It generates electricity inside a cell through reactions between a fuel and an oxidant, triggered in the presence of an electrolyte. The reactants flow into the cell, and the reaction products flow out of it, while the electrolyte remains within it. Fuel cells can operate continuously as long as the necessary reactant and oxidant flows are maintained. Fuel cells are different from conventional electrochemical cell batteries in that they consume reactant from an external source, which must be replenished – a thermodynamically open system. By contrast, batteries store electrical energy chemically and hence represent a thermodynamically closed system. Figure 4.1 shows the working principle of the hydrogen car.

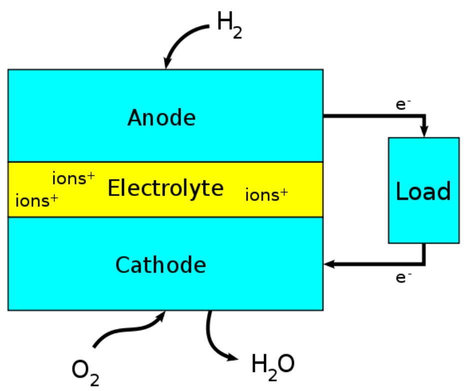

Fig 4.1: Working principles of hydrogen car

4.1 Engine theory and hydrogen engine design

After becoming familiar with the physical characteristics of hydrogen, the engine criteria can be focused on. The initial goal was to design and develop a working hydrogen fueled internal combustion engine without extraordinary modifications. This chapter will discuss basic engine theory with a description and specifications of the engine used in this research. Before an engine is selected, designed, and built some engine theory is important to know. Most engines used in automobiles are known as four stroke engines. The four-stroke cycle means that each cylinder requires four strokes of its piston, or two crankshaft revolutions. Descriptions of the four strokes are as follows.

- Intake Stroke - On the intake stroke the piston moves from the top to the bottom of the cylinder. The intake valve is open creating a constant pressure increase in volume. The air/fuel mixture is pulled into the combustion chamber.
- Compression Stroke - During the compression stroke, both intake and exhaust valves are closed and the piston is driven up the cylinder. As the piston moves upward the air/fuel mixture is compressed and the pressure in the cylinder increases. Toward the end of the stroke the sparks plug fires giving enough energy to ignite the air/fuel mixture.
- Expansion Stroke, or Power Stroke - As a result of the air/fuel mixture ignited the piston is pushed downward by the flame front causing the crankshaft to rotate. An increase in volume is experienced.
- Exhaust Stroke - On the piston's way back up the cylinder, the exhaust valve is open while the intake valve is closed. The burnt gases are pushed out of the cylinder and the process is ready to begin again. Figure 4.3shows the Schematic view of Hydrogen engine (Two wheeler).

4.2. Advantages and disadvantages

- Hydrogen cars are beneficial for the environment in a number of ways. For example, they do not emit greenhouse gases that are harmful to the welfare of the ecosystem.

- These cars are much more fuel efficient than gasoline vehicles, and let out less pollution overall. However, there are many drawbacks to using hydrogen-powered vehicles, though scientists are working to eliminate these downsides.

4.3 Going green

- The main objective of using hydrogen cars is to save the environment from the negative impacts of burning fossil fuels. According to greenliving.com, hydrogen fuel is better because it does not release carbon dioxide into the air. Hydrogen cars also give more mileage as compared to gasoline-powered vehicles; for example, a car using hydrogen fuel can go up to twice the mileage as a gasoline car with the same amount of fuel.

4.4 Engine durability

- Another advantage of hydrogen cars is the engine's strength and durability. Many other types of engines cannot work properly in high temperatures, and tend to overheat. Hydrogen engines, however, can work in extremely high temperatures, plus the engines do not corrode as easily as their gasoline counterparts.

4.5. Cost

- There is a disadvantage around the cost of hydrogen fuel: the initial expenditure convert the infrastructure from gasoline to hydrogen is huge. It would cost billions of dollars to replace all of the current gas stations with hydrogen fueling stations.

4.6. Hydrogen availability

- Another disadvantage of hydrogen fuel cars is the difficulty of obtaining liquid hydrogen to use as a fuel. Hydrogen is not readily gotten from air, so it must be obtained from water molecules. There are several ways for hydrogen to be extracted from water, but none are efficient and all are very expensive.

4.7. Key factors in the design of an efficient hydrogen IC engine

To achieve the most output for the minimum input of fuel in an IC engine the critical issues are;-

- High level of fuel trapping
- Fast and complete combustion
- Minimal effect from combustion quenching
- Minimal parasitic losses from friction and pumping

Beyond these fundamental requirements there is the potential to optimize the efficiency of an H2ICE with a hydrogen/electric hybrid system. However this will only provide sufficient advantage in a stop start city environment and so for reasons of vehicle usage patterns and additional cost there will remain a large sector of the market which prefers a simple and efficient hydrogen IC engine.

Thermal control- Complete thermal control of the combustion environment is fundamental to the efficient operation of the engine. Control of head and piston surface temperature is essential as well as the surfaces that the induction air or air/fuel charge comes in contact with as it enters the working chamber of the engine.

High level of fuel trapping- A high level of fuel trapping will be required to ensure that the efficiency and range of the vehicle is optimized. It will be necessary to utilize a direct to chamber fuel delivery system. It is accepted that DI is

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required for a two-stroke engine to achieve optimum fuel efficiency and in a hydrogen engine it will be needed for this reason as well as to obtain good volumetric efficiency for high performance.

Low friction and pumping losses- Up to 40% of the cranking energy in a current automotive is spent turning the engine over against friction and pumping losses. The opportunity to make gains in this area with a new hydrogen IC engine design cannot be ignored. The elimination of a valve drive train and sliding piston friction accounts for a significant reduction in engine friction. The wide range of fuel-air equivalency ratio at which hydrogen can be ignited presents the potential to control engine output with a minimum of engine throttling thereby reducing pumping losses.

Long service life and low manufacturing cost- There is always a durability/cost ratio trade off in the manufacture of engine components. An engine with few components is more cost effective to develop and manufacture to meet a set standard of reliability and durability. Modular assembly minimizes product development time and manufacturing cost. It is also desirable to avoid the added cost and weight of power boosting mechanisms such as superchargers and inter-coolers.

Minimum size and weight- A compact and lightweight engine is needed to reduce total vehicle mass and extend vehicle range or to allow more room for passengers and cargo along with perhaps multi- tank hydrogen storage.

4.8. Hydrogen storage

Hydrogen storage is another problem. It takes enormous amounts of space to store liquid hydrogen. Research is in process on how to more effectively store hydrogen in vehicles, but the solution is yet to be found. According to greenliving.com, several companies have invested billions of dollars in the development of efficient hydrogen fuel cells which will carry more hydrogen fuel in a vehicle. Figure 4.2 shows the Schematic view of hydrogen engine.

4.9 Applications

- Two wheeler Application
- Four wheeler Applications

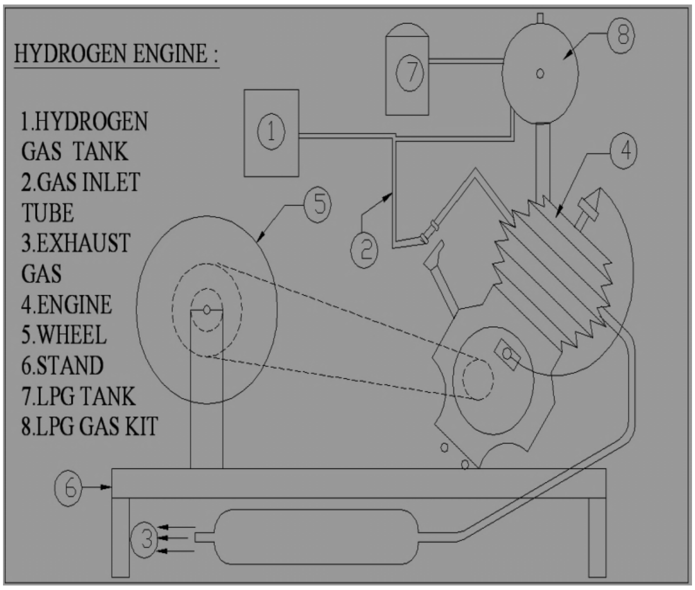

Fig 4.2: Schematic view of hydrogen engine

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Fig 4.3: Schematic view of Hydrogen engine (Two wheeler)

Figure 4.3 shows the schematic view of hydrogen engine. It mainly consists of the following

1. Four stroke engine-100 cc, 6000 RPM, 7BHP

2. Sprocket with chain- Pitch 3/8, Ratio 3:1

3. Wheel Diameter -300 mm, Width 100 mm

4. Electronic unit- Anode, Cathode

5. Hydrogen tank- Capacity 2.5 litres

6. L.P.G Tank -Capacity 2 litre

7. Gas cutter

8. Operating voltage-240

9. Hose

4.10. Components of the Supply Systems

4.10.1 Pressure-Relief Devices

In any pressurized system, each component of the system must have a pressure rating that equals or exceeds the maximum allowable working pressure (MAWP). The MAWP is the maximum pressure at which a system is safe to operate. This is the maximum setting for the primary pressure relief device.

4.10.2 Valves

To allow for maintenance activities and emergency response, *isolation valves* are required. An isolation valve shall be installed at an accessible location in a hydrogen pipeline so that hydrogen flow can be shut off when necessary.

4.10.3 Regulators

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Shutoff valves that come with gas cylinders cannot be used to control the discharge rate of the gas in use. Additional equipment that is required for hydrogen gas delivery systems includes *regulators* with *pressure gauges.* As with valves and piping materials, these instruments must be intended for use with hydrogen gas.

4.11. Electrical Equipment

Because of the extremely low energy required to ignite flammable mixtures of hydrogen gas, you must exercise caution when using hydrogen around electrical equipment. All flexible hoses and piping systems must be electrically grounded. The National Fire Protection Association has established standards for the specifications of electrical equipment intended to be used around hydrogen gas.

4.12. Hydrogen Gas Cylinders

The following are some safe-handling guidelines that have been established by the Compressed Gas Association for using hydrogen gas cylinders. By following these guidelines you can help assure the safety of your hydrogen gas operations.

4.12.1 Moving Hydrogen Gas Cylinders

When moving cylinders, the following general precautions should be observed:

Replace cylinder valve cap before moving a cylinder from its secured, in-use position. Move cylinders on cylinder carts or with other approved cylinder-transporting devices. Never roll or drop cylinders. Severe foot injury or damage to the cylinder could result.

4.12.2 Storing Hydrogen Gas Cylinders

The following points are important to follow for storing hydrogen gas cylinders that are awaiting removal or are anticipated for use.

Hydrogen gas cylinders should be stored outside and away from doors, windows, and building air intakes. Indoor storage of hydrogen requires specially designed facilities. Consult the Industrial Hygiene and Safety Group (ESH-5) and the Facility Risk Management Group (ESH-3) before setting up indoor storage locations for hydrogen cylinders not in use.

4.12.3 Ventilation and Alarms

Because of its small molecular size, hydrogen can leak from apertures through which other gases cannot pass. Ventilation with large quantities of air is vital to dilute small leaks of hydrogen to below the lower flammable limit of 4% in air. Whenever possible, hydrogen should be stored and used outside, with natural ventilation, or under a shed with a nonpeaked roof and no walls. Indoor locations must have ventilation adequate to handle the largest anticipated hydrogen leak or spill. Exhaust fans must be explosion-proof.

4.13. Emergency Procedures

Exposure to cryogenic materials may result in serious injury to body tissues similar to heat burns. If a worker comes in contact with liquid or cold gaseous hydrogen, he/she should be transported to the Occupational Medicine Group (ESH-2) or the Los Alamos Medical Center for treatment. If transportation for medical treatment is not available, the affected area can be thawed with tepid water; however, the area should not be rubbed.

If a Leak Is Detected

When a hydrogen leak is discovered or when an alarm sounds, take the following steps:

1. Evacuate the immediate area of all nonessential personnel.

2. Shut off the hydrogen source immediately and vent all hydrogen to a safe outside location.

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3. Increase indoor ventilation with emergency explosion-proof exhaust fans, if possible.

4. Initiate the emergency plan and make the required emergency contacts. Call 911 and 667-6211 [Emergency Management and Response (EM&R)].

In Case of Fire

To detect a small, local hydrogen fire (the flame is nearly invisible), use a piece of tissue paper on a stick; the paper will readily ignite when it contacts a flame. If fire is present, perform the following:

Shut off the hydrogen source. Let the fire burn itself out. (If the flame is snuffed out, it may reignite and cause greater damage.)If you have received hands-on training in the proper operation of a water fire extinguisher then you may use water spray to thermally protect people and equipment if the fire is hot enough to warrant it. However, a venting hydrogen flame cannot normally be extinguished with water. Figure 4.4: shows the schematic views of Hydrogen tank, gas cylinder and battery (Two wheeler).

Fig 4.4: schematic views of Hydrogen tank, gas cylinder and battery (Two wheeler)

4.14 Handling compressed gas cylinder leaks and emergencies

Despite strict adherence to laboratory safety practices, accidents involving gases may occur in the laboratory. The amount of damage sustained by personnel and property from these accidents will be directly related to the quality of the laboratory's emergency plan and procedures. Users of compressed gas cylinders must be familiar with necessary safety precautions. Standard Operating Procedures (SOPs) for experiments using compressed gases shall include a discussion of possible accident scenarios, appropriate employee responses and should take into account the following factors:

- The nature of the operation (e.g., experimental design, equipment used and type of injury that might be inflicted).
- The potential location of a release or spill (e.g., outdoors versus indoors, in a laboratory, corridor or storage area, on a table, in a hood or on the floor).
- The quantities of material that might be released and the type of containment (i.e., compressed gas tank size, manifold systems, etc.).
- The chemical and physical properties of the compressed gas (e.g., its physical state, vapor pressure and air or water reactivity).

- The hazardous properties of the compressed gas (e.g., its toxicity, corrosively and flammability).
- The availability and locations of emergency supplies and equipment.
- A contingency plan which identifies building evacuation routes, emergency telephone numbers, chemical containment procedures, fire extinguisher usage, etc., should be posted in the lab.

5. HYDROGEN FUEL FILLING

5.1 Infrastructure

- The hydrogen infrastructure consists mainly of industrial hydrogen pipeline transport and hydrogen-equipped filling stations like those found on a hydrogen highway. Hydrogen stations which are not situated near a hydrogen pipeline can obtain supply via hydrogen tanks, compressed hydrogen tube trailers, liquid hydrogen tank trucks or dedicated onsite production.
- Hydrogen use would require the alteration of industry and transport on a scale never seen before in history. For example, according to GM, 70% of the U.S. population lives near a hydrogen-generating facility but has little access to hydrogen, despite its wide availability for commercial use. The distribution of hydrogen fuel for vehicles throughout the U.S. would require new hydrogen stations costing, by some estimates, 20 billion dollars. and 4.6 billion in the EU. Other estimates place the cost as high as half trillion dollars in the United States alone.
- The California Hydrogen Highway is an initiative to build a series of hydrogen refueling stations along that state. These stations are used to refuel hydrogen vehicles such as fuel cell vehicles and hydrogen combustion vehicles. As of March 2011, the California Fuel Cell Partnership showed 20 stations in operation, with eight more planned. These are located mostly in and around Los Angeles, with a few in the Bay area South Carolina also has a hydrogen freeway project, and the first two hydrogen fueling stations opened in 2009 in Aiken and Columbia, South Carolina. According to the South Carolina Hydrogen & Fuel Cell Alliance, the Columbia station has a current capacity of 120 kg a day, with future plans to develop on-site hydrogen production from electrolysis and reformation. The Aiken station has a current capacity of 80 kg. There are several funding projects for Hydrogen fuel cell research and infrastructure in South Carolina. The University of South Carolina, a founding member of the South Carolina Hydrogen & Fuel Cell Alliance, received 12.5 million dollars from the Department of Energy for its Future Fuels Program.

6. RESULTS AND DISCUSSION

- Compressed and liquefied gases are routinely used in laboratory and various other operations at ISU. This Gas Cylinder Safety Guideline applies to all ISU employees who use or otherwise handle compressed or liquefied gases or systems that use compressed or liquefied gases. It is the intent of this guideline to provide information on the safe usage of compressed and liquefied gases at ISU and afford employee protection from potential health and physical hazards associated with gas and cylinder usage. ISU promotes the safe use of gases by offering training and information on the proper storage, handling, usage and disposal of gases and gas cylinders.
- With the increase in CNG vehicles regionally across India have paved the way towards alternative fuel technologies. Use of HCNG in CNG vehicle is quite attractive Sequential injection of CNG makes HCNG as attractive and safer for higher blends
- ***'r*** Compressibility factor and the storage pressure play a major role in determining the range of vehicle. The reduction in volumetric energy density of HCNG (20% H2 in CNG) against CNG which leads to a reduction in vehicle range to the tune of *25.7%* which is significant. Increasing the storage cylinder pressure from 200 bars to 3&0 bar will improve the HCNG fueled vehicle range closer to CMG for the same tank size. Increasing pressure has the issues associated with it, and needs to be further studied.

7. CONCLUSION

- A significant improvement in total vehicle efficiency through an advanced hydrogen ICE design will impact on the volume of H2ICE powered vehicles in operation in a future hydrogen economy. The development of a suitable IC engine design specifically for hydrogen fuel is yet to be undertaken and the potential to achieve a viable, long term outcome is therefore unknown. The lower thermal efficiency of even the ideal hydrogen IC engine as compared to current fuel cell technologies must be weighed against the full life cycle cost from manufacture to disposal of the H2ICE.
- The hydrogen internal combustion engine has a long way to go and converting current four-stroke automotive engines to operate on hydrogen will not provide us with a benchmark that gives an indication of the full potential of the hydrogen ICE. The important decision is to invest R&D dollars into a design which has an inherent capability of meeting the target requirements. The bright side is that it could be relatively inexpensive to explore and the result can be better than is currently anticipated. Table 7.1 shows the comparison of hydrogen characteristics.

Table 7.1:Comparison of Hydrogen Characteristics

Characteristic	Hydrogen	Natural Gas	Gasoline
Lower heating value kJ/g	120	50	44.5
Self-ignition temperature (ºC)	585	540	228-501
Flame temperature (ºC)	2,045	1,875	2,200
Flammability limits in air (vol%)	4 – 75	5.3 – 15	1.0 – 7.6
Minimum ignition energy in air (uJ)	20	290	240
Detonability limits in air (vol%)	18 – 59	6.3 – 13.5	1.1 – 3.3
Theoretical explosive energy (kg TNT/m3 gas)	2.02	7.03	44.22
Diffusion coefficient in air (cm2/s)	.61	.16	.05

The physical characteristics of hydrogen make operation of a hydrogen fueled internal combustion spark ignition engine considerably differs from conventional gasoline fueled engines. The flame speed of hydrogen, while the progression of the flame front is very similar to that of gasoline, dramatically affects the ignition timing. The ignition timing may be retarded considerably from gasoline engine timing. The exact ignition timing maps must be produced and tuned during actual engine operation. The physical characteristics of hydrogen can have a disadvantage when using hydrogen as a fuel. Equivalence ratio can have a dramatic effect on pre-ignition. Despite hydrogen's high equivalent octane rating its wide flammability limits cause many problems with premature ignition. Reducing hotspots in the combustion chamber and better control algorithms may overcome these disadvantages and enhance the performance of a hydrogen fueled engine.

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