HYDROGEN USED AS AN ALTERNATIVE FUEL

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ABSTRACT--The concern for the cleaner air, along with stricter air pollution regulation and the desire to reduce the dependency on fossil fuels has resulted in the hydrogen as the alternate fuel for the use in the internal combustion, IC engines.
The automobiles, at present day use the products of fossil fuels. These have the main carbon molecule. This after combustion is converted into carbon oxides emissions and nitrogen and sulphur compounds are emitted as Sox, NO x, smoke, unburnt carbon and particulate matter.
Hydrogen gas fuel was considered as an alternate substitution for the petrol requirement, and also safe guard against the other emissions**.**

1. INTRODUCTION
The difference in cost between natural gas and petroleum fuel has been increasing and that trend is expected to continue in the long term. The transportation industry is looking for ways to reduce costs. A natural gas-diesel dual-fuel engine is a proven technology that can provide substantial fuel savings. Expensive fuel is substituted with natural gas, and only a small amount of petrol is used to ignite the natural gas air mixture. A relatively simple and inexpensive retrofit kit is used to convert the engine onto a natural gas dual fuel engine. The gas fuel is stored on board the vehicle in the petrol bunk.
A variety of studies have shown that dual fuel engines provide dramatic reductions in NO x and particulate emissions. Hydrogen gas also produces substantially less CO2 compared to petrol combustion, which could be important in meeting future global warming restrictions. One issue with natural gas dual fuel engines is that some tests have shown relatively high emissions when the engines are operating at light loads. This is because the low concentration of natural gas has approached the lean limit and some of the natural gas has remained unburned.

The most significant aspect to which I wish to draw you attention is, The Combustive Properties of Hydrogen'
The properties of hydrogen are detailed in Section 1. The properties that contribute to its use as a combustible fuel are its:

- Wide range of flammability
- Low ignition energy
- Small quenching distance
- High auto ignition temperature
- High flame speed at stoichiometric ratios
- High diffusivity
- Very low density

An understanding of 'The Pre-Ignition Problems and its Solutions is essential for comprehending the rest of my presentation-----.

The primary problem that has been encountered in the development of operational hydrogen engines is premature ignition. Premature ignition is a much greater problem in hydrogen fueled engines than in other IC engines, because of hydrogen's lower ignition energy, wider flammability range and shorter quenching distance.
Premature ignition occurs when the fuel mixture in the combustion chamber becomes ignited before ignition by the spark plug, and results in an inefficient, rough running engine. Backfire conditions can also develop if the premature ignition occurs near the fuel intake valve and the resultant flame travels back into the induction system.

A number of studies have been aimed at determining the cause of pre-ignition in hydrogen engines. Some of the results suggest that pre-ignition are caused by hot spots in the combustion chamber, such as on a spark plug or exhaust valve, or on carbon deposits. Other research has shown that backfire can occur when there is an overlap between the opening of the intake and exhaust valves.

Fuel Delivery Systems:

Adapting or re-designing the fuel delivery system can be effective in reducing or eliminating pre-ignition. Hydrogen fuel delivery system can be broken down into three main types: central injection (or "carbureted"), port injection and direct injection.

Central Injection or Carbureted Systems:

The simplest method of delivering fuel to a hydrogen engine is by way of a carburetor or central injection system. This system has advantages for a hydrogen engine. Firstly, central injection does not require the hydrogen supply pressure to be as high as for other methods. Secondly, central injection or carburetors are used on gasoline engines, making it easy to convert a standard gasoline engine to hydrogen or a gasoline/hydrogen engine.

Port Injection Systems:

The port injection fuel delivery system injects fuel directly into the intake manifold at each intake port, rather than drawing fuel in at a central point. Typically, the hydrogen is injected into the manifold after the beginning of the intake stroke. At this point conditions are much less severe and the probability for premature ignition is reduced.

Direct Injection Systems:

More sophisticated hydrogen engines use direct injection into the combustion cylinder during the compression stroke. In direct injection, the intake valve is closed when the fuel is injected, completely avoiding premature ignition during the intake stroke. Consequently the engine cannot backfire into the intake manifold.

Thermal Dilution:

Pre-ignition conditions can be curbed using thermal dilution techniques such as exhaust gas recirculation (EGR) or water injection.

As the name implies, an EGR system re circulates a portion of the exhaust gases back into the intake manifold. The introduction of exhaust gases helps to reduce the temperature of hot spots, reducing the possibility of pre-ignition. Additionally, re circulating exhaust gases reduce the peak combustion temperature, which reduces NO x emissions. Typically a 25 to 30% recirculation of exhaust gas is effective in eliminating backfire.

On the other hand, the power output of the engine is reduced when using EGR. The presence of exhaust gases reduces the amount of fuel mixture that can be drawn into the combustion chamber.

Another technique for thermally diluting the fuel mixture is the injection of water. Injecting water into the hydrogen stream prior to mixing with air has produced better results than injecting it into the hydrogen-air mixture within the intake manifold. A potential problem with this type of system is that water can get mixed with the oil, so care must be taken to ensure that seals do not leak.

Engine Design:

The most effective means of controlling pre-ignition and knock is to re-design the engine for hydrogen use, specifically the combustion chamber and the cooling system.

A disk-shaped combustion chamber (with a flat piston and chamber ceiling) can be used to reduce turbulence within the chamber. The disk shape helps produce low radial and tangential velocity components and does not amplify inlet swirl during compression.

Since unburned hydrocarbons are not a concern in hydrogen engines, a large bore-to-stroke ratio can be used with this engine. To accommodate the wider range of flame speeds that occur over a greater range of equivalence ratios, two spark plugs are needed. The cooling system must be de-signed to provide uniform flow to all locations that need cooling.

Additional measures to decrease the probability of pre-ignition are the use of two small exhaust valves as opposed to a single large one, and the development of an effective scavenging system, that is, a means of displacing exhaust gas from the combustion chamber with fresh air.

After discussing the most effective means of controlling pre-ignition, we shall discuss on various Ignition Systems….

Due to hydrogen's low ignition energy limit, igniting hydro-gen is easy and gasoline ignition systems can be used. At very lean air/fuel ratios (130:1 to 180:1) the flame velocity is reduced considerably and the use of a dual spark plug sys-tem is preferred.

Ignition systems that use a waste spark system should not be used for hydrogen engines. These systems energize the spark each time the piston is at top dead center whether or not the piston is on the compression stroke or on its exhaust stroke. For gasoline engines, waste spark systems work well and are less expensive than other systems. For hydrogen engines, the waste sparks are a source of pre-ignition.
Spark plugs for a hydrogen engine should have a cold rating and have non-platinum tips. A cold-rated plug is one that transfers heat from the plug tip to the cylinder head quicker than a hot-rated spark plug. This means the chances of the spark plug tip igniting the air/fuel charge is reduced. Hot-rated spark plugs are designed to maintain a certain amount of heat so that carbon deposits do not accumulate. Since hydrogen does not contain carbon, hot-rated spark plugs do not serve a useful function. Platinum-tip spark plugs should also be avoided since platinum is a catalyst, causing hydrogen to oxidize with air.

Crankcase Ventilation:
Crankcase ventilation is even more important for hydrogen engines than for gasoline engines. As with gasoline engines, un burnt fuel can seep by the piston rings and enter the crankcase. Since hydrogen has a lower energy ignition limit than gasoline, any un burnt hydrogen entering the crankcase has a greater chance of igniting. Hydrogen should be prevented from accumulating through ventilation.
Ignition within the crankcase can be just a startling noise or result in engine fire. When hydrogen ignites within the crankcase, a sudden pressure rise occurs. To relieve this pressure, a pressure relief valve must be installed on the valve cover.
Exhaust gases can also seep by the piston rings into the crankcase. Since hydrogen exhaust is water vapour, water can condense in the crankcase when proper ventilation is not provided. The mixing of water into the crankcase oil reduces its lubrication ability, resulting in a higher degree of engine wear.

Thermal Efficiency:
The theoretical thermodynamic efficiency of an Otto cycle engine is based on the compression ratio of the engine and the specific-heat ratio of the fuel as shown in the equation:
The higher the compression ratio and/or the specific-heat ratio, the higher the indicated thermodynamic efficiency of the engine. The compression ratio limit of an engine is based on the fuel's resistance to knock. A lean hydrogen mixture is less susceptible to knock than conventional gasoline and therefore can tolerate higher compression ratios.
The specific-heat ratio is related to the fuel's molecular structure. The less complex the molecular structure, the higher the specific-heat ratio. Hydrogen ($\gamma = 1.4$) has a much simpler molecular structure than gasoline and therefore its specific-heat ratio is higher than that of conventional gasoline ($\gamma = 1.1$).

2. Main Work
2.1 *Emissions***:**
The combustion of hydrogen with oxygen produces water as its only product:

$$2H_2 + O_2 = 2H_2O$$

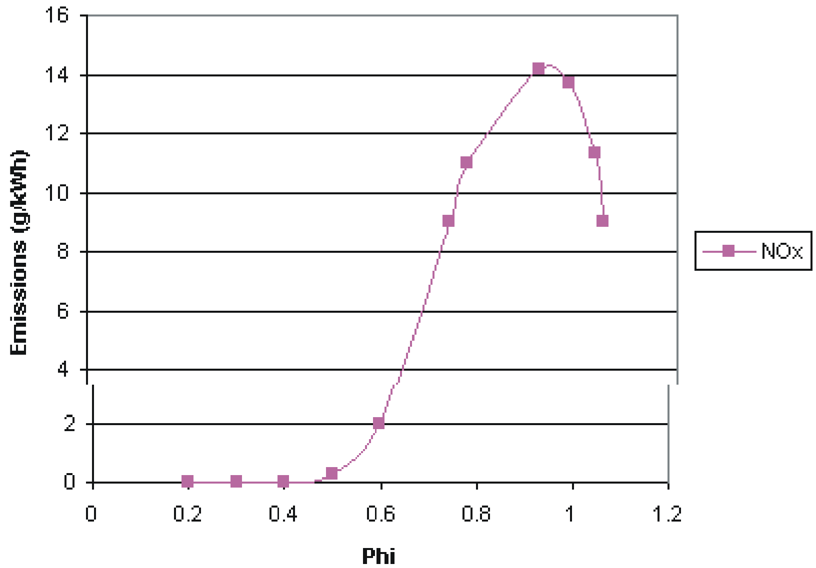
The combustion of hydrogen with air however can also produce oxides of nitrogen (NO x):

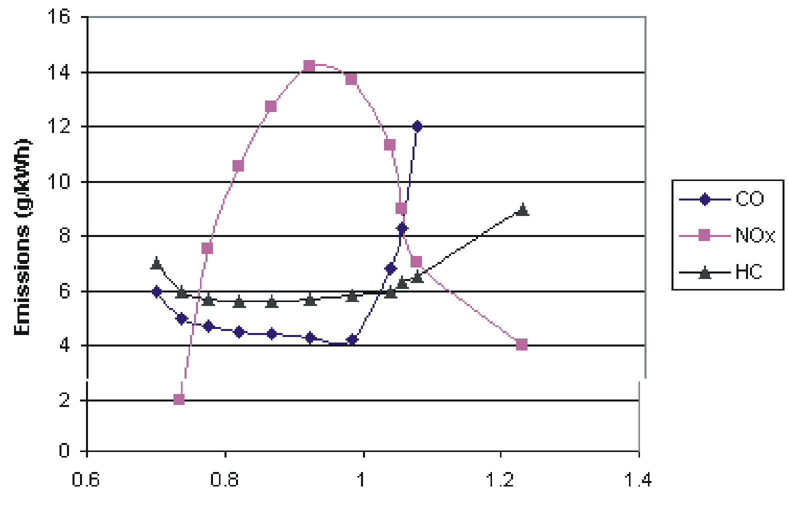
$$H_2 + O_2 + N_2 = H_2O + N_2 + NO_x$$

The oxides of nitrogen are created due to the high temperatures generated within the combustion chamber during combustion. This high temperature causes some of the nitrogen in the air to combine with the oxygen in the air. The amount of NO x formed depends on:

- **The air/fuel ratio**
- **The engine compression ratio**
- **The engine speed**
- **The ignition timing**
- **Whether thermal dilution is utilized**

In addition to oxides of nitrogen, traces of carbon monoxide and carbon dioxide can be present in the exhaust gas, due to seeped oil burning in the combustion chamber.
Depending on the condition of the engine (burning of oil) and the operating strategy used (a rich versus lean air/fuel ratio), a hydrogen engine can produce from almost zero emissions (as low as a few ppm) to high NO x and significant carbon monoxide emissions.
Figure illustrates a typically NO x curve relative to phi for a hydrogen engine.
A similar graph including other emissions is shown in Figure for gasoline.





2.2 Power Output:

The theoretical maximum power output from a hydrogen engine depends on the air/fuel ratio and fuel injection method used.

The stoichiometric air/fuel ratio for hydrogen is 34:1. At this air/fuel ratio, hydrogen will displace 29% of the combustion chamber leaving only 71% for the air. As a result, the energy content of this mixture will be less than it would be if the fuel were gasoline (since gasoline is a liquid, it only occupies a very small volume of the combustion chamber, and thus allows more air to enter).

Since both the carbureted and port injection methods mix the fuel and air prior to it entering the combustion chamber, these systems limit the maximum theoretical power obtain-able to approximately 85% of that of gasoline engines. For direct injection systems, which mix the fuel with the air after the intake valve has closed (and thus the combustion chamber has 100% air), the maximum output of the engine can be approximately 15% higher than that for gasoline engines.

After having said about various ignition systems, I must emphasize on the advantages of hydrogen in internal combustion engines.

2.3 Hydrogen Gas Mixtures

Hydrogen can be used advantageously in internal combustion engines as an additive to a hydrocarbon fuel.

Hydrogen is most commonly mixed with high pressure natural gas for this purpose since both gases can be stored in the same tank. If hydrogen is blended with other fuels, it usually has to be stored separately and mixed in the gaseous

state immediately before ignition. In general, it is impractical to use hydrogen in conjunction with other fuels that also re-quire bulky storage systems, such as propane.
Gaseous hydrogen cannot be stored in the same vessel as a liquid fuel. Hydrogen's low density will cause it to remain on top of the liquid and not mix. Furthermore, liquid fuels are stored at relatively low pressures so that very little hydrogen could be added to the vessel.
Liquid hydrogen cannot be stored in the same vessel as other fuels. Hydrogen's low boiling point will freeze other fuels resulting in fuel "ice"!
Hydrogen can be used in conjunction with compact liquid fuels such as gasoline, alcohol or diesel provided each are stored separately. In these applications, the fuel tanks can be formed to fit into unused spaces on the vehicle. Existing vehicles of this type tend to operate using one fuel or the other but not both at the same time. One advantage of this strategy is that the vehicle can continue to operate if hydrogen is unavailable.
Hydrogen cannot be used directly in a diesel (or "compression ignition") engine since hydrogen's auto ignition temperature is too high (this is also true of natural gas). Thus, diesel engines must be outfitted with spark plugs or use a small amount of diesel fuel to ignite the gas (known as pilot ignition). Although pilot ignition techniques have been developed for use with natural gas, no one is currently doing this with hydrogen.

2.4 We have been discussing the Advantages of Hydrogen in internal combustion engines so far, I believe it is time now to focus on the significant applications of Hydrogen in Marine field

Air & Marine Transport Emissions -
- Domestic Air Transport 5% = 295 million tCO2e
- Int'l Air Transport 7% = 413 million tCO2e
- Marine Transport 10 % = 590 million tCO2e

Compared to
- Land transport emissions = 4.720 million tCO2e

Other relevant facts -
- Shipping is responsible for 90% of world's trade.

IMO reports that:
- Total maritime trade doubled from 1985 to 2007
- Total container trade has grown 8-fold over the period
- 1120 million tCO2e emitted in 2005, much higher than the Stern Report numbers
- Energy used per tonne delivered by sea has been declining
- Marine transport related emissions to go up by 72% by the year 2020 without action

Maritime transport GHG emissions -
-Technological developments on marine engine efficiency
- Better fuels
-Ship speed (4% reduction = 13% less fuel)
-Use of on-board renewable energies
- Advanced sail technology
- Photovoltaics
- Hydrogen

2.5 Why hydrogen used in marine applications?
- No / low emissions (GHG reduction)
- No noise / vibrations
- No water pollutants
- No dependency on imported oil
- Production of H2 possible from a variety of sources
- Electric propulsion systems on ships superior to IC

- Flexible placement of energy-generator and electric engines
- Higher efficiency than conventional
Engine -generator set for electricity production
- Fuel cell: ~ 50%
- Diesel Gen Set : ~ 15%
- Lower rotation speed and larger diameter propellers
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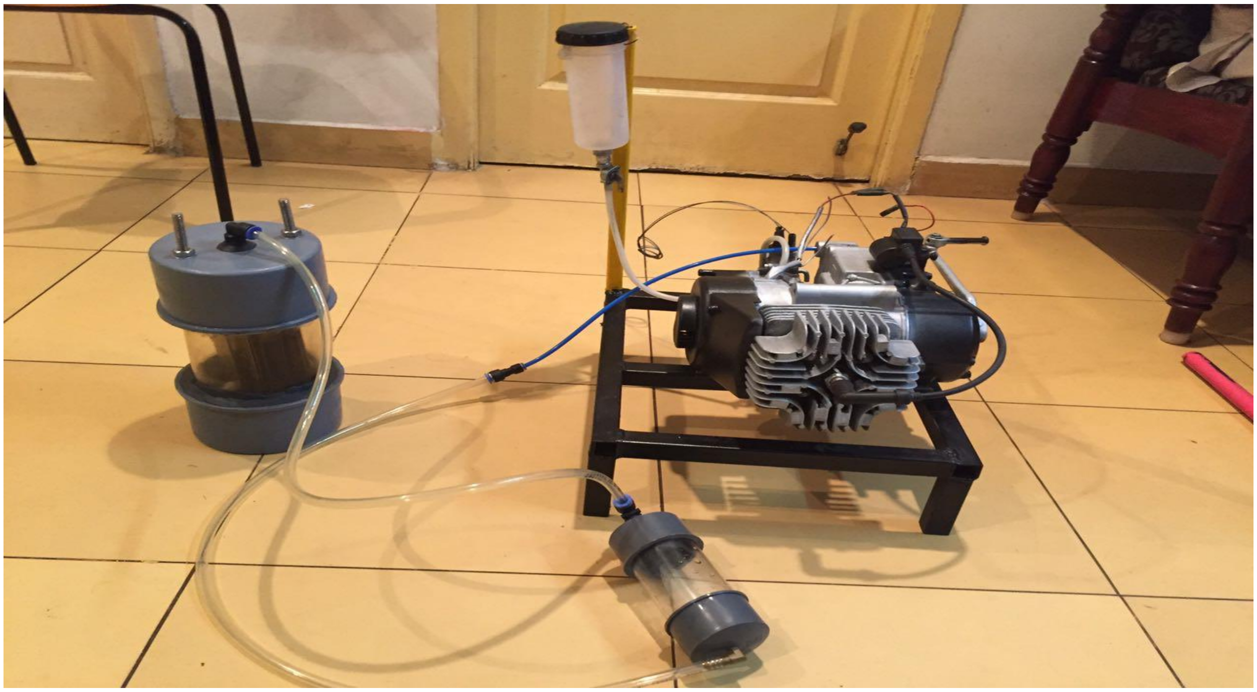
2.6 PRACTICAL APPROACH



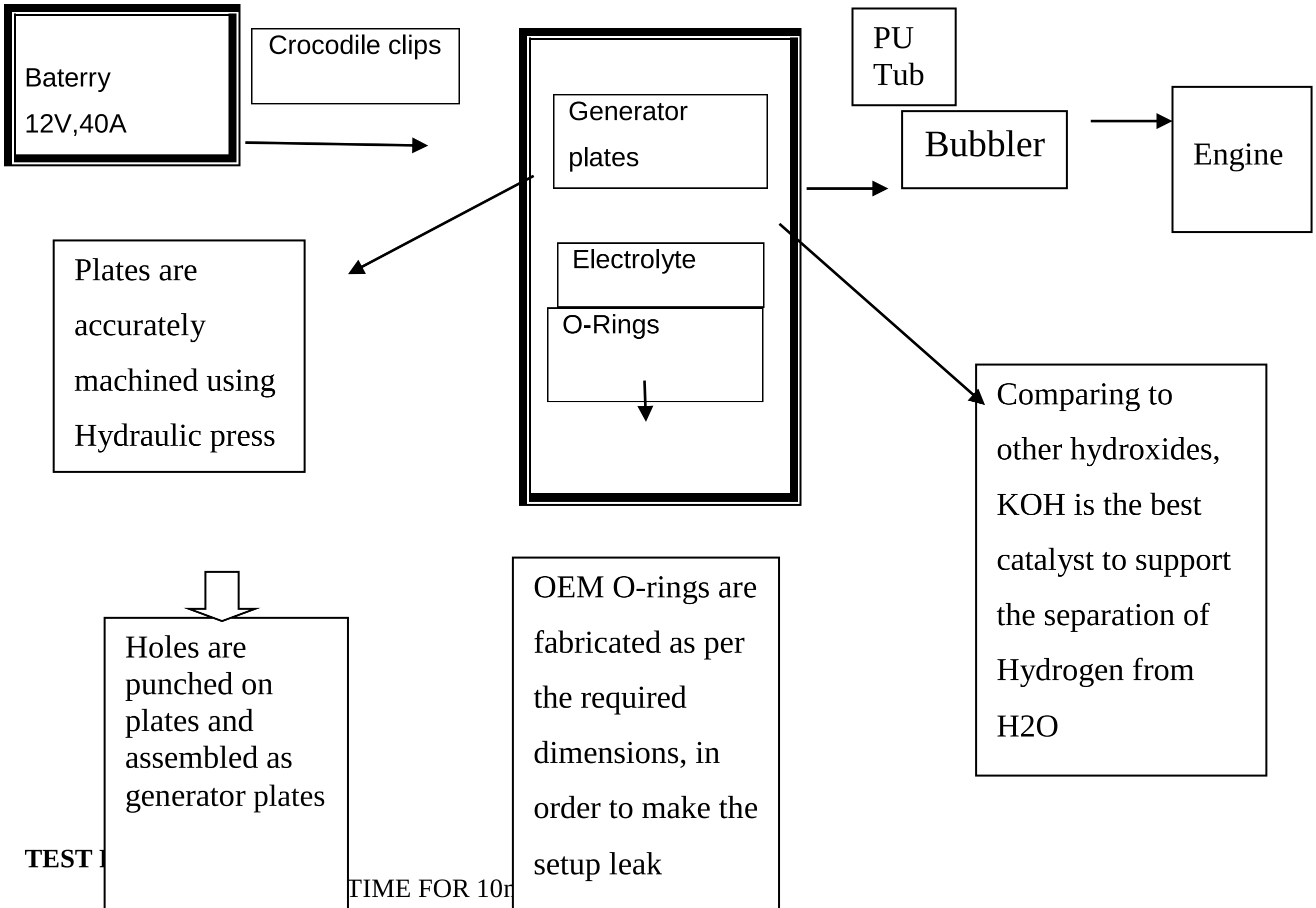
CONSTRUCTION OF HYDROGEN GENERATOR:
The major parts of the oxy-hydrogen generator are,

- Generator plates
- Generator body
- Bubbler body
- End caps
- O-rings
- Swivel elbow
- Delivery tubes
- Nozzle
- Bolts
- Nuts
- Washers

WORKING OF GENERATOR

The basic methodology involved in this process is a simple electrolysis process. The electrolyte used here is distilled water and potassium hydroxide solution is used as catalyst, in order to initiate the reaction. Potassium hydroxide is mixed with distilled water in the ratio 1:4 and of normality 0.1N. When DC current is supplied to the electrolyte through the generator plates, displacement of ions take place. Due to this displacement of ions, electrochemical reactions take place. Hydrogen gas is liberated at the cathode while oxygen gasis liberated at the anode. Both these gases travel through the PU connecting tubes to the bubbler where the impurities are removed.
The pure gas is then fed to the nozzle. It is then passed through the PU delivery tubes and is collected in the collected jar.

Deliver
y tube



TEST I

- TIME FOR 10r
- (WITHOUT HHO GENER ... dling speed
- RUNIING TIME FOR 10ml FUEL
- (WITH HHO GENERATOR):11min49secs in idling speed
- EMMISSION TEST(%CO):1.7 (without hho generator)
- EMMISSION TEST(%CO):0.96 (with the hho generator)
- HYDROCARBON EMMISSIONS:2360 (without hho generator)
- HYDROCARBON EMMISSIONS:1856 (with hho generator)

2.6 What are the Environmental effects of hydrogen?

Hydrogen in the environment: Hydrogen forms 0.15 % of the earth's crust, it is the major constituent of water. 0.5 ppm of hydrogen H_2 and various proportions as water vapour are present in the atmosphere. Hydrogen is also a major component of biomass, constituting the 14% by weight.

Environmental stability: hydrogen occurs naturally in the atmosphere. The gas will be dissipated rapidly in well-ventilated areas.

Effect on plants or animals: Any effect on animals would be related to oxygen deficient environments. No adverse effect is anticipated to occur to plant life, except for frost produced in the presence of rapidly expanding gases.

Effect on aquatic life: No evidence is currently available on the effect of hydrogen on aquatic life.

Health effects of hydrogen:

Effects of exposure to hydrogen: **Fire**: Extremely flammable. Many reactions may cause fire or explosion. Explosion: Gas/air mixtures are explosive. Routes of exposure: The substance can be absorbed into the body by inhalation. Inhalation: High concentrations of this gas can cause an oxygen-deficient environment. Individuals breathing such an atmosphere may experience symptoms which include headaches, ringing in ears, dizziness, drowsiness, unconsciousness, nausea, vomiting and depression of all the senses.

Inhalation risk: On loss of containment, a harmful concentration of this gas in the air will be reached very quickly.

Physical dangers: The gas mixes well with air, explosive mixtures are easily formed. The gas is lighter than air.

Chemical dangers: Heating may cause violent combustion or explosion. Reacts violently with air, oxygen, halogens and strong oxidants causing fire and explosion hazard. Metal catalysts, such as platinum and nickel, greatly enhance these reactions.

First aid: Fire: Shut off supply; if not possible and no risk to surroundings, let the fire burn itself out; in other cases extinguish with water spray, powder, carbon dioxide. Explosion: In case of fire: keep cylinder cool by spraying with water. Combat fire from a sheltered position. Inhalation: Fresh air, rest. Artificial respiration may be needed. Refer for medical attention. Skin: Refer for medical attention.

3. CONCLUSION

The proposed prototype of oxy-hydrogen generator was successfully made besides fulfilling the portability criterion. The prototype worked according to our expectation and did all the operations it was intended to deliver. We suggest further improvements for the further advancement of the prototype with our experience during this project. By making very small changes to the proposed prototype this oxy-hydrogen generator can be manufactured successfully and used for commercial purpose.

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