**Different types of Hydrogen Purification System:**

Hydrogen purification technology is related to Hydrogen production and Hydrogen utilization. Since none of the aforementioned processes produce pure hydrogen, purification is required to produce hydrogen with the requisite purity for its intended downstream applications. Hydrogen can be produced in various methods including coal gasification, natural gas reforming, water electrolysis and photo electrolysis. But the hydrogen produced by this technique is called cured Hydrogen. It cannot be immediately used for Fuel cells and others without purification [1-2].

**Table:** Summary of Hydrogen Production Process and the impurity content in Hydrogen.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Methods | H2 | CO | CO2 | CH4 | H2O | N2 | O2 |
| Biomass Gasification [3] | 30-50 | 25-40 | 8-20 | 6-15 | -- | -- |  |
| Steam methane reforming [4] | 70-75 | 10-15 | 10-15 | 1-3 | -- | -- |  |
| Coal Gasification [5] | 35-38 | 26-28 | 23-24 | 5-6 | 15-20 | 6-7 |  |
| Methanol purge gas [6] | 70-80 | 4-8 | 5-10 | 2-8 | --- | 5-15 |  |
| Synthetic ammonia tail gas [7] | 60-75 | -- | -- | -- | -- | 15-20 |  |
| Water Electrolysis [8] | 60-80 | -- | -- | -- |  |  | 30-20 |

Following are typical methods for hydrogen recovery: Impurities can be removed using permselective membrane, cryogenic distillation, or pressure swing adsorption (PSA)[9]. These methods will be elaborated in the section. These explanations, in our opinion, will help readers understand how membrane-based separation differs from conventional PSA and cryogenic distillation.

PSA is the most commonly used modern industrial technique for hydrogen separation. The type of adsorbent and the technical procedure are the main determinants of the PSA separation effect. H2 is ideal for PSA separation and purification since it greatly differs in static capacity from the bulk of gas molecules, including CO2, CO, and CH4 [10]. The process includes five major steps entitled Adsorption, concurrent depressurization, counter-current depressurization, purge, and counter-current pressurization [11]. Basically PSA separates hydrogen by employing pressure-dependent adsorption of distinct polarities of gas in solid adsorbents (such as zeolites, alumina, activated carbon and silica gels). The polarized impure gases such as CO2, N2 and CH4 are captured under high pressure, while the non-polar hydrogen molecules are collected at the top of the adsorption column, achieving a high purity of 99.999% with 80%-85% hydrogen recovery [12-13]. PSA also works on a cyclical basis to renew spent adsorbents for subsequent adsorption processes. PSA system can be quite cost-effective if high input gas and high flow rates are used [14].

H2

CO2, CH4, N2

Pretreatment Unit

Feed gas

CO2

CH4

H2

N2

H2O

Compressor

Adsorption Column

Impurities

# Conversely, Cryogenic distillation is a popular low-temperature separation method [15]. Cryogenic distillation separates substances based on boiling point differences. Cryogenic distillation process is separated into two types: cryogenic condensation and cryogenic adsorption, both of which take advantage of hydrogen's ultralow boiling point (253°C at 1 bar). The first type condenses the impurities with low boiling points into a liquid phase, whilst the second type selectively adsorbs the contaminants using adsorbents [16]. Pretreatment of the supply gas is also required to remove components that may freeze; thus, water should be decreased to 1 ppm and CO2 to 100 ppm [17]. This approach is not viable for obtaining high-purity hydrogen; however, increased hydrogen recovery can be achieved at moderate hydrogen purity yields (95%). Both Cryogenic distillation and PSA are ideal at large industrial scales but unsuitable for tiny, portable applications [18].

Membrane separation, as a new gas separation technology, offers the advantages of flexible and easy operation, compact structure, low energy consumption, and friendly to the environment. The raw material components can selectively permeate the membrane under the action of driving forces (pressure variation, concentration variation, and potential variation) in membrane separation technology with a perm-selective membrane as a separation medium, achieving separation and purification [19]. Besides PSA and cryogenic distillation, Hydrogen purification by membrane separation is competitive in its own right and is regarded as a possible method for producing hydrogen-enriched gas streams [20]. The Separation of Hydrogen from other impurities by membrane is based on solution diffusion mechanism. Hydrogen has a higher diffusivity because it can diffuse quicker than other gas constituents, owing to the short kinetic diameter of hydrogen molecules [21].

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