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HYDROGEN PRODUCTION AND STORAGE ELECTROLYSIS

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ABSTRACT:

Through the use of direct electric current, the process of water electrolysis is able to separate oxygen and hydrogen in their most unadulterated forms from water. One strategy for accomplishing the objective of carbon-free recycling is to make use of hydrogen as the energy carrier. Hydrogen has the capacity to store the unpredictable nature of energy derived from renewable sources. By using the concept of converting electric power into either gas or liquid throughout the process of energy conversion, it is feasible to attain both a high level of efficiency and an absence of emissions. This strategy for the utilization of energy in the far future might potentially be of enormous benefit to future human society. The electrolysis of water is examined in this piece as a potential approach for the production of hydrogen in commercial and industrial settings. This article provides a summary of the most recent advancements that have been made in the field of proton exchange membrane (PEM) water electrolysis. In addition, the future research trend concerning the electrolysis of water is outlined here. In addition, this article offers a number of suggestions for the production of hydrogen by the electrolysis of water.

***Keywords**: Zero-carbon, Hydrogen, Electrolysis*

INTRODUCTION:

The need for fuel is always growing, and fluctuations in the price of hydrocarbons cause financial imbalances due to the high levels of volatility they exhibit. This relationship usually approaches 20%, according to Nigam et al.; hence, the nations need to establish policies for the adoption of renewable energy sources (RES) as a substitute for old thermal producing and power distribution networks. In order to reduce the quantity of fuel required for mobility, the government has implemented initiatives such as the use of biofuels, the electrification of vehicle fleets, improvements in the efficiency of combustion processes, and the use of alternative fuels such as hydrogen. These initiatives are all part of an effort to lower overall fuel consumption. When it comes to the generation of thermal energy for the production of electrical energy, the installation of hybrid systems for combustion can assist reduce the quantity of fossil fuels that are utilized. The generation of hydrogen is the byproduct of nuclear energy's waste heat, which may be used for other purposes.

Use in the production of electricity through the utilization of fuel cells

Because this fuel may be stored and used even when electricity prices are high, it can be substituted for traditional fuels that have a greater impact on the environment in order to obtain a lower environmental cost. Hydrogen is a candidate that might be considered for the role of an alternative fuel that could be put to use in the production of electricity through the utilization of fuel cells. Fuel cells are electrochemical devices that convert chemical energy into electrical energy. This transformation is accomplished via the use of an electrochemical process. This alternative was previously impossible because to the high cost of the energy that was necessary to generate it; however, now that it is possible to manufacture it using renewable energy, it is essential to do so. Previously, this option was impracticable because the high cost of the energy that was required to produce it. Because of the rise in the number of renewable energy resources contributing to the net installed electricity generating capacity (NIEGC), we are compelled to look into other ways of producing hydrogen.

This research identifies the knowledge gaps within each area, which focused on focused research and innovation aimed at sustainable development of hydrogen technologies; these results may be the basis for developing strategies, strengthening, and infrastructure development to produce hydrogen as an alternative fuel. This research identifies the knowledge gaps within each area, which focused on focused research and innovation aimed at sustainable development of hydrogen technologies. This research highlights the knowledge gaps that exist within each domain, and it focuses on targeted research and innovation that is aimed at the sustainable development of hydrogen technology.

Creating Hydrogen from Its Components

The creation of hydrogen may be achieved using thermal, electrolytic, or photolytic methods, and the feedstock can be either fossil fuels, biomass, or water. These processes can also be combined to produce water-based hydrogen. The photolytic processes are not going to be covered in this paper at all. The production of hydrogen from methane may be accomplished by the use of thermal processes such as steam methane reforming (SMR), partial oxidation (POX), and autothermal reforming (ATR), to name a few examples. The SMR and POX processes are combined into one through the ATR process. In most circumstances, the gasification process is applied when there is a requirement for the use of heavy oils or coal.

REVIEW OF LITERATURE:

Curran Crawford (2020). Even while societal, environmental, political, and economic challenges may all play a significant role in the provision of environmentally friendly, safe, and reliable energy sources, these energy sources are an imperative requirement for society if it is to achieve sustainable development and a high quality of life. Not only does this throw an ever-growing stress on the use of fossil fuels, which represent a major proportion of this expanding energy demand, but it also poses issues connected with increased greenhouse gas (GHG) emissions and resource depletion. This is because fossil fuels constitute a substantial percentage of this increasing energy demand. The rapid expansion of both our economy and our population is the primary driver of the continually rising level of energy that we require. The consumption of fossil fuels is being put under an ever-increasing strain as a result of this expansion. Because of the nature of these challenges, it is very necessary for the globe to transition away from conventional sources of energy and toward renewable sources of energy. Hydrogen is establishing itself as a new energy vector outside of its conventional role, and it is garnering greater attention worldwide as a prospective fuel route. This shift in hydrogen's role comes at a time when the world is becoming increasingly interested in alternative fuels. This is because hydrogen delivers advantages in use cases, and in contrast to synthetic fuels based on carbon, hydrogen has the potential to be totally carbon neutral or even carbon negative over its entire life cycle. This is in contrast to synthetic fuels based on carbon, which do not have this potential.

Haris Ishaq (2022) This review paper will provide a critical analysis of the current state of the art in blue and green hydrogen production methods using conventional and renewable energy sources, utilization of hydrogen, storage, transportation, and distribution, as well as key challenges and opportunities in the commercial deployment of such systems. The purpose of this review paper is to provide a critical analysis of the current state of the art in blue and green hydrogen production methods using conventional and renewable energy sources. Hydrogen appears to be the ideal candidate to be utilized for a wide variety of applications, since it is capable of merging the roles of fuel energy carrier and energy storage mode of operation. Solar and wind power, two of the most promising forms of renewable energy for the production of hydrogen, are, however, intermittent forms of energy. Additionally, this research includes a comparative analysis of many techniques of hydrogen generation, including both non-renewable and renewable methods. This analysis takes into consideration the system design, cost, global warming potential (GWP), infrastructure, and efficiency of each approach. The last phase involves a discussion of the key challenges and possible advantages associated with the creation of hydrogen, storage of hydrogen, transportation of hydrogen, and distribution of hydrogen, as well as its implementation on a commercial scale.

Collins C. Kwasi-Effah(2015) In general, the use of renewable energy sources possesses a large potential to minimize the emissions of greenhouse gases that come from the burning of fossil fuels and to assist in slowing or halting the advancement of climate change. This is the case since renewable energy sources do not release carbon dioxide during the combustion process. Renewable energy sources provide a potential solution to the ever-increasing scarcity of nonrenewable fossil fuels. These fuels are used up at a rate that cannot be replenished. However, some types of renewable energy and energy carriers, including biogas and biodiesel, are not as kind to the environment as others are. All of these various forms of energy carriers, which find significant use in the fields of transportation and power generation, contribute to the pollution of the environment when they are burned. This is one of the main causes of global warming. These many types of energy carriers are necessary in order to maintain a nation's economic growth going forward at a quick speed, which is crucial for the survival of the nation. Therefore, it is more advisable to research the creation of greener sources of energy and carriers of energy, such as hydrogen generated from water. One example of this would be solar power.

OBJECTIVE OF THE STUDY:

1. To study on Electrolysis for the Production of Hydrogen and Its Storage
2. To study on Liquefaction of Hydrogen and Storage

METHODOLOGY:

Steam Methane Reformation

Creating syngas, which is a mixture of hydrogen and carbon monoxide, from methane is typically done by a process known as steam reforming. Syngas is a combination of hydrogen and carbon monoxide. Natural gas is by far the most typical feedstock, and it may be discovered in a wide variety of forms, including dry gas, wet gas, sweet gas, and sour gas. The labels represent the many components that come together to form the gas as a whole. When compared to dry gas, which is composed of methane for the most part, wet gas contains a higher concentration of hydrocarbons. Sweet gas is characterized by having much lower concentrations of hydrogen sulfide as compared to sour gas. On the other hand, the concentration of hydrogen sulfide in sour gas is significantly higher.

In most cases, the reformation of methane by steam requires the following four processes to be completed in order: Hydrogen sulfide and other sulfur compounds are removed to prevent catalyst poisoning;

Pre-reforming is used to protect against carbon formation during the main reforming step and also reduce the amount of steam required;

Primary reforming, in which steam and heat are supplied to allow the reaction to proceed over a nickel catalyst at temperatures between 700 and 830 degrees Celsius;

A secondary reformer makes use of air to produce heat through combustion reactions in order to bring the temperature down;

A tertiary reform Desulfurization is an exothermic process that is often carried out in a packed bed reactor. This type of reactor is designed to maximize heat transfer. Sulfur is removed from the gas stream while this operation is being carried out. The sulfur compounds are absorbed by the packed bed, which is commonly comprised of zinc oxide. This bed is responsible for the adsorption process.

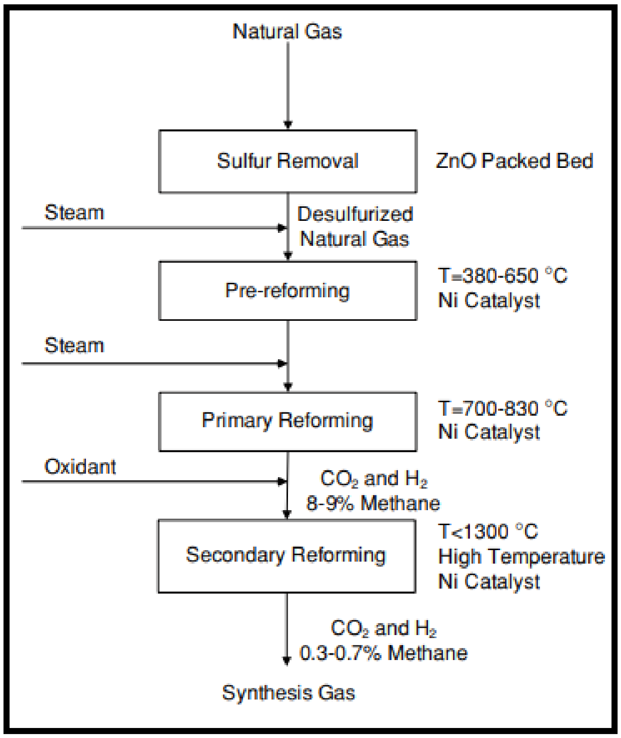

Figure 1 Steam reforming of natural gas process block diagram

In the presence of a catalyst, the process of pre-reforming begins with the heating of the material to temperatures ranging from 380 to 650 degrees Celsius. When a feedstock consisting of natural gas is utilized in the process, heat of the endothermic variety is produced; nevertheless, heat of the exothermic variety is produced when heavier feedstocks are utilized. This method eradicates any lingering traces of sulfur that may have been present as a result of the step that came before it. The first stage of steam methane reforming is an endothermic process that comprises the interaction of methane with steam. The DH value for this stage is 298 14 206 kJ mol1, and it has an endothermic value..

$$CH_4 + H_2O \leftrightarrow CO + 3H_2$$

There are two stages that are involved in the secondary reformer. To begin, an oxidant, which can either be air or oxygen, is introduced into the surroundings of the process. An exothermic reaction takes place when the oxidant interacts with the entering gas from the primary reformer. This results in the formation of water and a subsequent increase in temperature. During the second stage of the process, an endothermic reforming reaction is catalyzed by a bed of nickel catalyst. This procedure decreases the amount of methane that is present in the gas that is produced by the main reformer stage. 8–9% to 0.3–0.7%.

Water–Gas Shift Reaction

After the syngas has been produced, it is allowed to cool down before being put through the water gas shift (WGS) process (Equation 3.2), which ultimately leads in the generation of more hydrogen. In the WGS reaction, carbon monoxide and steam interact with a catalyst in order to produce hydrogen and carbon dioxide. This reaction takes place in the presence of the catalyst.

$$(\Delta H^\circ_{298} = -41\ \mathrm{kJ\ mol^{-1}}).$$

$$CO + H_2O \rightarrow CO_2 + H_2$$

Partial Oxidation of Methane

It is an exothermic reaction when methane undergoes partial oxidation (Equation 1). $(\Delta H^\circ_{298} = -36\ \ \mathrm{kJ\ mol^{-1}})$ ……………………………………………(1)

By the reaction of a fuel with oxygen, a combination of carbon monoxide and hydrogen is produced..

$$CH_4 + 1/2O_2 \rightarrow CO + 2H_2$$

Degradation of the catalyst caused by carbon deposition is one of the issues that might arise during this process. Additionally, there is a risk of explosion when the reactant gases are mixed..

Autothermal Reformation of Methane

During the process of autothermal reformation, also known as oxy-steam reforming, SMR and POX are mixed. This process is also known as autothermal reformation. This tactic will likely result in a variety of positive consequences if it is implemented. Steam may be used in a chemical reaction called as the WGS reaction, which can transform some of the carbon monoxide that is present into carbon dioxide. In addition to this, there is a possibility that there will be less of a chance of an explosion, as well as a reduction in the accumulation of carbon on the catalyst. When the correct ratios of fuel, air, and steam are present, a process known as partial oxidation takes place. This process creates all of the heat that is required to power the steam reforming reaction, making it possible for the reaction to take place.

Combustion of heavy crude oil and coal leading to the production of hydrogen Procedures for converting heavy oil and coal fuel into hydrogen are relatively comparable to one another. Hydrogen may be produced from either of these fuels. The process that is carried out while working with oil is known as partial oxidation, and it is one of the methods that are used. Syngas, carbon dioxide, carbon monoxide, and hydrogen sulfur may be produced by this method from petroleum feedstock, provided that the feedstock already has some sulfur.

The oil is exposed to steam and various concentrations of oxygen at temperatures ranging from 1200 to 1500 degrees Celsius and pressures ranging from 30 to 80 bars. There are three stages involved in carrying out this process successfully: Steam is utilized in a technique called as cracking, which reduces the length of hydrocarbon chains by breaking them apart. After that, amounts of oxygen below stoichiometric are added to the oil in order to oxidize it and produce syngas. The last step involves the combination of carbon particles, carbon dioxide, and steam to form syngas. If sulfur is present, it must be removed before the WGS process can begin because it has the potential to poison the catalyst that is used for the WGS reaction . Sulfur must be removed before the WGS process can begin. When coal is used as a feedstock in the process, there is also the possibility of producing syngas from the coal. Pretreatment, primary gasification, secondary gasification, and shift conversion are the operations that need to be carried out in this process.

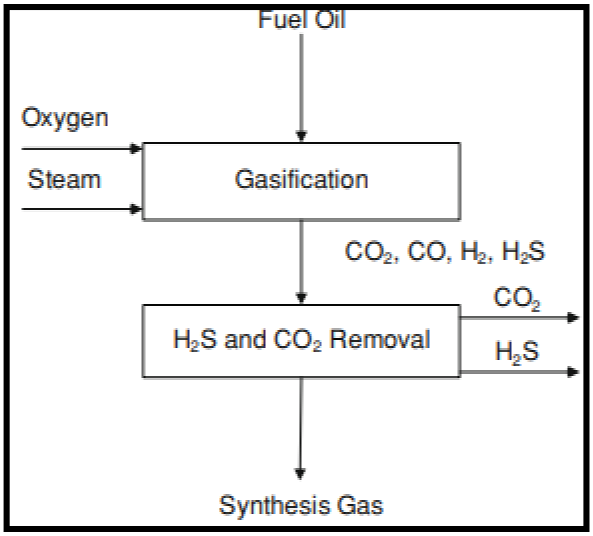

Figure 2 Synthesis gas

During the pretreatment process, oxygen is added in order to eliminate chemicals that, in the absence of oxygen, would cause the coal to agglomerate within the gasifier. Between 900 and 1000 degrees Celsius is the average operating range for the main gasifier, which results in the production of synthesis gas, CO2, H2O, CH4, N2, char (mostly carbon), and other chemicals. In the second gasifier, the char undergoes further reactions with steam in order to form syngas. The water gas shift reaction is employed as the final step in the process to establish the final CO_2 to H_2 ratio.

Separation of Product Gases

PSA is an abbreviation for pressure swing adsorption, which is a technique for separating the product syngas of any of the aforementioned processes. This technique is also known by its full name, pressure swing adsorption. The amount of affinity that each species has for an adsorbent substance is taken into consideration in this procedure, which involves the use of pressure to separate a number of different species from one another. The adsorptive material is employed in the process of separating gases by adsorbing the unwanted gases under high pressure. This makes it possible for a stream of hydrogen to flow through while simultaneously inhibiting the passage of other gases. Because of the waste gases, the adsorbent material will eventually reach its full capacity if enough time passes. The pressure in the adsorbent bed is lowered, which makes it possible for the molecules of waste gas that have been absorbed to flow out of the bed and into the surrounding environment. After that, the procedure repeats itself from the beginning. The gas that has been desorbed is then sent back through the furnace to be burned at a higher temperature.

Water Electrolysis

The process of electrolysis, also known as splitting water into its component elements hydrogen and oxygen by passing an electric current through it, is a method that may be used to separate water into its component parts. This technology contributes a minimal amount to the world's supply of hydrogen, the great majority of which is created for applications that require only very small volumes of extremely pure hydrogen. Earlier electrolysis cells had efficiencies that ranged from 60–75%, while small-scale units may today obtain efficiencies that are closer to 80%–85%. Larger units, on average, have an efficiency that falls anywhere between 75 and 80 percent of the time.

DATA ANALYSIS:

A reduction process that results in the production of hydrogen gas takes place at the cathode of an electrolytic cell when hydrogen ions absorb electrons.:

$$2H_3O + (aq) + 2e- \rightarrow H_2(g) + 2H_2O(l)$$

In an oxidation reaction that takes place at the anode, hydrogen ions give up electrons to the anode, which results in the formation of water and oxygen gas.:

$$3H_2O(l) \rightarrow \tfrac{1}{2}O_2(g) + 2H_3O + (aq) + 2e-$$

The overall reaction is:

$$H_2O(l) \rightarrow H_2(g) + \tfrac{1}{2}\, O_2(g)$$

Under typical conditions, the transformation of water into hydrogen and oxygen does not result in a process that is thermodynamically favourable. Following is an expression for the cathode half-cell potential, which was obtained . The potential U for the cathode half reaction is 0 V; however, because [H3O+] is not 1 M as some have assumed, but rather 10-7 M, U is not the same as U and instead equals:

$$U(\text{cathode}) = 0 - \frac{RT}{nF}\ln\frac{P_{H_2}}{[10^{-7}]^2}$$

If the hydrogen is produced at atmospheric pressure, this becomes:

$$\begin{aligned} U(\text{cathode}) &= 0 - \frac{RT}{nF}\ln\frac{1}{[10^{-7}]^2} \\ &= -0.414\,\text{V} \end{aligned}$$

For the anode half reaction, the half cell potential is:

$$U(\text{anode}) = U^{\circ} - \frac{RT}{nF}\ln\frac{1}{(P_{O_2})^{1/2}[H_3O^+]^2}$$

U = 1.229 V is the value that is given for the standard potential when conditions are standard. Assuming that the O_2 pressure is at atmospheric levels:

$$\begin{aligned} \mathrm{U(cathode)} &= 1.229\,\mathrm{V} - \frac{\mathrm{RT}}{\mathrm{nF}} \ln \frac{1}{[10^{-7}]^2} \\ &= 0.815\,\mathrm{V} \end{aligned}$$

The overall cell voltage is then:

$$\begin{aligned} \Delta \mathrm{U} = \mathrm{U(cathode)} - \mathrm{U(anode)} &= -0.414 - 0.815\,\mathrm{V} \\ &= -1.229\,\mathrm{V} \end{aligned}$$

The fact that the DU value is negative provides support for the hypothesis that the process will not occur in the absence of an external driving potential. The amount of potential energy that is released as a result of the breakdown of water is referred to as the decomposition potential of water, and it is measured in volts.

This potential energy was measured to be 1.229 V after being calculated. If we apply this potential, the cathode will make hydrogen, and the anode will produce oxygen. Both of these products will be obtained as a result of our actions. The example that came before it was an opportunity to practise pure thermodynamic analysis. Because of the incredibly low concentration of H3O+ that is found in pure water, the reaction would move at an extremely snail's pace as it progressed. An electrolyte solution is used in the majority of the processes that take place in the actual world, and this is done so in order to speed up the reaction time..

Alkaline Water Electrolyzers

A corrosive solution like potassium hydroxide is used most of the time in alkaline electrolyzers' liquid electrolyte systems. In these kinds of systems, oxygen ions pass through the electrolytic material and end up dissolving into the water stream, leaving behind hydrogen gas. This hydrogen is taken from the water, and then it is directed into a tank that is specifically designed to separate the components.

PEM Electrolyzers

Hydrogen ions are transported into and through the membrane of a proton exchange membrane (PEM) electrolyzer cell, where they then recombine with electrons to produce hydrogen molecules. Oxygen gas is left behind in the water after the reaction. In a tank that is used for separation, the water is recycled while oxygen builds up.

Hydrogen Storage

The storage of hydrogen is a crucial component for the study, development, and eventual commercialization of hydrogen and fuel cell technologies for use in applications linked to transportation as well as stationary uses. The use of hydrogen storage for transportation reasons has, up to this point, drawn the most interest from governments and organizations who are striving to bring the technology to market. This is because hydrogen can be stored in a fuel cell. In order to facilitate the development of this technology, the Department of Energy (DOE) of the United States of America issued a road map specifying important milestones that were to be accomplished between the years 2010 and 2015 (see Table 3.1). The performance characteristics that are of interest for practical hydrogen storage devices are as follows: the volumetric (kWh/L) and gravimetric (kWh/kg) energy densities, cost, refueling time, discharge kinetics, and cycle life. In this section, we will talk about the many various technologies that are now available for storing hydrogen, in addition to some of the ones that are now under investigation. These technologies include both old and new methods. Some examples of these techniques include compression, liquefaction, the storage of metal hydrides and chemical hydrides, storage based on carbon, and storage based on liquid carriers..

Compressed Hydrogen Storage

The technology that allows for the compression of hydrogen for the purpose of storing it has been around for quite some time. The only components it requires are a compressor and a storage vessel that can endure being pressured, making it the form of energy storage that is currently in use that is the least complicated. Tanks are typically made of one of three materials: steel, aluminum that has been coated in fiberglass, or high molecular weight lined tanks with a carbon composite shell. Steel is the most frequent material used for tanks. Tanks built of steel are a possibility in circumstances in which the system requirements do not set constraints on factors such as weight or volume, as is the case with stationary applications. One example of such a circumstance is the storage of liquids. The two additional sorts of tanks that have been covered up until this point are utilised whenever weight and volume are major limitations on the system design, such as they are in applications that include vehicles..

Hydrogen Liquefaction and Storage

Cryogenic tanks are used to store liquid hydrogen at a temperature of 21.2 K and an atmospheric pressure of 1 atmosphere. Hydrogen has a critical temperature of 33 kelvin, which means that the liquid can only be held in open systems. The process of converting gaseous hydrogen into a liquid state involves cooling the hydrogen first. The Joule Thompson expansion cycle is the most straightforward method for liquifying a substance. The gas is first subjected to compression, then cooled in a heat exchanger, and then routed through a throttling valve, where it experiences isenthalpic expansion, which ultimately leads to the formation of some liquid. Through the use of a heat exchanger, the liquid is extracted, and the gas is brought back to the compressor. The lower heating value of hydrogen is almost exactly half of the work that is required to liquefy it, which comes in at 15.2 kWh/kg. After it has been turned into a liquid, the hydrogen needs to be kept in a container that is well insulated. When it comes to storing liquid hydrogen, one of the most important considerations is reducing the amount of hydrogen that is lost due to liquid boiloff. Some of the hydrogen in the liquid will evaporate as a result of heat being transferred from the surrounding environment to the liquid. The vessel can be cooled to reduce losses caused by boil-off, although doing so requires a significant amount of energy. If the hydrogen gas is not chilled, it can be discharged into the atmosphere or caught, liquefied, and put back into the storage tank. In double-walled, vacuum-insulated tanks with a volume of 50 m3, these losses typically amount to 0.4% per day. The high amount of energy that is required to liquefy hydrogen, in addition to the losses that occur during boil-off, results in a significant increase in the cost of storing hydrogen using this approach..

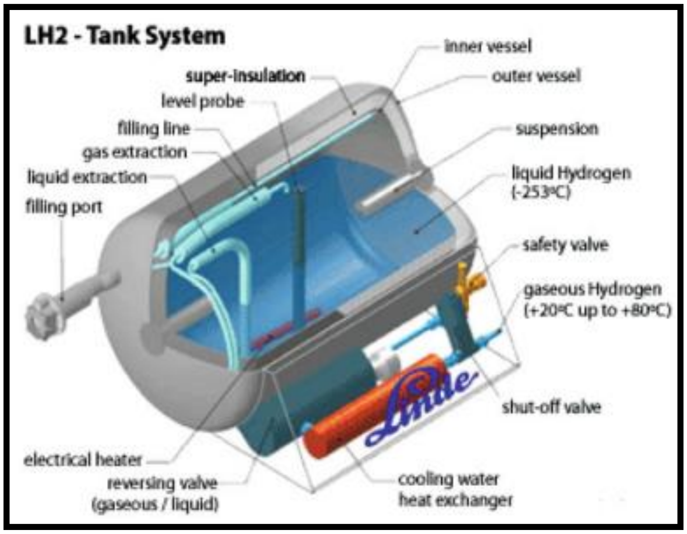

Fig. 2 Linde liquid hydrogen storage tank

Table 1 Technologies for water electrolysis

Technology	Alkaline water electrolysis	SPE (Solid polymer electrolyte) electrolysis	SOEC (Solid oxide electrolysis cell)
Process	Aqueous electrolysis	”Reversed PEFC”	”Reversed SOFC”
Feed	80% KOH, 80oC	Pure H2O, 100oC	Steam, 800-900oC
Charge carriers	OH- , K+	H+	O2-
Industrial use	Well developed Large scale	High current densities Differential pressure Expensive catalysts	Not yet commercial Pilot scale

Metal Hydrides

By establishing a chemical bond between the hydrogen and the metal element or alloy, hydrogen can be stored in metal hydrides. Metal hydrides can be used to store hydrogen. There is a following release of heat once a hydrogen storage container reaches its maximum capacity. When the pressure of the hydrogen is increased, the hydrogen begins to dissolve in the metal, and it is then able to begin bonding with the metal. When the pressure of the hydrogen is increased, the metal is able to begin bonding with hydrogen. It is vital to remove the heat that is produced throughout the production process in order to prevent the hydride from heating up. In order for the tank to work effectively when hydrogen is being released, it must receive heat at a rate that is proportional to the rate at which hydrogen is being released. This heat must be supplied to the tank at a rate that is proportional to the rate at which hydrogen is being released. It is possible to make use of a large number of different alloys, and each alloy has its own individual set of performance characteristics that are distinct from the others. Compounds that include hydrogen bonds are known to exist for every element in the periodic table, including metals and nonmetals, with the exception of the noble gases. These compounds can be either ionic or covalent in nature. They can be segmented into the three separate hydride categories described above. When you combine elements from the first and second groups, you get a saline, but when you combine elements from the transition metals, you almost always get metallic compounds. On the periodic table, the covalent hydrides can be found to the right of where the transition metals are positioned. Significant deviations from the ideal stoichiometry (n = 1, 2, 3) are illustrated by a sizeable fraction of these compounds, which are denoted by the superscript MHn. They are usually referred to as interstitial hydrides due to the fact that hydrogen frequently sits on the interstitial sites in the metal lattice. This is the reason why they are sometimes called interstitial hydrides..

When it comes to the storage of hydrogen, the intermetallic phases are of special relevance. Because of the wide variety of elements that make up the intermetallic complex, the properties of these hydrides can be altered to suit a variety of purposes. The most straightforward example is the ternary system ABxH, in which the element A is typically a rare earth or an alkaline metal and the element B is a transition metal..

CONCLUSION:

This study provided an update on the evolution of hydrogen research as a possible replacement for fossil fuels. It also described and contrasted the various methods that are utilised in the production of hydrogen. In addition to that, the article provided an account of the history of the research conducted on hydrogen. In conclusion, it went over the various approaches to storage, and the review made it possible to zero in on the issues that are still present. Because the chemical thermodynamic processes involved in manufacturing and storing hydrogen include exothermic reactions, there is a considerable demand for the amount of energy that must be used. This requirement must be met in order to produce hydrogen. In the review, hydrogen was proposed as a possible alternative fuel, the viability of which has been improved by the incorporation of renewable energy; storage may be exploited in scenarios in which there is not enough energy to supply the demand. Because of its high reactivity and the risks associated with its volatility, hydrogen's simplicity and nature are significant drawbacks due to the nature of the element itself. These drawbacks also contribute to the element's high reactivity. The state of the substance is changed to that of a liquid while it is being stored so that the risk of damage can be reduced. The raw material and energy source that is utilised are directly related to the reduction in costs that are linked with the production, storage, and transport chain, with the utilisation of renewable energies being an attractive technique due to the fact that they are sustainable. Transportation is still a highly vital aspect, despite the many risks that are there. Hydrogen has gained acceptance for use in automobiles through the utilisation of fuel cell technology.

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