Instrumentation & control Of Hydrogen production plant

<u>B.E. PROJECT REPORT</u>

Submitted in partial fulfilment of the requirement of University of Mumbai
For the Degree of

Bachelor of Engineering in
Instrumentation Engineering

By

Miss. Abha U Sonawane

Mr. Vedant S Kadam

Mr. Sanket S Vedpathak

Under the guidance of

Prof. Swati K Nadgaundi

Department of Instrumentation Engineering

Bharati Vidyapeeth College of EngineeringSector-7, CBD Belpada,

Navi Mumbai – 400614
(University of Mumbai)
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BHARATI VIDYAPEETH COLLEGE OF ENGINEERING, CBD BELPADA, NAVI MUMBAI

CERTIFICATE

Project entitled "CONTROL AND INSTRUMENTATION FOR HYDROGENPRODUCTION PLANT" and synopsis of the project is submitted by:

Mr. Vedant S Kadam

Miss. Abha U Sonawane

Mr. Sanket S Vedpathak

in partial fulfillment of the degree of

B. E. Instrumentation Engineering at Mumbai University is approved.

Name and Signature of Internal Guide

Name & Signature of Examiners:

1. Internal:

2. External:

Prof. Dilip. N. Pawar

H.O. D.

Dr. Sandhya Jadhav

PRINCIPAL

Date: ……/……../2023

Department of Instrumentation

Vision:

To inculcate competence and productive professionalism in instrumentation technocrats to face the current and future challenger of technological development

Mission:

1) Technical Skills - To promote innovative and original thinking in the minds of budding engineers toface the challenges of future.

2) Overall Development - To inculcate value-based, socially committed professionalism amongst the students.

3) Research - To facilitate research opportunities to faculty as well as students in multidisciplinary field

Program Educational Objectives (PEO's):

PEO1: Fundamental knowledge: Graduates will have successful career in industry or pursue higher studies to meet future challenges of technological development.

PEO2: Design skills: Graduates will develop analytical skill, software skill and logical skill to enable them to analyze and design Instrumentation and Control Systems.

PEO3: Professional Skills: Graduates will achieve professional skills, entrepreneurship skills along withethical attitude and will be able to relate Engineering issues to broader social context.

PEO4: Self-Learning: Graduates will undertake research activities in emerging multidisciplinary fields.

Program Specific Outcomes (PSO's):

PSO 1- Graduate will analyze Instrumentation engineering and multi-disciplinary problems of industriesand validate results by performing mini or main projects in collaboration with

industry experts and academicians.

PSO2- Graduate will interpret industrial processes design Instrumentation systems and carry out projectexecution and management with ISA standards and safety standards.

PSO 3- Graduate will Model, simulate, analyzes and implements complex Instrumentation systems using resent trends in industries and safely automate systems.

Acknowledgement

We would like to take this opportunity to show our sincere appreciation and respect to our advisors, Prof. Swati K. Nadgaundi and Rachana Dighe (Managing Director of UTTPN GREENTECH PVT LIMITED) and RatanKumar Prasad, for their outstanding direction, close supervision, and unwavering support throughout the completion of this thesis.

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With Due Regards,

Miss. Abha U Sonawane

Mr. Vedant S Kadam

Mr. Sanket S Vedpathak

Abstract

Hydrogen production is becoming increasingly important as a source of clean and sustainable energy. This report provides an overview of a hydrogen production plant, including its location, capacity, and process for producing hydrogen. The report also includes an analysis of the plant's efficiency and cost, safety protocols, environmental impact, and plans for future expansion and improvements. Overall, the report highlights the importance of hydrogen production as a means of transitioning to a more sustainableenergy future and the role that this particular plant plays in meeting that goal.

	UTPNN GREENTECH PRIVATE LIMITED Address: Office No. 101, Haware Nirmiti, 4A, Plot No. 15, Sector –22, Kamothe, Navi Mumbai, Raigad, Maharashtra, India – 410206.	**Instrumentation & control Of Hydrogen production plant**

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Chapter 1

INTRODUCTION

Hydrogen production is the family of industrial methods for generating hydrogen gas. As of 2020, the majority of hydrogen (~95%) is produced from fossil fuels by steam reforming of natural gas and other light hydrocarbons, partial oxidation of heavier hydrocarbons, and coal gasification Other methods of hydrogen production include biomass gasification, zero-CO_2-emission methane pyrolysis, and electrolysis of water. The latter processes, methane pyrolysis as well as water electrolysis can be done directly with any source of electricity, such as solar power .The production of hydrogen plays a key role in any industrialized society, since hydrogen is required for many essential chemical processes. In 2020, roughly 87 million tons of hydrogen was produced worldwide for various uses, The global hydrogen generation market was valued at US$135.94 billion in 2021, and expected to grow to US$219.2 billion by 2030, with a compound annual growth rate (CAGR) of 5.4% from 2021 to 2030.
Hydrogen is a clean alternative to methane, also known as natural gas. It's the most abundant chemical element, estimated to contribute 75% of the mass of the universe. Here on earth, vast numbers of hydrogen atoms are contained in water, plants, animals and, of course, humans. But while it’s present in nearly all molecules in living things, it’s very scarce as a gas – less than one part per million by volume. Hydrogen can be produced from a variety of resources, such as natural gas, nuclear power, biogas and renewable power like solar and wind. The challenge is harnessing hydrogen as a gas on a large scale to fuel our homes and businesses.

Hydrogen gas can be obtained from a variety of sources through different processes. Here are some common methods for obtaining hydrogen gas:

Steam Methane Reforming: The most common method of producing hydrogen gas is through steam methane reforming, where high-temperature steam is used to react with methane (natural gas) to produce hydrogen gas and carbon dioxide. This process is widely used in industrial applications to produce large quantities of hydrogen gas.

Electrolysis: Hydrogen gas can also be produced through the process of electrolysis, where an electric current is passed through water to split it into hydrogen and oxygen. This process requires a source of electricity and is commonly used in small-scale applications such as fuel cell vehicles or for the production of laboratory-grade hydrogen.

Biomass Gasification: Biomass gasification is another method of producing hydrogen gas. In this process, organic materials such as wood chips, agricultural waste, or municipal solid waste are heatedin the absence of oxygen to produce a gas that contains hydrogen, carbon monoxide, and other gases.

Coal Gasification: Coal gasification is a process where coal is heated in the presence of steam and oxygen to produce a gas that contains hydrogen, carbon monoxide, and other gases. This process is not commonly used due to the high greenhouse gas emissions associated with coal mining and processing.

Hydrogen from Renewable Energy: Hydrogen gas can also be produced from renewable energy sources such as solar, wind, or hydropower through the process of electrolysis. This is known as green hydrogen and is seen as a promising avenue for producing hydrogen gas sustainably.

Overall, the production of hydrogen gas is a complex process that requires careful consideration of energy sources, efficiency, and environmental impact.

Hydrogen gas is a clean and sustainable energy source that produces zero greenhouse gas emissions when used as fuel. This makes it a key element in the transition to a low-carbon economy and in meeting global emissions reduction targets. Hydrogen gas can be used in a wide range of applications, including transportation, power generation, and industrial processes. It can also be used as a feedstock for the production of chemicals and materials.

Hydrogen gas can be used as an energy storage medium, allowing excess renewable energy to be stored and used when needed. This can help to stabilize the grid and support the integration of variable renewable energy sources like wind and solar power. Hydrogen is the most abundant element in the universe, making it a potentially abundant and widely available energy source. Hydrogen can be produced from a variety of sources, reducing reliance on imported fossil fuels and increasing energy security.

Overall, hydrogen gas offers a promising avenue for meeting our energy needs sustainably and reducing greenhouse gas emissions. As such, it is being increasingly considered as an important part of the energy mix in many countries around the world.

Chapter 2

OVERVIEW OF PRODUCTION PLANT

The basis of the hydrogen plant system involves two main equipment, the hydrogen generator and power supply. Hydrogen generator consists of mechanical equipment and piping systems supporting the electrolysis process. Control systems and instruments are located near the generator. The control panel shows the process conditions and information data for the efficiency of the operating system. the power supply consists of equipment to convert AC power input into DC power in the electrolysis process. The power supply at the installation is separate from the hydrogen generator.
The process of the hydrogen plant requires demineralized water as raw material, nitrogen as the initial cleaner, and cooling water to remove heat due to the electrolysis process.
In the electrolysis process, two products will be produced, namely hydrogen (H2) and oxygen (O2). The oxygen produced is discharged into the air, the oxygen produced is an average of 1.5 times the hydrogen produced. Generators in complete hydrogen systems must have to supply feed-water, nitrogen, cooling water, electrical power inputs, and piping systems to distribute gas hydrogen and separates hydrogen and oxygen into the air.
The process of the hydrogen plant begins with electrolysis of pure water on the electrolyze. The electrolysis process in pure water has very low efficiency, this is because water has a low ionization constant. To increase the efficiency of electrolysis, KOH is added in water. KOH is used as a catalyst that speeds up the electrolysis process. The results of the electrolysis process will produce hydrogen gas (H2) and oxygen gas (O2). Hydrogen gas produced from electrolysis will be separated from the water point by the mist separator. Once separated from the water point, hydrogen gas will be stored in the gas holder.
The hydrogen plant is designed to work automatically. When the initial operating conditions are carried out with a system at low pressure, the system will automatically start the process gradually until the pressure is ready to deliver gas. Average gas production depends on the system requirements to reach the maximum production capacity of the generator.
If the distribution of hydrogen gas is not needed, the system will return to pressure during standby conditions where the gas is ready to be distributed. All-important parameters must be monitored continuously. For example, when an operating condition deviates from a predetermined limit, the system will shut down automatically. If the hydrogen plant system is turned off, the system will return to the initial pressure where the system starts up.
The hydrogen plant has been designed to work in safe and reliable conditions. Although preventive maintenance is also very important to maintain system reliability. When there is a problem with the hydrogen system, the control system will notify the cause and location of the part which results in a shutdown of the hydrogen plant system.

- ## Demineralized Water input supply:

Main input of the system is demineralized water, also known as deionized water, is water that has been purified of its mineral ions and impurities through a process called ion exchange. In this process, wateris passed through a series of resin beds that contain electrically charged ions. These charged ions attract and remove minerals and other impurities from the water, leaving it free of minerals and other substances.

Demineralized water is commonly used in industrial and laboratory settings where mineral-free water is required for specific applications. For example, it is used in the manufacturing of pharmaceuticals, electronics, and semiconductors where even small amounts of impurities can cause problems. Demineralized water is also used in cooling systems, automotive batteries, and other applications where minerals can cause scaling or corrosion.

It is important to note that demineralized water is not the same as distilled water, which is another type of purified water. Distilled water is produced through a process of boiling and condensation, while demineralized water is produced through ion exchange. Demineralized water is important for the production of hydrogen gas through electrolysis. Electrolysis is a process where an electric current is passed through water to split it into hydrogen and oxygen. During this process, the mineral ions in water can cause problems by interfering with the process or contaminating the final product. When demineralized water is used for electrolysis, it ensures that the water is free of minerals and other impurities that can interfere with the process. This helps to ensure the efficiency of the electrolysis process and to produce high-quality hydrogen gas that is free of impurities. In addition, the use of demineralized water can also help to prolong the life of the electrolysis equipment by preventing mineral buildup and corrosion. This can result in lower maintenance costs and longer equipment lifetimes. Overall, the use of demineralized water is essential for producing high-quality and efficient hydrogen gas through electrolysis

- ## Electrolysis Process:

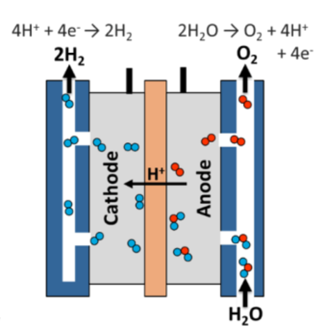

Fig 2.1

Electrolysis is a process that uses an electric current to drive a non-spontaneous chemical reaction. Inthe context of hydrogen production, electrolysis is the process of using electricity to split water into its constituent parts, hydrogen and oxygen. The electrolysis process takes place in an electrolytic cell, which contains two electrodes and an electrolyte solution (in this case, water).

The two electrodes in the electrolytic cell are typically made of an inert material such as platinum or carbon, and they are connected to a power source (a battery or power supply). When the power source is turned on, an electric current flows through the electrolyte solution from one electrode (the anode) tothe other electrode (the cathode).

At the anode, water molecules are oxidized, releasing oxygen gas and positively charged hydrogen ions (H+). These positively charged ions move towards the negatively charged cathode. At the cathode, the hydrogen ions are reduced to form hydrogen gas (H2) and electrons (e-). The electrons flow through an external circuit to the anode, where they combine with oxygen atoms to form oxygen gas.

Overall, the electrolysis process can be summarized as follows:

$2H_2O(l) + \text{energy} \rightarrow 2H_2(g) + O_2(g)$

The efficiency of the electrolysis process depends on several factors, including the voltage applied, the size and design of the electrolytic cell, the concentration of the electrolyte solution, and the purity of the water used. With the proper conditions, electrolysis can be a highly efficient and effective method for producing hydrogen gas.

There are several types of electrolyzes used for hydrogen production through the electrolysis of water. The main types of electrolyzers are:

Alkaline Electrolyzers: Alkaline electrolyzers are the most common type of electrolyzer and have been used for hydrogen production since the 1920s. They use a potassium hydroxide (KOH) solution as the electrolyte and have relatively high efficiency and low cost. Alkaline electrolyzers are typically used for large-scale hydrogen production, such as for industrial and energy storage applications. Alkaline electrolyser They use a liquid electrolyte solution, such as potassium hydroxide or sodium hydroxide, and water. Hydrogen is produced in a cell consisting of an anode, a cathode and a membrane. The cells are usually assembled in series to produce more hydrogen and oxygen at the same time. When current is applied to the electrolysis cell stack, hydroxide ions move through the electrolyte from the cathode to the anode of each cell, generating bubbles of hydrogen gas on the cathode side of the electrolyser and oxygen gas at the anode.

Polymer Electrolyte Membrane (PEM) Electrolyzers: PEM electrolyzers use a solid polymer electrolyte membrane to separate the electrodes and electrolyte. They operate at lower temperatures and pressures than alkaline electrolyzers and can be more efficient, making them well-suited for small-scale hydrogen production, such as for fuel cell vehicles.

Solid Oxide Electrolyzers (SOECs): SOECs use a solid ceramic electrolyte to separate the electrodes and electrolyte. They operate at high temperatures and can achieve high efficiency, making them suitable for high-temperature industrial processes.

Molten Carbonate Electrolyzers (MCEs): MCEs use a molten carbonate electrolyte and operate athigh temperatures. They are typically used for large-scale hydrogen production and can achieve high efficiency.

Each type of electrolyzer has its own advantages and disadvantages, and the choice of electrolyzer will depend on the specific application and requirements. Alkaline electrolyzers are the most mature and widely used technology, while PEM electrolyzers are gaining popularity due to their lower cost, higher efficiency, and suitability for small-scale applications.

- ## Hydrogen Storage Tank

Hydrogen storage tanks are needed to store hydrogen gas at high pressure or low temperature, so it can be used as a fuel for a range of applications. Hydrogen has a low energy density per unit volume compared to other fuels, such as gasoline or diesel, which means it takes up more space to store the same amount of energy. This is why hydrogen storage tanks are essential to increase the energy density of hydrogen and make it practical for use in transportation and other applications.

There are different types of hydrogen storage tanks, including compressed gas storage tanks and cryogenic liquid storage tanks. Compressed gas storage tanks store hydrogen at high pressure, typically between 5,000 and 10,000 psi, which increases its energy density and allows for more efficient storage. Cryogenic liquid storage tanks store hydrogen at very low temperatures, around -253°C, which also increases its energy density and allows for more efficient storage.

Hydrogen storage tanks are essential for a range of applications, including fuel cell vehicles, stationary power systems, and portable devices. They allow hydrogen to be stored safely and efficiently, and makeit possible to use hydrogen as a low-carbon alternative to fossil fuels.

Hydrogen gas can be stored using different methods, depending on the application and the required energy density. Here are some of the most common ways to store hydrogen gas:

<u>Compressed Gas Storage:</u> Hydrogen gas can be stored in high-pressure tanks at pressures ranging from 3,000 to 10,000 psi. The tanks are typically made of carbon fiber, metal or plastic and are designed to withstand the high pressure of the hydrogen gas.

<u>Liquid Hydrogen Storage:</u> Hydrogen gas can be stored as a liquid at very low temperatures (-253°C). Liquid hydrogen storage tanks are heavily insulated and typically made of stainless steel or other materials that can withstand the extremely low temperatures.

<u>Metal Hydride Storage:</u> Hydrogen gas can be stored in metal hydride tanks that use a chemical reaction to absorb and release hydrogen gas. Metal hydrides are compounds of hydrogen and metals such as magnesium, titanium, or lithium. These tanks can store hydrogen at low pressure and room temperature.

<u>Chemical Hydrogen Storage:</u> Hydrogen gas can also be stored in chemical compounds that release hydrogen when heated or exposed to a catalyst. Examples include methanol, ammonia, and formic acid. Chemical hydrogen storage is still in the research and development stage and is not yet widely used.The choice of hydrogen storage method depends on factors such as the application, required energy density,

and cost. Compressed gas storage is currently the most common method for storing hydrogen gas, but research is ongoing to improve the efficiency and safety of all methods.

Compressed gas storage is a commonly used method for storing hydrogen gas. In this method, hydrogen gas is compressed to a high pressure and stored in a tank made of carbon fiber, metal, or plastic. The tank is designed to withstand the high pressure of the compressed gas.

Hydrogen gas is typically compressed to pressures ranging from 3,000 to 10,000 psi, depending on the application. The higher the pressure, the more energy-dense the hydrogen gas becomes, allowing for more efficient storage and transport.

Compressed gas storage is a mature and well-established technology, and it has been used for many years to store hydrogen gas for a variety of applications, including fuel cell vehicles, industrial processes, and power generation.

However, there are some challenges associated with compressed gas storage. One challenge is the potential for the tank to rupture or leak if it is damaged or exposed to high temperatures. Another challenge is the cost of the tanks, which can be relatively expensive, particularly for tanks that can withstand very high pressures.

Despite these challenges, compressed gas storage remains an important and widely used method for storing hydrogen gas, particularly for applications that require high energy density and portability, suchas fuel cell vehicles.

When storing hydrogen gas in a storage tank, there are several important terms to take into consideration to ensure safe and efficient operation. Here are some of the key terms to be aware of:

Pressure: The pressure of the hydrogen gas in the storage tank must be carefully controlled and monitored to ensure that it does not exceed the safe operating limits of the tank. Excessive pressure can lead to tank rupture or explosion.

Temperature: The temperature of the hydrogen gas in the storage tank must be carefully controlled and monitored to ensure that it does not exceed the safe operating limits of the tank. Excessive temperature can lead to tank rupture or explosion.

Leakage: It is important to ensure that the storage tank is properly sealed and does not leak any hydrogen gas. Hydrogen gas is highly flammable and can be dangerous if it escapes from the tank.

Ventilation: Adequate ventilation is required to prevent the accumulation of hydrogen gas in confined spaces. Hydrogen gas is lighter than air and can rise to the top of a room or enclosure, where it can create an explosive atmosphere if it accumulates.

Material Compatibility: The tank and associated components should be made of materials that are compatible with hydrogen gas and do not degrade or corrode over time. The choice of materials is important to ensure the safe and efficient operation of the storage tank.

- **Compressor**

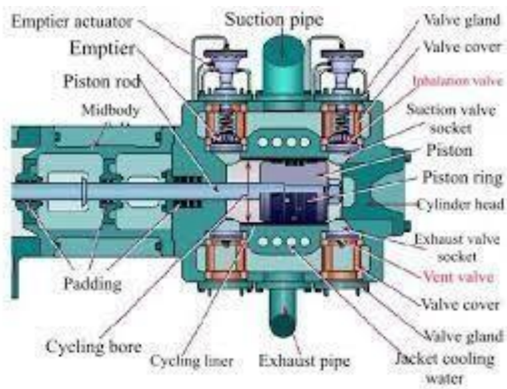

Fig. 2.2

A compressor is a device that is used to increase the pressure of a gas or air by reducing its volume. It works by drawing in gas or air from the surrounding environment and compressing it into a smaller space, which increases its pressure. Compressors are used in a wide variety of applications, including refrigeration and air conditioning, industrial manufacturing, and power generation. They are typically powered by an electric motor or a gasoline or diesel engine. There are many different types of compressors, each with its own unique features and benefits. Some of the most common types of compressors include:

Positive Displacement Compressors: These compressors work by trapping a fixed amount of gas or airin a chamber and then reducing the volume of the chamber to compress the gas or air. Examples include reciprocating compressors and rotary screw compressors.

Dynamic Compressors: These compressors work by imparting energy to the gas or air using high-speed rotating impellers or vanes. Examples include centrifugal compressors and axial compressors.

Scroll Compressors: These compressors use two spiral-shaped scrolls to compress gas or air. The scrolls move in opposite directions and trap gas or air between them, compressing it as it moves towards the center of the scrolls

Compressors are an essential component of hydrogen production plants because hydrogen gas is typically produced at low pressure, and it needs to be compressed to a higher pressure for use in various applications.Hydrogen gas is often produced through processes such as steam methane reforming, which produces hydrogen gas at relatively low pressures of around 10-20 bar (145-290 psi). In many applications, such as fuel cells, industrial processes, and transportation, hydrogen gas needs to be compressed to much higher pressures of 700 bar (10,000 psi) or more.

The compressor is used to increase the pressure of hydrogen gas to the desired level for storage and transportation or for use in various applications. Compressors can also be used to boost the pressure of hydrogen gas that is produced on-site for use in industrial processes or fuel cells.Compressors are available in various types and sizes depending on the specific requirements of the hydrogen production plant. Factors such as the desired output pressure, the flow rate, and the efficiency of the compressor will all play a role in selecting the appropriate compressor for the application.Overall, compressors are critical for hydrogen production plants to enable the efficient and safe transport and use of hydrogen gas in various applications.

In hydrogen production plants, different types of compressors are used depending on the specific process and application.

One common type of compressor used in hydrogen production plants is the reciprocating compressor. This type of compressor uses a piston to compress gas and is well-suited for high-pressure applications. Reciprocating compressors can be used to compress hydrogen gas for storage, transport, and various industrial processes.

Another type of compressor used in hydrogen production plants is the diaphragm compressor. Diaphragm compressors are positive displacement compressors that use a flexible membrane to compress gas. They are often used in applications that require a high level of purity, such as in the production of ultra-pure hydrogen for semiconductor manufacturing.

Centrifugal compressors are also used in hydrogen production plants for some applications, such as in large-scale hydrogen production facilities. These compressors use high-speed rotating impellers to impart energy to the gas and increase its pressure.

In addition to these types of compressors, other technologies such as scroll compressors and screw compressors may also be used in some hydrogen production applications.

Overall, the choice of compressor for a hydrogen production plant will depend on factors such as the specific process requirements, the desired level of efficiency, and the safety and reliability considerations.

When working with compressors in a hydrogen production plant, it is important to take appropriate safety precautions to minimize the risk of accidents and ensure safe and efficient operation. Here are some key safety precautions to consider:

Proper Training: Only trained and qualified personnel should operate and maintain compressors in a hydrogen production plant. Workers should receive thorough training on the safe operation of compressors and the hazards associated with hydrogen gas.

Explosion-Proof Equipment: All electrical equipment and wiring associated with the compressor should be designed for use in a hazardous location and be certified as explosion-proof.

Adequate Ventilation: The compressor room should be adequately ventilated to prevent the accumulation of hydrogen gas. Proper ventilation is necessary to ensure that any leaks or releases of hydrogen gas are quickly diluted and do not pose a risk of explosion or asphyxiation.

Leak Detection and Monitoring: The compressor system should be equipped with appropriate leak detection and monitoring equipment to quickly detect any leaks and prevent the build-up of hydrogen gas.

Pressure Relief Devices: Compressors should be equipped with pressure relief devices to prevent over-pressurization and potential explosion. The relief devices should be properly sized and designed to quickly relieve excess pressure in the event of an emergency.

Regular Maintenance: Compressors should be regularly inspected and maintained to ensure that theyare operating safely and efficiently. Any damaged or worn parts should be replaced promptly, and all safety devices should be tested regularly.By following these safety precautions, it is possible to operate compressors in a hydrogen production plant safely and efficiently. It is important to always prioritize safety when working with hydrogen gas, as even small amounts of hydrogen can be highly flammable and pose a serious risk of explosion or fire.

- **Heat Exchanger**

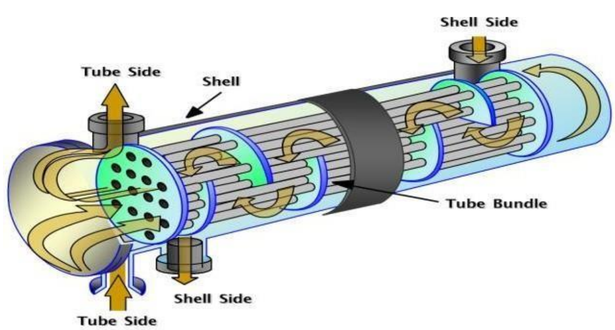

Fig 2.3

A heat exchanger is a device that is used to transfer heat between two or more fluids that are at different temperatures. Heat exchangers are commonly used in a wide range of industrial applications, including power generation, chemical processing, HVAC systems, and refrigeration.

The basic operation of a heat exchanger involves the transfer of heat energy from one fluid to another through a thermally conductive surface or barrier. The two fluids typically flow in opposite directions within the heat exchanger, with one fluid being heated as it passes through the heat exchanger, while the other fluid is cooled.

There are several types of heat exchangers that can be used in a hydrogen production plant, depending on the specific requirements of the plant. Here are some common types of heat exchangers that may be used in a hydrogen production plant:

1)Shell and Tube Heat Exchangers: These heat exchangers are commonly used in hydrogen production plants for heat recovery and to cool the hydrogen gas. In this type of heat exchanger, hydrogen gas flows through a series of tubes while a coolant, such as water, flows around the tubes in a shell. This allows for efficient heat transfer and cooling of the hydrogen gas.

Overall, the specific type of heat exchanger used in a hydrogen production plant will depend on factors such as the temperature and pressure of the hydrogen gas, the required cooling capacity, and the availability of cooling water or other cooling media. The selection of the appropriate heat exchanger is critical to ensure efficient operation of the hydrogen production plant and to maximize energy efficiency.

Heat exchangers are an essential component of hydrogen production plants because they are used to transfer heat energy between process fluids and optimize the efficiency of the overall process.

In hydrogen production plants, heat exchangers are typically used for the following purposes:

Heat recovery: Heat exchangers are used to recover heat from hot process streams, such as steam and flue gases, and transfer it to colder process streams, such as feedwater or hydrogen gas. This improvesthe overall energy efficiency of the process and reduces the amount of fuel required to produce hydrogen.

Cooling: Hydrogen gas is typically produced at high temperatures and needs to be cooled before it canbe compressed or stored. Heat exchangers are used to cool the hot hydrogen gas by transferring heat toa coolant, such as water or air.

Preheating: Heat exchangers can be used to preheat the feedstock before it enters the hydrogen production process, which can help to reduce the energy required for the process and improve overall efficiency.

In hydrogen compression system, it is a heat exchanger installed to lower the temperature of high-temperature hydrogen before passing through the compressor and entering the high-pressure container. The system's heat exchanger uses a reverse flow-type double-tube heat exchanger. The double-tube heat exchanger is composed of a single tube and a jacket, and the high-temperature fluid flows through the inner tube. The low-temperature fluid flows outward, and the heat is transferred through the tube wall under normal conditions.

- ## Moisture Trap

A moisture trap is a device used to remove moisture or water vapor from a gas or air stream. In the context of a hydrogen production plant, a moisture trap is used to remove water vapor from the hydrogen gas stream before it is compressed and stored.Water vapor can be problematic in a hydrogen production plant because it can cause corrosion of the equipment, reduce the efficiency of the process, and lower the quality of the hydrogen gas. Water vapor can also freeze in the compressed gas and cause blockages or damage to the equipment.A moisture trap typically consists of a vessel that contains a desiccant material, such as silica gel or molecular sieve. As the hydrogen gas flows through the vessel, the desiccant material absorbs the water vapor, allowing the dry hydrogen gas to continue on to the next stage of the process. The moisture trap may need to be periodically replaced or regenerated, depending on the specific application and operating conditions.

- **Dryer**

A dryer is an essential component of a hydrogen production plant because it is used to remove moisture from the feedstock or process gases, such as natural gas or steam, before they enter the hydrogen production process.moisture can react with the catalyst, leading to a decrease in catalyst activity and an increase in the formation of by-products. Moisture can also cause corrosion of the equipment and reducethe overall efficiency of the process.To prevent these problems, a dryer is used to remove moisture from the feedstock or process gases before they enter the hydrogen production process. Typically, a dryer consists of a vessel containing a desiccant material, such as silica gel or molecular sieve. As the feedstock or process gas flows through the vessel, the desiccant material absorbs the moisture, allowing the dry gas to continue on to the next stage of the process. dryer is an important component of a hydrogen production plant to ensure the quality and safety of the hydrogen gas, and to prevent damage to the equipment.

Chapter 3

CONTROL PHISLOSOPHY OF HYDROGEN GAS PROCESS

PFD Designed and Developed by :- UTPNN Green Tech Pvt. Ltd.

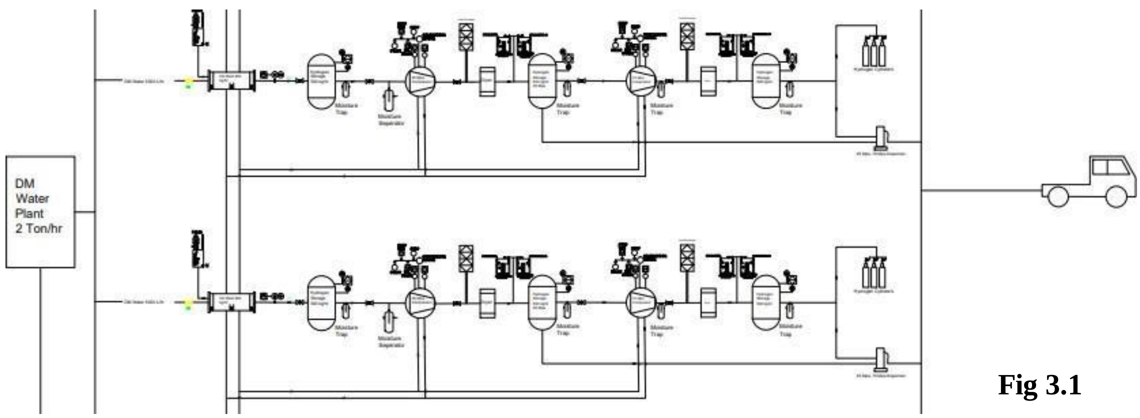

Fig 3.1

Main Input of the system is demineralized water, also known as deionized water, water that has been purified of its mineral ions and impurities through a process called ions. These charged ions attract and remove minerals and other impurities from the water, leaving it free of mineral and other substances.

Capacity of Dm water tank is 20 Ton / hr is divided into four different process line individually, per line consume capacity of 5,000 Liters/Hours (L/h) in flow rate.

The Closed loop operation is suitable for the water tank process. Feedback signal process control to get compared with the reference input thereby providing controlled action.

DM-water storage tank is used to store water which will be used in the H2 plant for electrolysis process.The capacity of DM-water storage tank is 5000 Lt/hr. For level measurement level switch – Vibrating Fork Switch

Vibrating fork level switch provides you with point level detection for alarm, monitoring , and control. It is reliable and perfect for overfill prevention and pump protection applications. The frequency changes depending on the media in which it is immersed. When liquid covers the forks, the frequency drop. Changes to the frequency are continuously monitored by the switch electronics ,which then change the output state to operate an alarm, pump, or valve

Level switch sends electronic signal to indicator and LAH (Level alarm high) and LAL(Level alarm low) according to alarm operator will get to know level of the storage tank

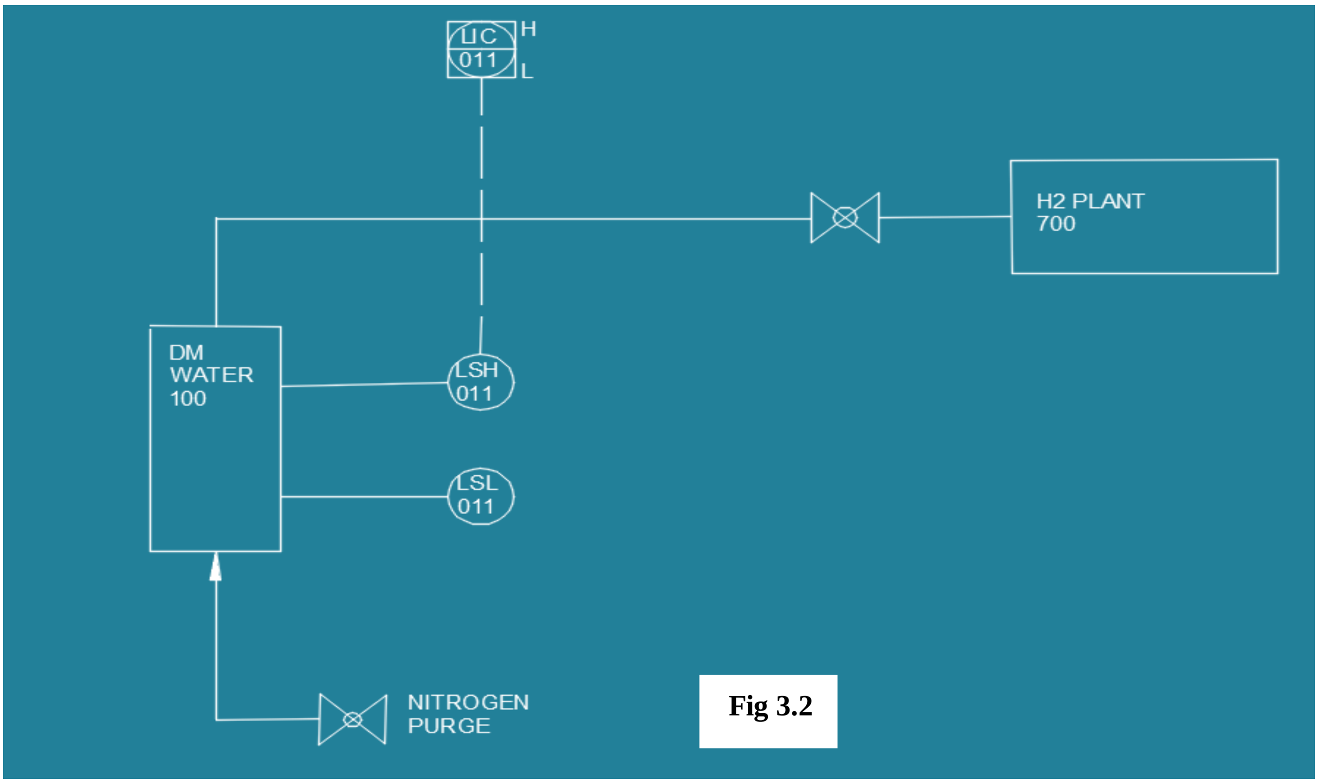

Fig 3.2

For final control element (control valve) Ball valve will work. Ball valve used for fluid regulation and control it can be equipped with different driving devices to form a variety of different control method.

The hydrogen plant system involves two main equipment, the hydrogen generator and power supply. Hydrogen generator consists of mechanical equipment and piping systems supporting the electrolysis process. Control systems and instruments are located near the generator.

The power supply consists of equipment to convert AC power input into DC power in the electrolysis process. The power supply at the installation is separate from the hydrogen generator.

Main Input (raw material) of Hydrogen Plant is Demineralized water,, nitrogen as the initial cleaner, and cooling water to remove heat due to the electrolysis process. In the electrolysis process, two products will be produced, namely hydrogen (H2) and oxygen (O2).

The electrolysis process in pure water has very low efficiency, this is because water has a low ionization constant. To increase the efficiency of electrolysis, KOH is added in water. KOH is used as a catalyst that speeds up the electrolysis process. The results of the electrolysis process will produce hydrogen gas (H2) and oxygen gas (O2). Hydrogen gas produced from electrolysis will be separated from the water point by the mist separator. Once separated from the water point, hydrogen gas will be stored in the gas holder.

So here we will segregate oxygen Product in separate storage line and as well as Hydrogen in independent Storage line.

Hydrogen generator works on Electrolysis process. Electrolysis of water is the best method of producing high purity hydrogen gas on demand. The most important element of the generator is the electrolyzescell where the electrolysis reaction takes place. The cell consists of two electrodes (an anode and a cathode), which are separated by the ion exchange membrane. To produce the highest purity of hydrogen. The gas separation system is used to separate the hydrogen and oxygen gases that are produced in the electrolysis cell. The gases are typically separated using a membrane or pressure swing adsorption (PSA) system. Given capacity of hydrogen plant 500 Kg/hr.

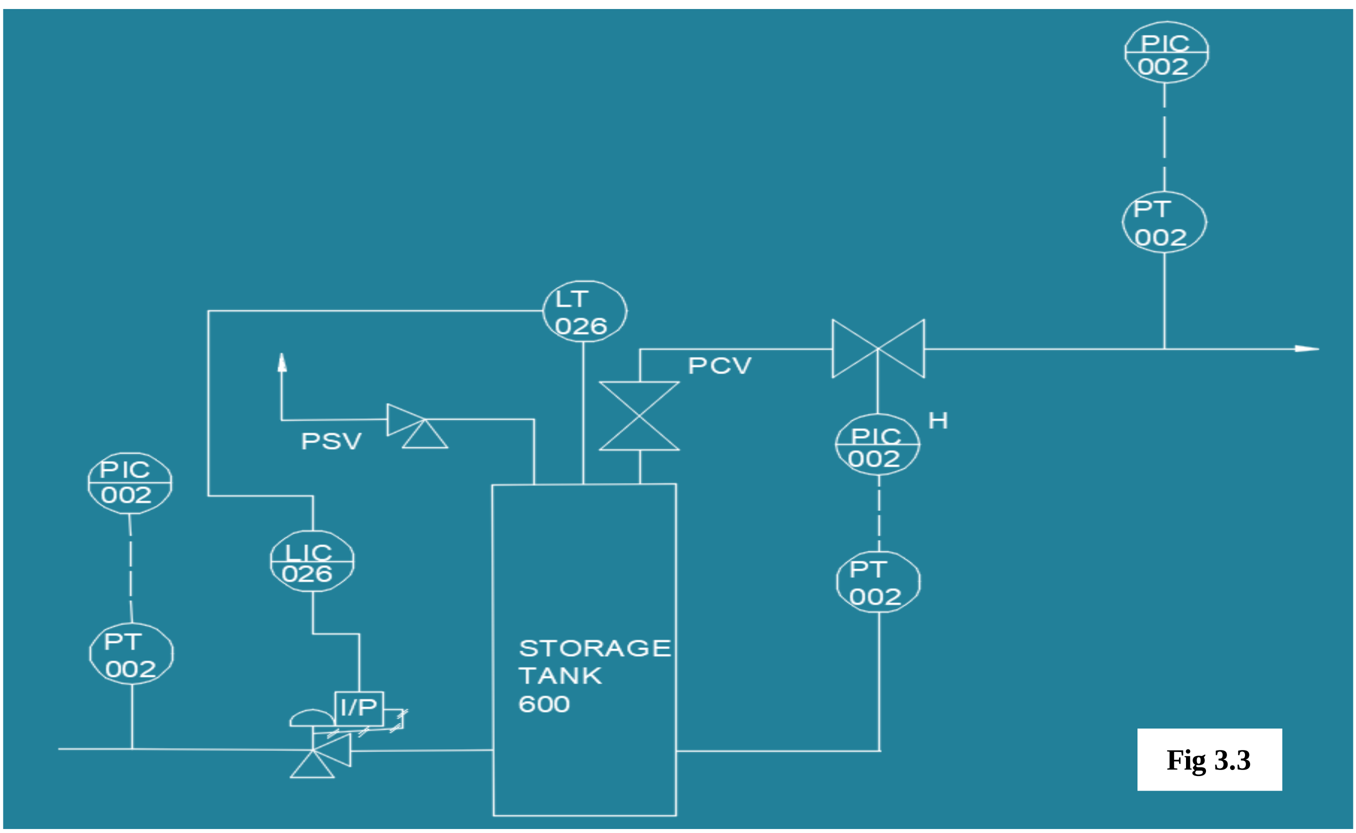

Fig 3.3

A pressure transmitter and a pressure indicator is to be provided to indicate inlet pressure. On the developed piping and instrumentation diagram, PT 002and PI 002 are provided for this purpose. PT 002 measures the inlet pressure and sends the measured value via electrical signals to the pressure indicator.

A level transmitter is connected at top of the tank LT 026. It is used to transmit the gas level of the storage tank to the controller.A Level indicator controller LIC026 is connected which is mounted in the control room will calculate if the tank gas level is at desired value. If it is less than the set point then it will give the signal to the I/P converter connected to the control valve to open the control valve. If it is more than the desired valve then it will give the signal to the I/P converter to shut off the control valve. A pressure safety valve is to be provided in the instrumentation to relieve and vent excess pressure to a flare system. PSV is provided to relieve excess pressure and protect the gas vessel.

We will store Hydrogen gas in hydrogen storage tank what we acquire from Electrolysis Process. A moisture trap is a device used to remove moisture or water vapor from a gas or air stream. In the contextof a hydrogen production plant, a moisture trap is used to remove water vapor from the hydrogen gas stream before it is compressed and stored.

Water vapor can be problematic in a hydrogen production plant because it can cause corrosion of the equipment, reduce the efficiency of the process, and lower the quality of the hydrogen gas. Water vapor can also freeze in the compressed gas and cause blockages or damage to the equipment.
A moisture trap typically consists of a vessel that contains a desiccant material, such as silica gel or molecular sieve. As the hydrogen gas flows through the vessel, the desiccant material absorbs the water vapor, allowing the dry hydrogen gas to continue on to the next stage of the process. The moisture trap may need to be periodically replaced or regenerated, depending on the specific application and operating conditions. A moisture trap is an important component of a hydrogen production plant to ensure the quality and safety of the hydrogen gas, and to prevent damage to the equipment.

Store Hydrogen Gas will be discharged from the outlet to the moisture trap. Moisture trap is used to remove water from hydrogen.The gas which enters the moisture trap removes water and other impurities from hydrogenThe purified gas is discharged from moisture trap to the moisture separator. Moisture separators are devices used to remove moisture from a gas stream.When the hydrogen gas enters the moisture separator it removes water vapor from the gas before it enters the compressor

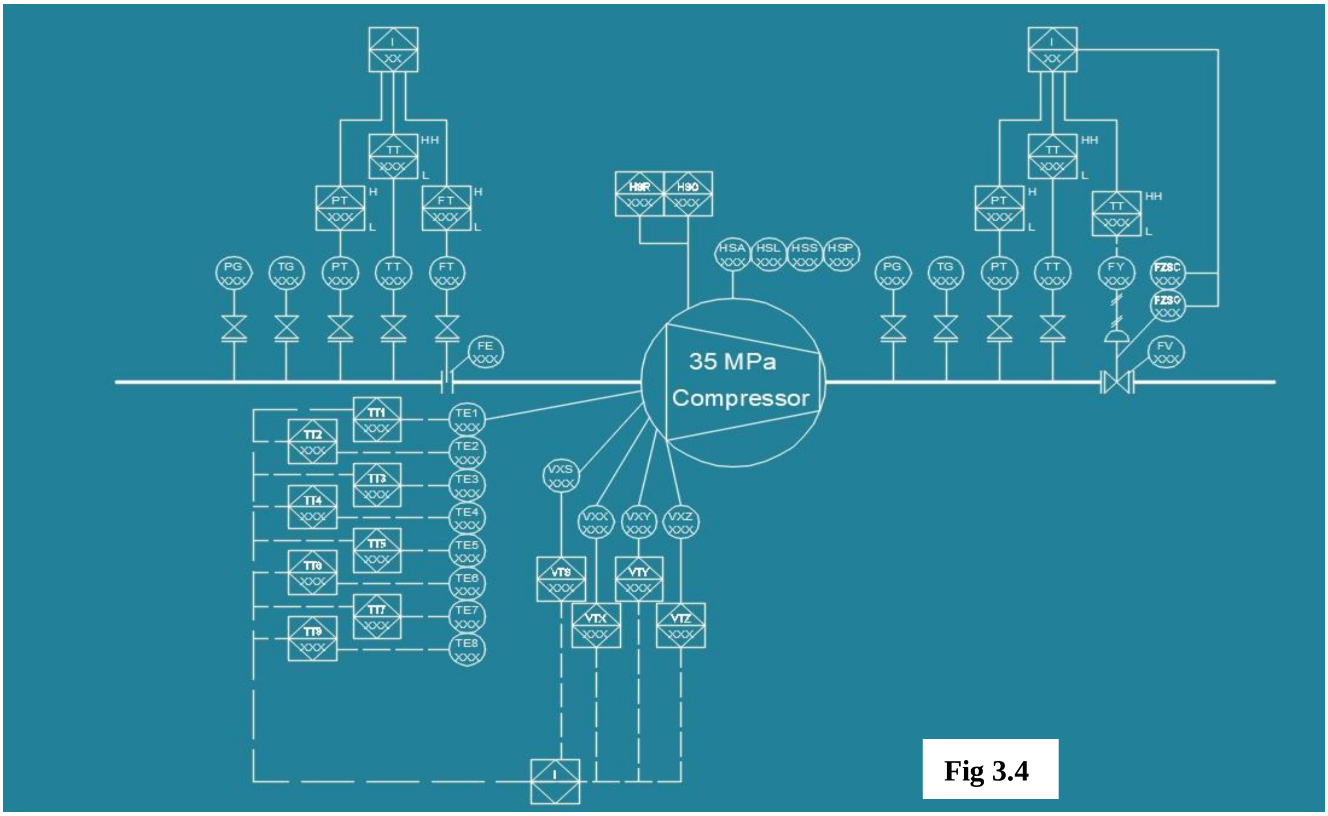
35 MPa
Compressor
PG
TG
PT
TT
FT
FE
HSR
HSO
HSA
HSL
HSS
HSP
FY
FZSC
FZSO
FV
TE1
TE2
TE3
TE4
TE5
TE6
TE7
TE8
VXS
VXX
VXY
VXZ
VTX
VTY
VTZ
HH
H
L
I

Fig 3.4

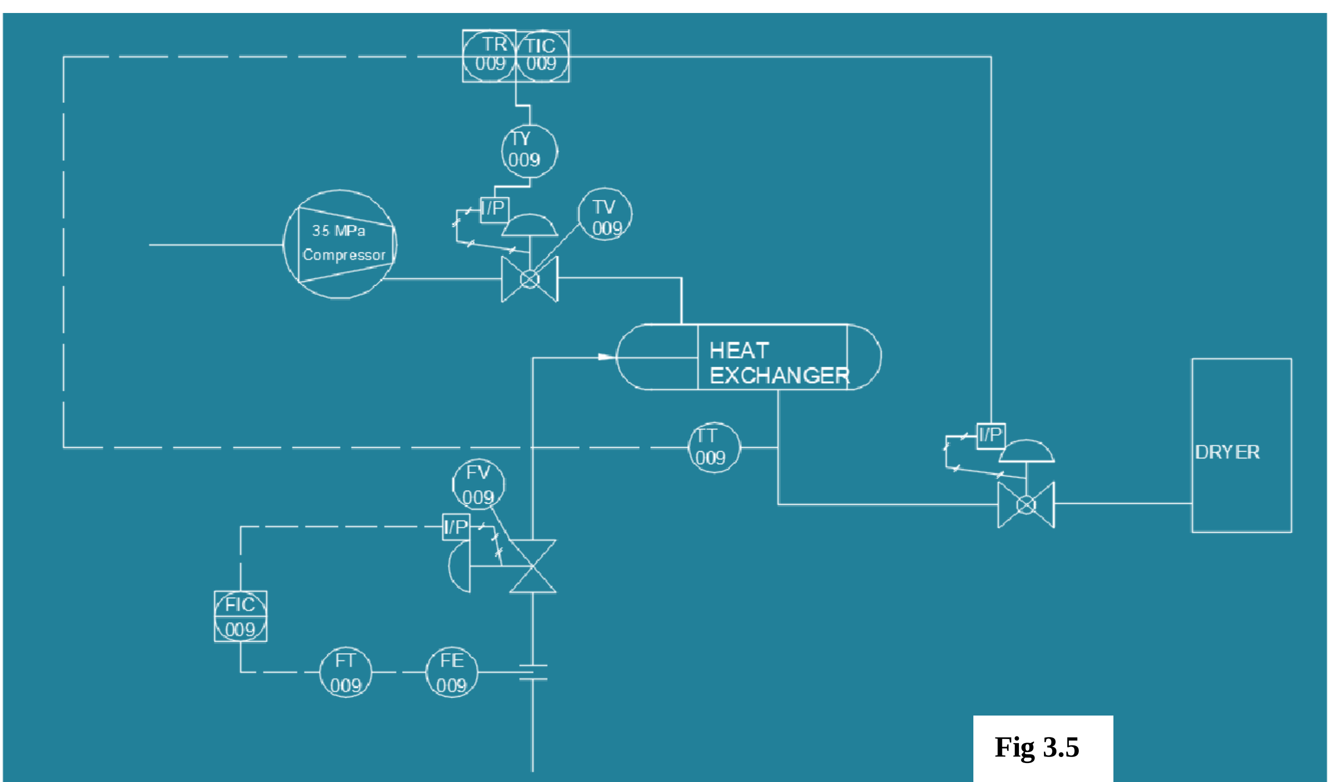
TR
009
TIC
009
TY
009
I/P
TV
009
35 MPa
Compressor
HEAT
EXCHANGER
TT
009
DRYER
FV
009
FIC
009
FT
009
FE
009

Fig 3.5

35 MPa compressor, compare dispense compressed gas of 35 MPa pressure range. when the gas is compressed, its molecules come closer & internal energy of gas will increased and the number of collisions will also increase. The moment gas is compressed, the work done on it shows output as increased in internal energy(heat). As gas is compressed the gas temperature increases, to maintain the temperature this compressed gas will be pass through shell and tube heat exchangers.This heat exchangeris used to heat up to process fluid at desired outlet temperature. Therefore, action must be taken to correct any deviation so as to maintain the outlet process temperature at it's desired value.

Here, we have to maintained the range of the temperature at 25°C. On the line from Compressor (capacity 35 MPa) to heat exchanger Actuated Ball valve is install Actuated ball valves are rotating ball type pipe valves that Come without manual turn handles. These valves are used together with an actuator device to automate valve. opening and closing and therefore control plumbing fluid rates.

Temperature sensor (TE) can use RTD -Resistance Temperature Detector

RTD has a temperature measurement range of -200°C to 850°C. It is a 4wire Pt100 element type. It gives an output of 4-20mA.It possess high accuracy of measurement, it response quickly, it give stable and accurate performance over many years, temperature compensation is not required.The outlet temperature is measured by a sensor i-e. RTD and transmitted by smart transmitter Single Modular Auto-ranging Remote Transducer.

It is an Intelligent transmitter that has an analog output of simultaneously provides digital. Communication signal based. Signal based on HART Protocol or FOUNDATION FIELDBUS or PROFIBUS. The input signal receives. from external sensing element (RTD). & output is in the form 4 - 20 mA standard loop arrangement mg also be in the form of pulse digital output.

Our final control element is control valve present in the loop it works on pneumatic signal (3-15 psig) to convert this pressure signal into electronic signal we need converter. For temperature signal conversion we need temperature converter this conversion of electronic signal will help us to show reading on indicator and controller thus we can manipulate and control the signal as per the desired output by setting a set points from PLC.

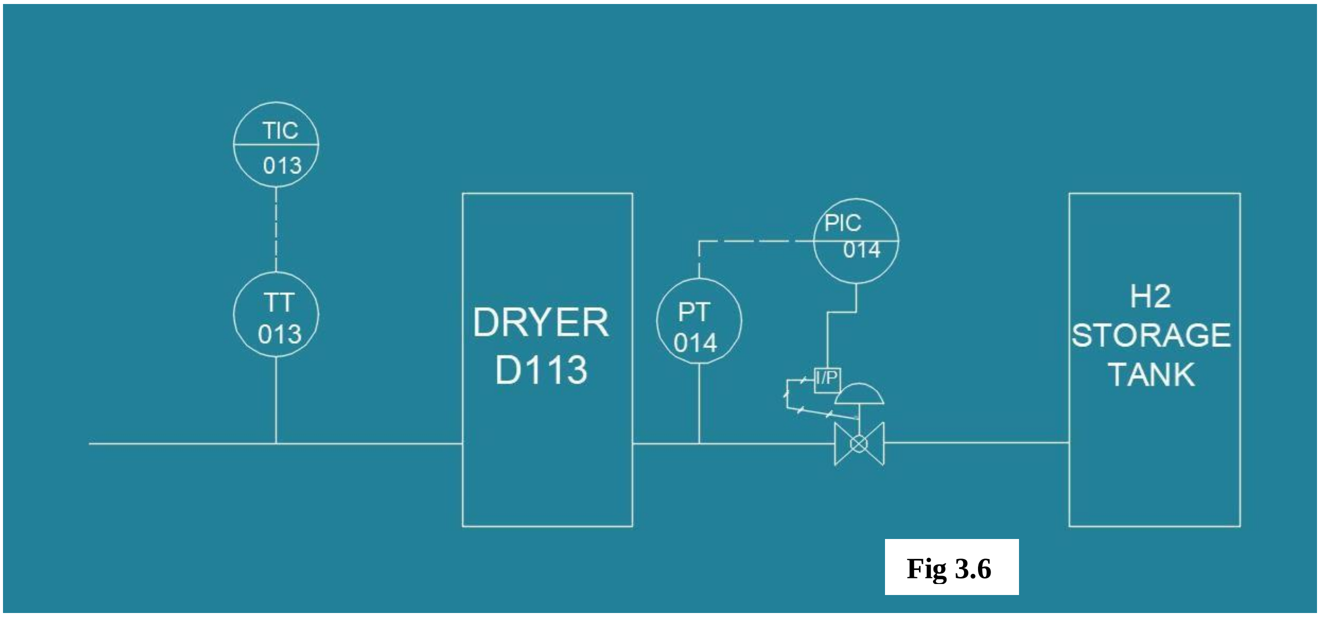

Fig 3.6

After Heat Exchanger the Hydrogen Gas will pass through dryer.Process dryers are used to remove liquids or moisture from bulk solids, powders, parts, continuous sheets, gases or other fluids.

TC-013 (Temperature Controller) that is used to control temperature. It does this by first measuring the temperature, it then compars it to the desired value (set value). it's mounted at upstream side of Dryer. In drying process all leftover moisture will get cancel out and thus this pass to the Hydrogen storage capacity of 35 Mpa. At the downstream of the dryer PC-014(Pressure controller) is mounted to control and measure pressure.

One fluid line from Hydrogen Storage tank capacity 35 Mpa will go to the dispenser for furthermore uses, and another line from Hydrogen storage tank will go ahead to another Multistage Compressor who's capacity is set on 70Mpa. Here we want two final output capacity of 35 Mpa and 70 Mpa.

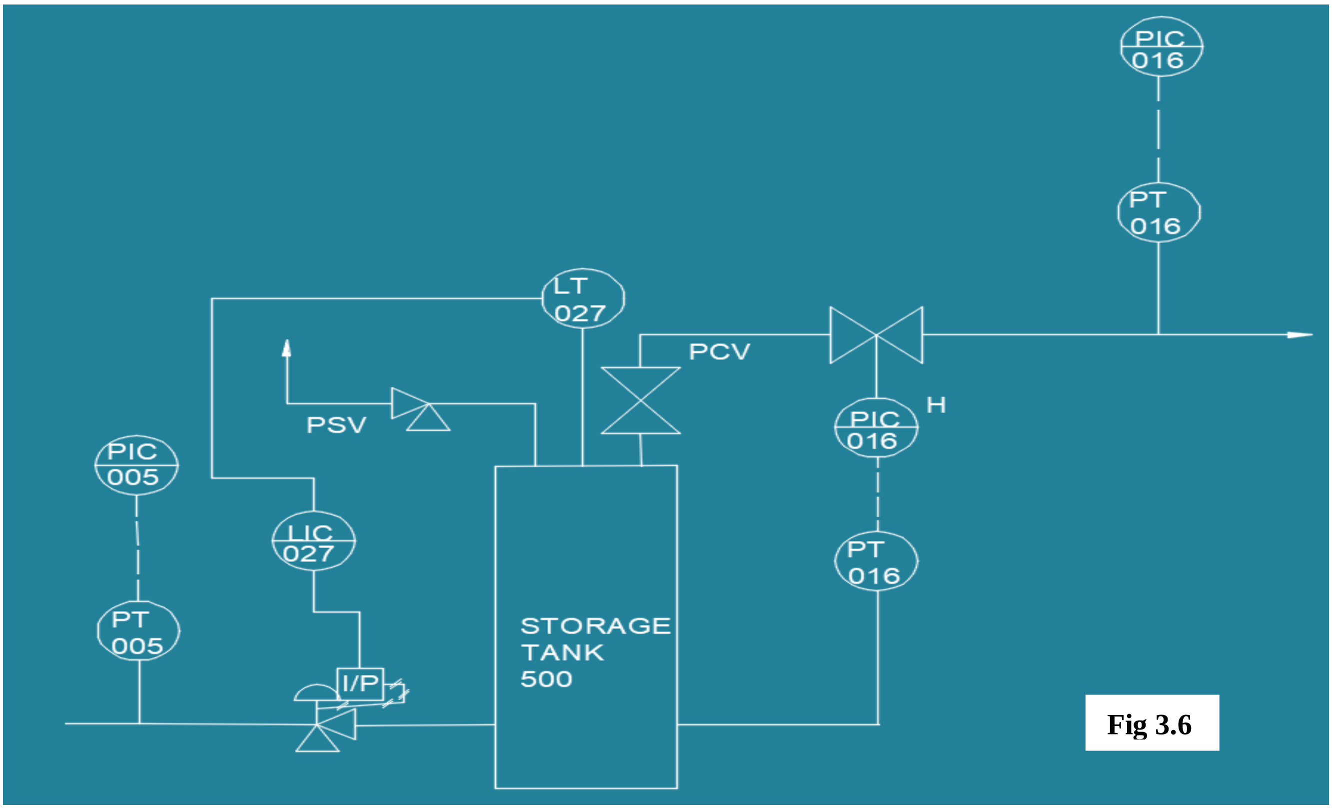

Fig 3.6

A pressure transmitter and a pressure indicator is to be provided to indicate inlet pressure. On the developed piping and instrumentation diagram, PT 003 and PI 003 are provided for this purpose. PT003 measures the inlet pressure and sends the measured value via electrical signals to the pressure indicator.

A level transmitter is connected at top of the tank LT 027. It is used to transmit the gas level of the storage tank to the controller.A Level indicator controller LIC027 is connected which is mounted in the control room will calculate if the tank gas level is at desired value. If it is less than the set point then it will give the signal to the I/P converter connected to the control valve to open the control valve. If it is more than the desired valve then it will give the signal to the I/P converter to shut off the control valve. A pressure safety valve is to be provided in the instrumentation to relieve and vent excess pressure to a flare system. PSV is provided to relieve excess pressure and protect the gas vessel.

We will store Hydrogen gas in hydrogen storage tank what we acquire from Compressor.Store Hydrogen Gas will be discharged from the outlet to the moisture trap. Moisture trap is used to remove water from hydrogen.The gas which enters the moisture trap removes water and other impurities from hydrogenAfter the gas is compressed to 35Mpa, hydrogen gas is discharged from two outlet of the storage tank one outlet goes to the moisture trap and the other outlet goes to the dispenser.A DP transmitter is connected on-line to the outlet which goes to the dispenser. It will measure whether thegas pressure is 35Mpa or more.If the gas pressure is more than 35Mpa the pressure transmitter connected to the DP transmitter will give the signal to the controller and the controller will give the signal to the pressure relief valve and the excess pressure will be released to the atmosphere. If the gas pressure is equal to 35Mpa then the hydrogen gas will pass to the dispenser.

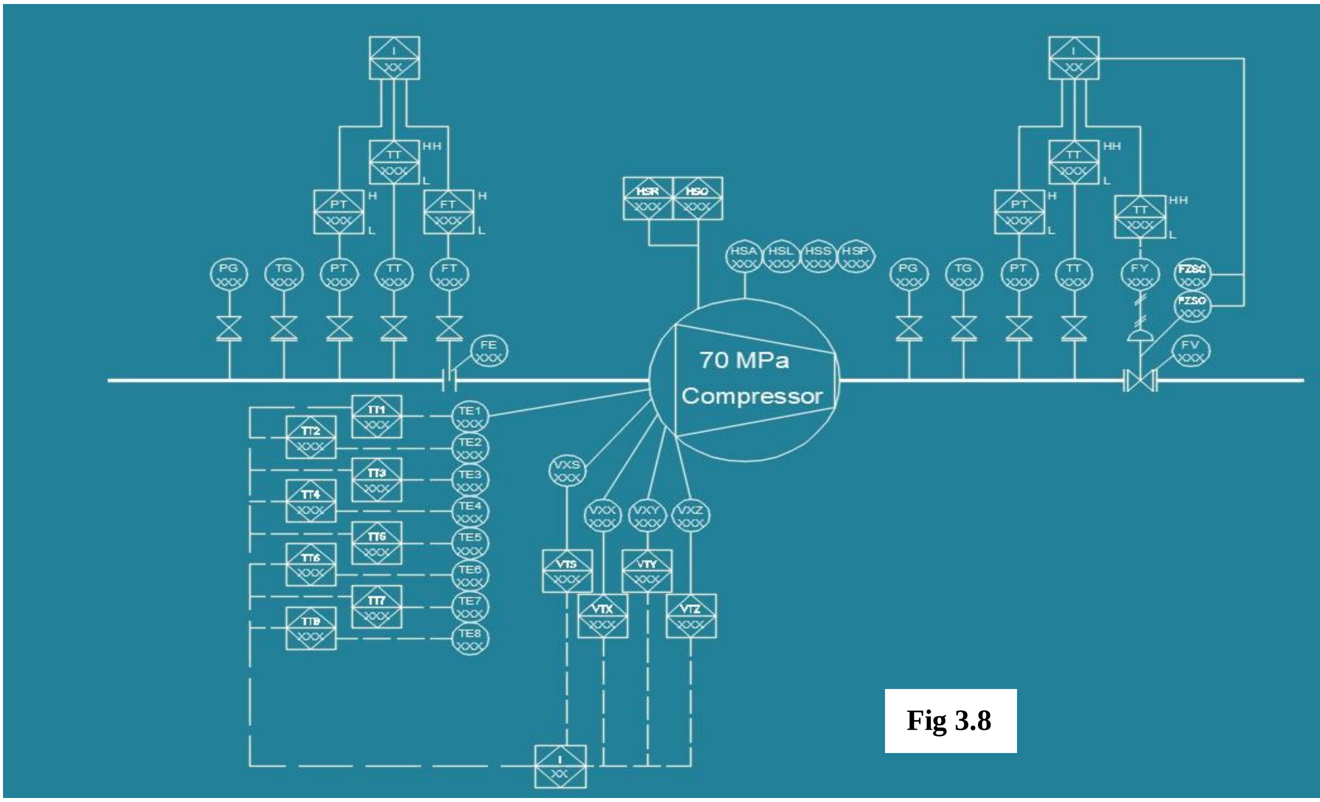
70 MPa
Compressor
PG
TG
PT
TT
FT
FE
HSR
HSO
HSA
HSL
HSS
HSP
FY
FV
VXS
VXX
VXY
VXZ
VTS
VTY
VTX
VTZ
TE1
TE2
TE3
TE4
TE5
TE6
TE7
TE8

Fig 3.8

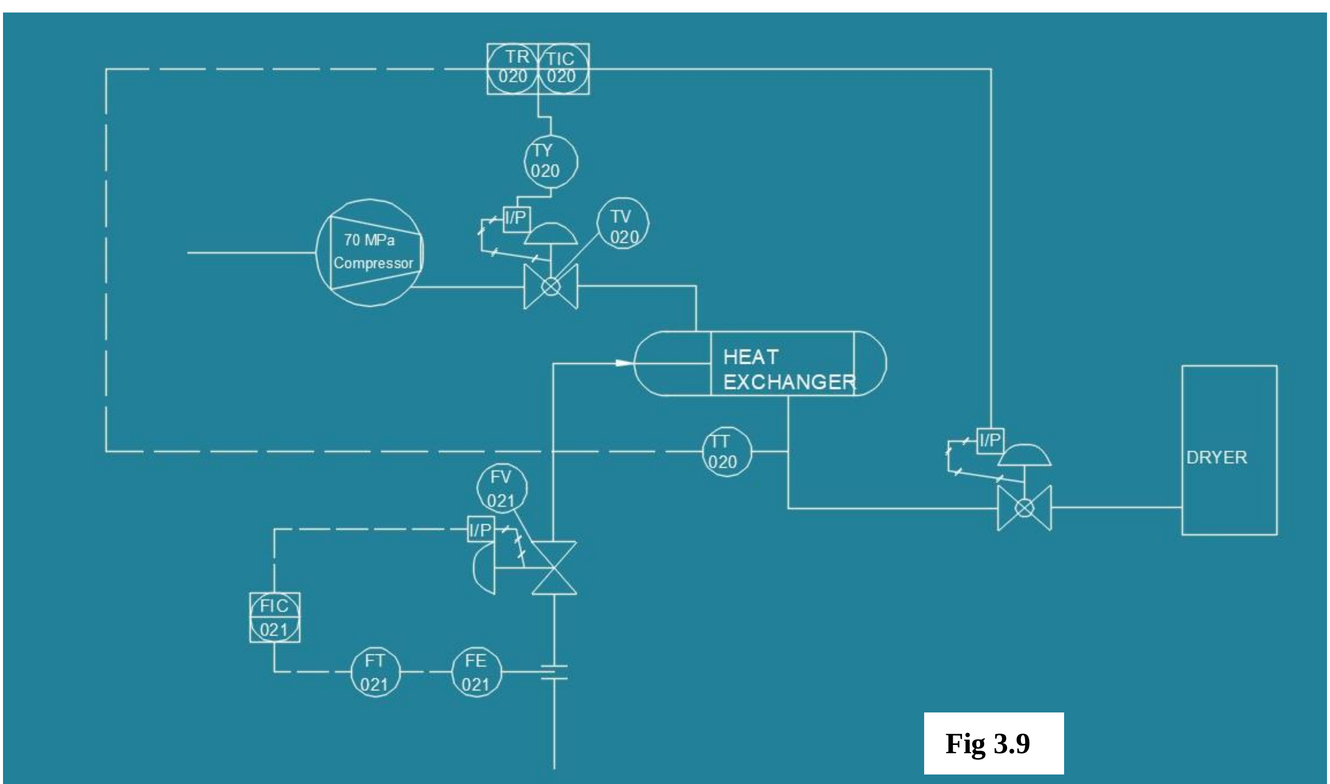
TR
020
TIC
020
TY
020
I/P
TV
020
70 MPa
Compressor
HEAT
EXCHANGER
TT
020
FV
021
DRYER
FIC
021
FT
021
FE
021

Fig 3.9

70 MPa compressor, compare dispense compressed gas of 70 MPa pressure range. when the gas is compressed, its molecules come closer & internal energy of gas is increased & the number of collisions will also increase.

As the gas is compressed, the work done on it shows op as increased internal energy. As gas compressed the gas temperature increases, so that is for a certain, this compressed gas will get going through shell and tube heat exchangers.

This heat exchanger is used to heat up to process fluid desired outlet temperature. Therefore, action must be taken to correct any deviation so as to maintain the cutlet process temperature at it's desired value.Here, we have to maintained the range of the temperature at 25 Celsius. On line from Compressor (capacity 70 MPa) to heat exchanger Actuated Ball valve can install Actuated ball valves are rotating ball type pipe valves that Come without manual turn handles. These valves are used together with an actuator device to automate valve. opening and closing and therefore control plumbing fluid rates.

Temperature sensor (TE) can use RTD -Resistance Temperature Detector

RTD has a temperature measurement range of -200°C to 850°C. It is a 4wire Pt100 element type. It gives an output of 4-20mA.It possess high accuracy of measurement, it response quickly, it give stable and accurate performance over many years, temperature compensation is not required.The outlet temperature is measured by a sensor i-e. RTD and transmitted by smart transmitter Single Modular Auto-ranging Remote Transducer.

It is an Intelligent transmitter that has an analog output of simultaneously provides digital. Communication signal based. Signal based on HART Protocol or FOUNDATION FIELDBUS or PROFIBUS. The input signal receives. from external sensing element (RTD). & output is in the form 4 - 20 mA standard loop arrangement mg also be in the form of pulse digital output. Our final control element is control valve present in the loop it works on pneumatic signal (3 -15 psig) to convert this pressure signal into electronic signal we need converter. For temperature signal conversion we need temperature converter this conversion of electronic signal will help us to show reading on indicator and controller thus we can manipulate and control the signal as per the desired output by setting a set points from PLC.

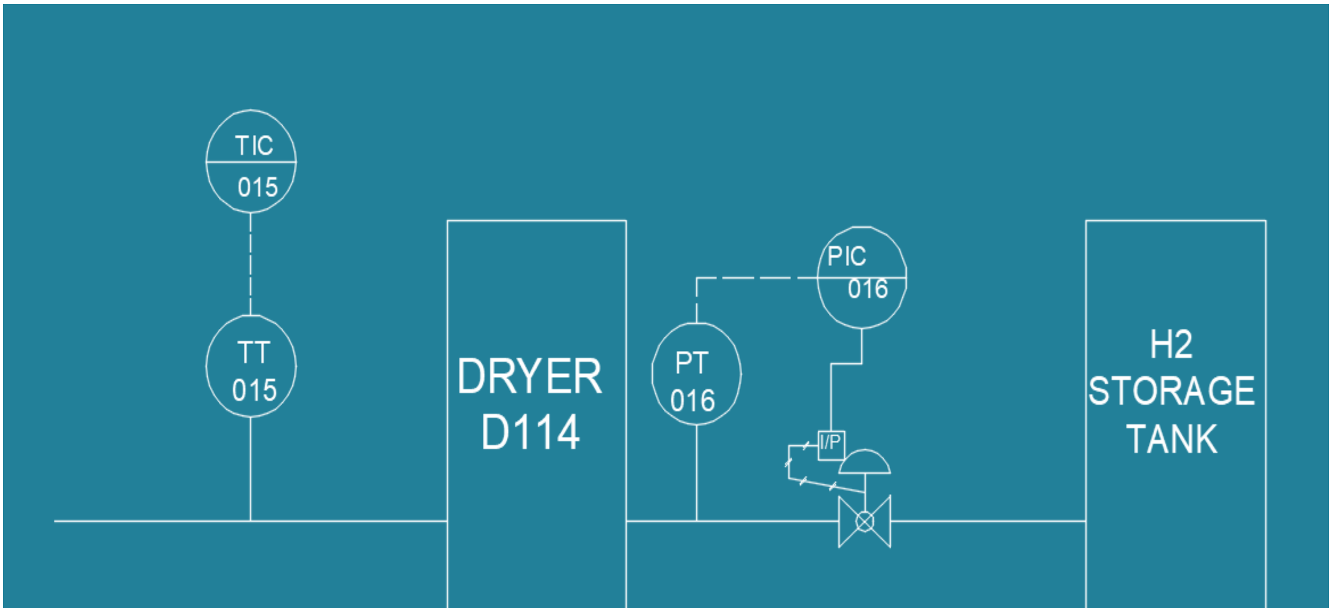

Fig 3.10

After Heat Exchanger the Hydrogen Gas will pass through dryer.Process dryers are used to remove liquids or moisture from bulk solids, powders, parts, continuous sheets, gases or other fluids.

TC-015 (Temperature Controller) that is used to control temperature. It does this by first measuring the temperature, it then compars it to the desired value (set value). it's mounted at upstream side of Dryer. In drying process all leftover moisture will get cancel out and thus this pass to the Hydrogen storage capacity of 70 Mpa. At the downstream of the dryer PC-016(Pressure controller) is mounted to control and measure pressure.

One fluid line from Hydrogen Storage tank capacity 70 Mpa will go to the dispenser for furthermore uses, and another line from Hydrogen storage tank will go ahead to another Multistage Compressor who's capacity is set on 70Mpa. Here we want two final output capacity of 35 Mpa and 70 Mpa.

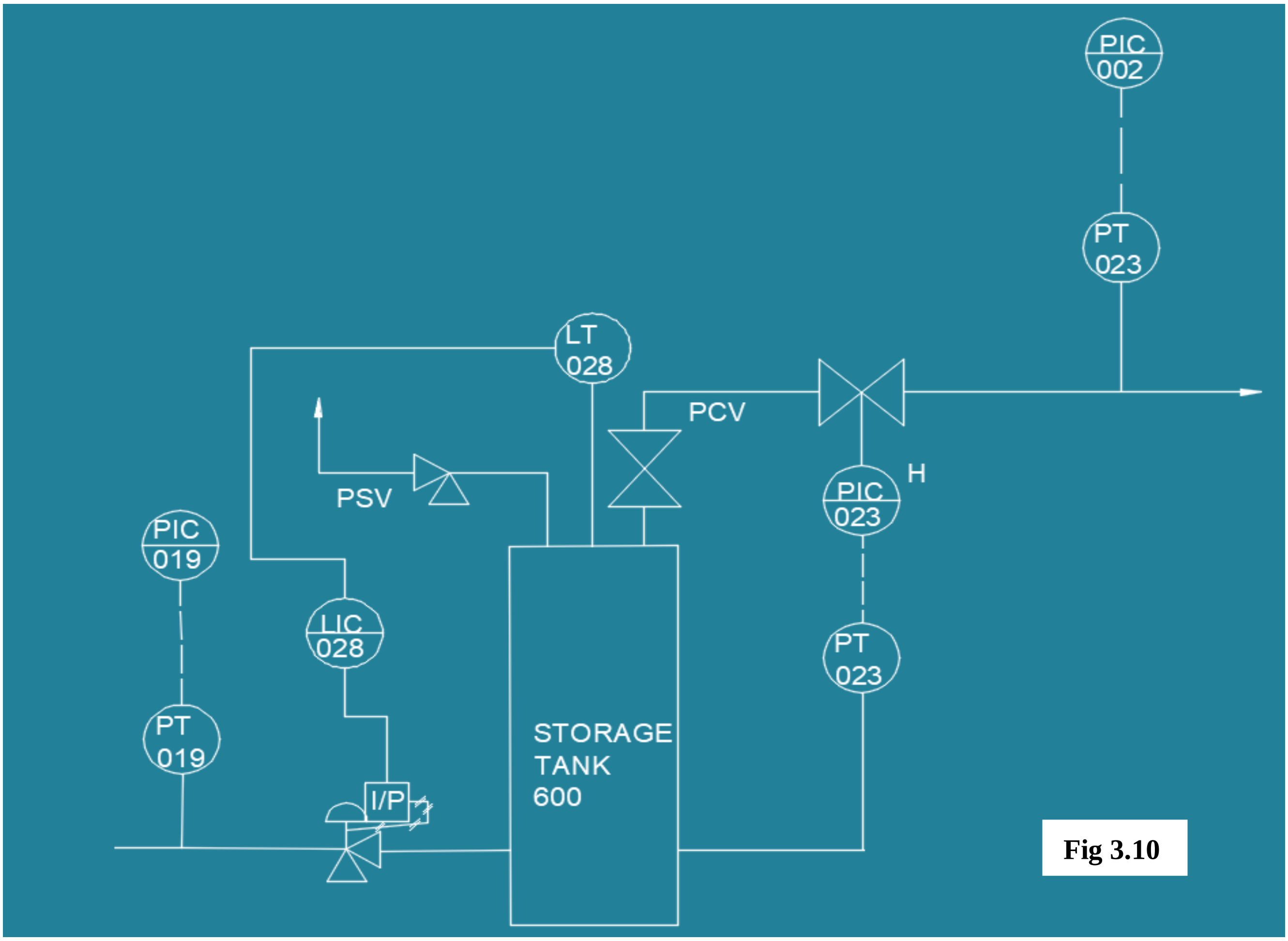

Fig 3.10

A pressure transmitter and a pressure indicator is to be provided to indicate inlet pressure. On the developed piping and instrumentation diagram, PT 019 and PI 019 are provided for this purpose. PT019 measures the inlet pressure and sends the measured value via electrical signals to the pressure indicator.

A level transmitter is connected at top of the tank LT 0278 It is used to transmit the gas level of the storage tank to the controller.A Level indicator controller LIC028 is connected which is mounted in the control room will calculate if the tank gas level is at desired value. If it is less than the set point then it will give the signal to the I/P converter connected to the control valve to open the control valve. If it is more than the desired valve then it will give the signal to the I/P converter to shut off the control valve. A pressure safety valve is to be provided in the instrumentation to relieve and vent excess pressure to a flare system. PSV is provided to relieve excess pressure and protect the gas vessel.

We will store Hydrogen gas in hydrogen storage tank what we acquire from Compressor Store Hydrogen Gas will be discharged from the outlet to the moisture trap. Moisture trap is used to remove water from hydrogen. The gas which enters the moisture trap removes water and other impurities from hydrogen

After the gas is compressed to 70Mpa, hydrogen gas is discharged from two outlet of the storage tank one outlet goes to the moisture trap and the other outlet goes to the dispenser.A DP transmitter is connected on-line to the outlet which goes to the dispenser. It will measure whether the gas pressure is 70Mpa or more.If the gas pressure is more than 70Mpa the pressure transmitter connected to the DP transmitter will give the signal to the controller and the controller will give the signal to the pressure relief valve and the excess pressure will be released to the atmosphereIf the gas pressure is equal to 70Mpa then the hydrogen gas will pass to the dispenser.

Valve Placement: Valves can be placed at the beginning and end of the pipeline to control the flow of hydrogen in and out of the pipeline. This can be useful for isolating the pipeline for maintenance or emergencies, or for diverting the flow of hydrogen to another location.

At the control points: Valves can also be placed at control points along the pipeline to allow for the isolation of specific sections of the pipeline for maintenance or troubleshooting.

The specific placement of valves will depend on the design and operation of the pipeline, and it's recommended to consult with experts and literature for the best options for a particular pipeline and application. Additionally, it is recommended to use explosion-proof and corrosion resistant.To detect and monitior the positoin of valve of storage tank pipeline and other equipment can be used to ensure that the valve are operating correctly and that the hydrogen gas is flowwing through storage tank and pipeline as intended.

Valve sensors are instruments used to indicate the position of a valve. For example, when installed on a shutoff valve like a ball valve, sensors such as limit switches are used to indicate whether the valve is fully open or fully closed. Other types of position sensors may also be used to communicate real time position data throughout the rotation of the valve.

Valve position sensor readouts can be displayed via lights, dials with hands or digital screens. In more complex systems, the limit switch or position sensor will wire directly into the programmable logic system (PLC) in order to automate processes when the valve reaches a certain position.

A UV/IR flame detector consists of ultraviolet (UV) and infrared (IR) sensors that are joined together in a single apparatus. UV sensors work by detecting the UV radiation emitted by the flame and are sensitive to a wide range of flammable fuels including hydrocarbons, sulfur, hydrazine and ammonia.

UV/IR flame detector are connected to F&G(Fire and Gas System) for safety of plant. The location of the detectors are set looking to the leakage points at the inlet and outlet connections and around the storage tank surroundings.

Chapter 4

Leak Detection

Increased uptake of hydrogen technologies is not without its downsides. While hydrogen performs well as a fuel, it presents a much greater explosion hazard than many other liquid and gas fuels. This is for two reasons. Firstly, hydrogen is much more difficult to contain than other gases. Hydrogen gas consists of H2 molecules: each molecule is made up of two hydrogen atoms bound together. This makes H2 the smallest molecule in the universe. Hydrogen gas is therefore prone to leaking out of containment. In addition to this, hydrogen is extremely flammable. Hydrogen in air is flammable at concentrations between 4% and 75% by volume (for comparison, methane is flammable in air only in a proportion between 4.4% and 17% by volume). The amount of energy required to ignite a hydrogen/air mixture is also much lower than for other fuels. The minimum amount of energy required to ignite a mixture of hydrogen and air is just 0.017 mJ. In contrast, the minimum ignition energy for hydrocarbon fuel gases is much higher, at around 0.3 mJ for methane/air or propane/air mixtures. The result is that hydrogen leaks are common, and even very small hydrogen leaks can be relatively easily ignited.8 It is therefore essential that appropriate measures are put in place to mitigate the risk of hydrogen leaks.

Hydrogen Gas Detection

Hydrogen gas is highly flammable and can pose a risk of fire or explosion if it leaks. However, hydrogen gas is also lighter than air, so it tends to rise and disperse quickly in the atmosphere, which reduces the likelihood of a fire or explosion. If a hydrogen leak does occur, it is important to follow proper safety procedures, such as evacuating the area, ventilating the space, and avoiding any sources of ignition. It is also important to repair the source of the leak as soon as possible to prevent further releases of hydrogen gas.

Hydrogen is an odourless, colourless, and tasteless gas. Industry, therefore, relies on hydrogen gas detectors to detect leaks. IGD has two technologies suitable for detecting hydrogen: pellistor sensors and electrochemical sensors. Pellistor, or catalytic bead, sensors rely on the use of a catalyst that causes flammable gas within the sensor to ignite at a much lower temperature than usual. When combustion occurs, heat is produced in proportion to the amount of flammable gas present. The concentration of flammable gases can then be derived from this measurement and expressed as a percentage of the lower explosive limit (%LEL). Pellistor sensors are typically used as a general "catch-all" technology for flammable gas detection. Pellistors respond to any flammable gas, measuring 0-100% LEL. Since a 4% concentration of hydrogen is explosive, this corresponds to 100% LEL. Most legislation (such as the UK Dangerous Substance Explosive Atmosphere Regulations (DSEAR)) requires an atmosphere to be maintained below 25% LEL.

There are several components that may be included in a hydrogen leak detection system, including:

Sensors: These are used to detect the presence of hydrogen gas. There are various types of sensors that can be used for this purpose, including electrochemical sensors, catalytic bead sensors, and infrared absorption sensors.

Alarm: This is a device that is triggered by the sensors and alerts people in the area that there is a hydrogen leak. The alarm may be audible, visual, or both.

Shut-off valves: These are valves that automatically close when a hydrogen leak is detected, in order to stop the flow of gas.

Control panel: This is the central hub of the leak detection system, where information from the sensors is collected and processed. The control panel may also be used to manually activate the shut-off valves if necessary.

Display: This is a device that shows the status of the leak detection system, including the location and severity of any leaks that have been detected.

Communication system: This is used to alert personnel in the event of a hydrogen leak. The communication system may include pagers, radios, or other devices that can be used to notify people of the leak.

There are several types of sensors that can be used to detect hydrogen gas:

- **Electrochemical sensors**: These sensors use a chemical reaction to detect the presence of hydrogen gas. They are relatively inexpensive and have a good response time, but they may be affected by other gases that are present in the air. These sensors use a chemical reaction to detect the presenceof hydrogen gas.

Electrochemical sensors work by reacting with the gas of interest and producing an electrical signal proportional to the gas concentration. Consisting of two electrodes (a working electrode and a counter electrode), the sensor operates by allowing charged molecules to pass through a thin layer of electrolyte.

An electrochemical sensor consists of the following components:

<u>Gas permeable membrane</u> – this material covers the sensing electrode and is used to control the amount of gas molecules reaching the electrode surface. The membrane also performs the important role of filtering unwanted particulates.

<u>Electrode (anode) –</u> to create an effective reaction with gas molecules, the electrode is typically made from metals such as platinum or gold and works as a transducer. The anode is the point at which the current enters the electrode.

<u>Electrode (cathode)</u> – this is the point where the current leaves the electrode.

<u>Electrolyte</u> - the electrolyte facilitates the cell reaction and carries the ionic charge across the electrodes.

They are relatively inexpensive and have a good response time, but they may be affected by other gases that are present in the air.

- **Catalytic bead sensors:**

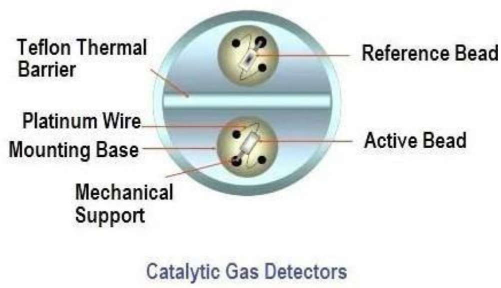

Fig4.1

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These sensors use a thin layer of platinum or palladium that is coated onto a ceramic bead.When hydrogen gas comes into contact with the bead, it causes a chemical reaction that generates a small electrical current. Catalytic bead sensors are relatively accurate, but they may be affected by high temperatures and may need to be replaced after extended use.Catalytic gas detectors are based upon the principle that when gas oxidizes it produces heat, and the sensor converts the temperature change via a standard Wheatstone Bridge-type circuit to a sensor signal that is proportional to the gas concentration. The sensor components consist of a pair of heating coils (reference and active).

<u>The limiting factors in catalytic detector technology:</u>

Catalysts can become poisoned or inactive due to contamination (chlorinated & silicone compounds, prolonged exposure to H2S and other sulfur &/or corrosive compounds).

The only means of identifying detector sensitivity loss is by checking with the appropriate gas on a routine basis and recalibrating as required.

Requires oxygen for detection.

Prolonged exposure to high concentrations of combustible gas may degrade sensor performance.

If flooded with a very high gas concentration, may show erroneously low or no response, and sensor may be damaged or rendered inoperable.

- **Ultrasonic Gas Leak Detectors**

Ultrasonic (acoustic) gas leak detection technology functions through the constant monitoring of wide areas by advanced acoustic sensors specially tuned to process ultrasound emitted from pressurized gas leaks. Ultrasonic gas leak detectors do not have to wait until a hazardous gas concentration has accumulated or the gas cloud made physical contact with a sensorFluids escaping from openings generate sonic and ultrasonic waves. With the acoustic emission technique leaks can be detected from a distance. The method can be considered for the location of leakage from buried pipes and tanks.Although the technique has limitations for low-pressure gas problems,it can detect the gurgling of leaks from sewers and other low pressure liquid lines.

One successful application of the ultrasonic leak detector is the detection of the leaking of steam traps from a distance.These portable probe-type units can also detect the in-leakage of atmospheric air into vacuum equipment.The UGLD is designed to ignore the audible sound and lower ultrasonic frequenciesand only sense ultrasonic frequencies in the range of 25 kHz to 70 kHz.UGLD measures the ultrasonic sound in decibels (dB). When there is a gas leak within the detector's range, the sound level will exceedthe trigger level of the UGLD and cause an alarm.

Conventional gas concentration base detectors became problematic in open ventilated areas wherethe gas easily dilutes and drifts away from the gas sensor. UGLD resolves this problem by detecting acoustic ultrasound generated by pressurized gas escape from the leak.

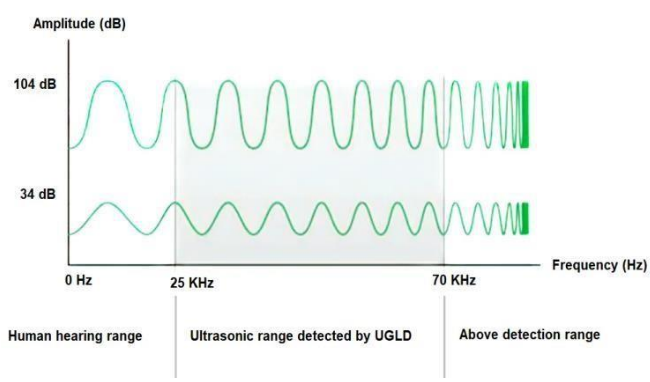

Fig 4.2

Detection Range

The ultrasound pressure pulse amplitude decrease over distance at predictable rate, manufacturers can establish detection coverage before ultrasonic gas leak detectors installation. The ultrasonic gas leak detectors are used for both large outdoor facilities and single installations. Detection range depends on the ultrasonic background noise level of the area and on the minimum gas leak rate to be detected. In an industrial environment wide variety of noise signals ranging from audible to ultrasonic frequencies are present. Basically it depends on the process equipment installed in the various parts of the plant.

For example process areas with turbines, pumps, compressors will have mix of sound frequencies at high decibel levels while other areas without any rotating equipment or remote locations will have mixof sound frequencies at low decibel levels.

Detection Criteria

Process element must be in gas phase;it cannot be a liquid Process pressure must be at least 150 psi to generate enough ultrasound.

- **Thermal Conductivity Detectors**

A TCD consistes of an electrically heated wire or thermistor.The temperature of the sensing element depend on thermal conductivity of the gas flowing around it.Thermal conductivity leak detectors have cells that contain coils in bridge circuits. Heat dissipation increases with the concentration of the gas or gases in the sample, and the cooling effect changes coil resistance.The instrument will detect many different gases and has a wide dynamic range.The portable, handheld leak detectors are provided with microprocessor-based intelligence. The unit is provided with a probe and a small fan that continuously draws in the gas that is present at the tip of the probe. The unit can be automatically zeroed (by pressing the re-zero button) based on the ambient air sample around the probe. Minimum Detectable Leak Rate of Hydrogen Gas Using Thermal Conductivity-Type Leak Detectors:-

Gas	Minimum Detectable Leak Rate (cc/s)	Minimum Detectable Leak Rate(cu. ft/ year)
Hydrogen	0.000005	0.06

- **Infrared absorption sensors:**

These sensors use infrared light to detect the presence of hydrogen gas. They are relatively accurate and can detect hydrogen at concentrations as low as 1% in air. However, they may be affected by other gases that absorb infrared light, and they may be more expensive than other types of sensors.

- **Pressurization or Hydrostatic Testing**

Pressurization by pneumatic or hydraulic means is probably the most widely used method in industry. The fall of a pointer on a pressure gauge can indicate a leak.Various standards and codes explain specific procedures for piping, pneumatic instrumentation systems, and vessels. The recommended practice of the National Fire Protection Association (NFPA) goes into considerable detail on how to handle underground leaks.

- **Using Paints, Dyes, or Bubble Emission**

Commercial for_x0002_emulations are available that will bubble or foam at the point of a leak. Safe materials are available for different chemical applications. Once the existence of a leak has been proved by pressurization, the bubble emission technique can help to isolate its location.

Aerosols, paints, and papers that change color due to chemical reaction are used in much the same way as the materials that bubble and foam. They are applied to the exact area that is being tested, and the color change spots the leak.

- **Thermography**

Thermography involves the detection of temperature differences by scanning in the IR region of the spectrum. The result is a thermal picture that is usually two colors, but sophisticated systems can convert the measurements into graded colors. If a hot fluid is escaping, it can be detected at a distance, above or below ground, or under insulation. Leaking valves and steam traps are easily located through the use of this technique.

Methods that will help to detect leak in pipelines of hydrogen gas

- **Pressure monitoring:** The pressure in the pipeline can be monitored using sensors. If the pressure drops unexpectedly, it may indicate a leak.
- **Ultrasonic testing**: Ultrasonic sensors can be used to detect the presence of hydrogen gas by listening for the characteristic sound that hydrogen gas makes when it escapes from a leak.
- **Thermal imaging:** Thermal imaging cameras can be used to detect the presence of hydrogen gas by detecting the heat that is generated when hydrogen gas escapes from a leak.
- **Tracer gas**: A small amount of a different gas, such as helium, can be introduced into the pipeline. If a leak occurs, the tracer gas will escape and can be detected using sensors.
- **Visual inspection:** Trained personnel can visually inspect the pipeline for signs of a leak, such as discoloration or damage to the pipe.
- **Sniffer testing:** Hydrogen gas has a distinct smell, so a trained operator can use a gas sniffer to detect the presence of hydrogen gas and locate the source of the leak.

There are several things to consider when designing a hydrogen leak detection system:
Sensitivity: The sensors used in the system should be able to detect hydrogen gas at a low concentration, in order to provide an early warning of a leak.

Response time: The sensors should be able to detect a hydrogen leak as quickly as possible, in order to minimize the risk of a fire or explosion.

Reliability: The system should be reliable and able to accurately detect hydrogen leaks. It should also be able to withstand harsh environments and have a long lifespan.

Cost: The cost of the system should be considered, as it may be necessary to install multiple sensors and alarms in a large facility.

Ease of maintenance: The system should be easy to maintain and repair, in order to ensure that it is always functioning properly.

Chapter 5

ALARM MANAGEMENT SYSTEM

An alarm management system in a plant typically involves the use of a variety of instruments and controls to monitor different process variables, such as temperature, pressure, flow rate, and so on. These instruments may include sensors, transmitters, and other types of measurement devices that are installed throughout the plant. The data collected by these instruments is then typically transmitted to a central control system, where it can be monitored and used to trigger alarms if certain predetermined conditions are met. The control system may also include manual control panels, switches, and other types of inputs that allow operators to manually adjust the process or to shut it down in the event of an emergency. Alarm management is usually necessary in a process manufacturing environment that is controlled by an operator using a supervisory control system, such as a DCS, a SCADA or a programmable logic controller (PLC).

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Alarms should be presented within the operators field of view, and use consistent presentation style (colour, flash rate, naming convention).

Each alarm should provide sufficient operator information for the alarm condition, plant affected, action required, alarm priority, time of alarm and alarm status to be readily identified.

Alarm systems are not normally safety related, but do have a role in enabling operators to reduce the demand on the safety related systems, thus improving overall plant safety.

Alarm management and process safety are closely intertwined, and there is a high degree of importanceof alarm management and process safety intersection. Your alarm management system and associated operator intervention are often the last line of defense before a safety system trip.

There are a wide range of sensors and transmitters that can be used in an alarm system in a plant, depending on the specific process variables that need to be monitored. Some common types of sensors and transmitters that may be used include:

Temperature sensors: These sensors can be used to measure the temperature of a process or a specific component in the plant, such as a piece of equipment or a container. Common types of temperature sensors include thermocouples, resistance temperature detectors (RTDs), and thermistors.

Pressure sensors: These sensors can be used to measure the pressure of a fluid, such as a gas or a liquid, within a system. Common types of pressure sensors include gauge pressure sensors, absolute pressure sensors, and differential pressure sensors.

Flow sensors: These sensors can be used to measure the flow rate of a fluid within a system. Common types of flow sensors include orifice plates, venturi tubes, and flow meters.

Level sensors: These sensors can be used to measure the level of a fluid within a container or vessel. Common types of level sensors include float switches, ultrasonic sensors, and capacitive sensors.

Process transmitters: These devices can be used to transmit data from various types of sensors to a central control system, where it can be monitored and used to trigger alarms if necessary. Process transmitters may be used to transmit data from sensors that measure variables such as temperature, pressure, flow rate, and level.

Sensors and transmitters are critical components of an alarm management system in a plant, as they provide the means for collecting data about the process and transmitting that data to the control system. By continuously monitoring various process variables, such as temperature, pressure, flow rate, and so on, sensors and transmitters can help to ensure that the process is operating within safe and acceptable limits. If a sensor detects that a process variable has exceeded a predetermined threshold, it can send a signal to the control system to trigger an alarm. This can alert plant operators to take corrective action to prevent potential problems, such as equipment failure or process upsets. In this way, sensors and transmitters play a vital role in helping to maintain the safety and reliability of the process.

There are a number of ways to interface sensors and transmitters with an alarm management system in a plant. One common method is to use a process control network, such as a fieldbus or an industrial Ethernet network, to connect the sensors and transmitters to the control system. These networks typically use standardized protocols, such as Modbus, Profibus, or EtherNet/IP, to transmit data between the sensors and transmitters and the control system.

Another option is to use a wireless communication system to connect the sensors and transmitters to the control system. This can be useful in situations where it is difficult or impractical to run cables to the sensors and transmitters, such as in hazardous or hard-to-reach areas. Wireless systems can use a variety of technologies, such as Zigbee, Bluetooth, or Wi-Fi, to transmit data over short distances.

In some cases, it may also be possible to interface sensors and transmitters directly with the control system using analog or digital inputs. This can be done using cables or connectors, such as wiring harnesses or terminal blocks, to physically connect the sensors and transmitters to the control system.

Regardless of the method used, it is important to ensure that the interface between the sensors and transmitters and the control system is properly configured and tested to ensure that it is functioning correctly.

There are many different types of alarms that may be used in an alarm management system in a plant, depending on the specific process and the variables that need to be monitored. Some common types of alarms include:

Process alarms: These alarms are triggered when a process variable exceeds a predetermined threshold, such as a high temperature or a low flow rate.

Equipment alarms: These alarms are triggered when there is a problem with a piece of equipment, such as a malfunction or a failure.

Safety alarms: These alarms are designed to protect against potential hazards, such as leaks, spills, or other types of accidents.

Environmental alarms: These alarms are triggered when environmental conditions, such as air quality or noise levels, exceed acceptable limits.

Security alarms: These alarms are triggered when there is a security breach, such as an unauthorized access or tampering with equipment.

Maintenance alarms: These alarms are used to alert maintenance personnel when equipment needs to be serviced or replaced.

System alarms: These alarms are triggered when there is a problem with the alarm management system itself, such as a failure of the control system or a communication error

.It is important to carefully consider the types of alarms that are needed in a given system and to ensure that they are properly configured and tested to ensure that they are effective in detecting and responding to potential problems.

Alarm Prioritization

Every day, a control room operator comes across many alarms, and on some days the number of alarms flashing on the computer screen are soo huge that it can distract the operator that which alarm to take on first, that is why we need make make a differentiate between alarms that are in process control to get effective action in time.To simplify the situation the alarms are categorized based on their urgency. So, mainly there are 3 categories in which the alarms are divided.

1.High Priority alarms

2.Medium Priority alarms

3.Low Priority alarms

1) High Priority Alarms: As the name suggests, utmost importance has to be given to high priority alarms as it has the capacity to cause serious damage.

If such alarms are left unattended it can cause-Loss to living beings (human or animal)Can affect the environment. For e.g. can pollute the ground water, air etc.Can damage a costly equipment.Cause huge economic loss. (>1crore)

Example: Activation of a flame detector, leak detector installed on the top of a hydrogen storage tank as well as pipelines of the hydrogen gas is a high-priority alarm. alarms related to fire & gas have to be put into high-priority alarms and have to be attended as soon as possible.

2)Medium Priority Alarms: medium priority alarm, these are not as critical as high priority alarms, but still, if left unattended can cause-No loss to living beings (human or animal).Can effect the environment but not in large scale.Can effect the long term run life of an equipment.Significant economic loss. (10lacs-1crore)

Example: A low-pressure alarm at the suction of a centrifugal pump is a medium priority alarm. It will not cause any damage to site personnel or the local community, neither can it affect the environment, but it can cause wear & tear of the pump components decreasing the life span of the pump.

3)Low Priority Alarms: These are the least priority alarms among all if left unattended can cause-No loss to living beings (human or animals).No loss to environment.No equipment damageMinor economic loss (<10lac).

Example: A valve related to a drain vessel did not give closed feedback after giving a close command.

During alarm prioritization, care has to be taken such that, out of the total alarms configured in a plant, approximately,

5% has to be High priority alarms,

15% Medium priority alarms

80% Low priority alarms.

Chapter 6

Future Scope

For now, global hydrogen consumption is still low, less than 2% of global energy. But according to the Hydrogen Council, this consumption could reach 25% by 2050.The Solar Impulse Label is granted to innovative solutions for hydrogen mobility that meet high standards of sustainability and profitability.The prospects for the hydrogen economy are good. It could play a major role in the energy transition since it has a high energy efficiency, emits no pollutants locally and can contribute to massively reducing greenhouse gas emissions.Zero emission-The only emission from a fuel cell vehicle using hydrogen is water steam. Hydrogen is thus a clean fuel for cars without emissions of pollutants and greenhouse gases that contribute to climate change. Fast Refulling-Hydrogen charging stations are quite similar to the traditional filling stations. As hydrogen vehicles don’t need to be plugged in to charge unlike battery powered electric cars - the process of refuelling is quick.

Chapter 7

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Chapeter 8
Technical Paper to be Published

Instrumentation & Control of Hydrogen Production Plant

Vedant S Kadam
Instrumentation
Bharti Vidyapeeth College of Engineering
Navi Mumbai,India
vedantk517@gmail.com

Abha U Sonawane
Instrumentation
Bharti Vidyapeeth College of Engineering
Navi Mumbai,India
abhasonawane@gmail.com

Sanket S Vedpathak
Instrumentation
Bharti Vidyapeeth College of Engineering
Navi Mumbai,India
sanketvedpathak27@gmail.com

Prof. Swati K. Nadgaundi
Instrumentation
Bharti Vidyapeeth College of Engineering
Navi Mumbai,India
Swati.nadgaundi@bhartividyapeeth.edu

Abstract— **This paper is based on the control and monitoring process titled " Control and Instrumentation for Hydrogen Production Plant". Initial Stage of the plant, storage of the process which will be raw process fluid (Demineralized water) with the capacity of 20 Tons/hr is then divided into four different lines but with the same operation and the process. Hydrogen and oxygen will be the final products from this process. By taking PFD as a reference, the Piping and Instrumentation Diagram is prepared and Control Philosophy for the hydrogen Production plant.**

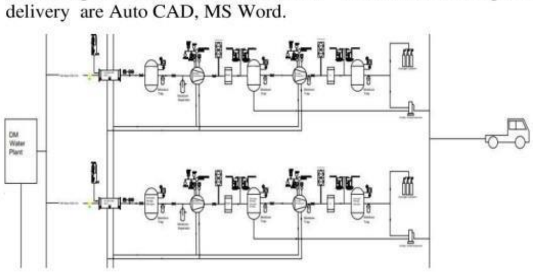
Keywords— ***Keywords: Green Hydrogen, Control and Instrumentation, Safety*.**

Introduction

Hydrogen was first artificially produced in the early 16th century by the reaction of acids on metals.and later on, scientists and engineers made progress with hydrogen developments and its uses Hydrogen is the most abundant chemical substance in the universe, constituting roughly 75% of all normal matter. There are several ways to produce hydrogen, but the most efficient way would be to use renewable energy sources to generate hydrogen . Here we will mainly focus on ' Green Hydrogen'. As its name says Green, the methods that are used to produce hydrogen are environmentally safe.Green Hydrogen is defined as hydrogen produced by splitting water into hydrogen and oxygen using renewable electricity. The paper titled " Control and Instrumentation for Hydrogen Production Plant" is based on the project which is in its initial phase . The production of the process is separated into two different quantitys's 35 Mpa and 70 Mpa.

And it will be stored in two different systems for various uses, like a dispenser system, a storage system and transportation. Here we developed the Control Philosophy for Hydrogen Production Plant

There are a number of control loops in the plant such as the equipment , instruments and other systems for operation or process. Control Philosophy is the document which is developed to give a description of these loops and system. and with the reference PFD, we created a Piping & Instrumentation Diagram for the Initial stage of the Plant, which specifies Instruments, Sensors, Measuring Elements, etc. The software be used for making this delivery are Auto CAD, MS Word.



I. Apparatus

- DM Water input supply: A water that has been purified of its mineral ions and impurities through a process called ion exchange.DM water is important for the production of hydrogen gas through electrolysis.The mineral ions in water can cause problems by interfering with the process or contaminating the final product.
- Electrolysis Process:Electrolysis is the process of using electricity to split water into its constituent parts, hydrogen and oxygen. The electrolysis process takes place in an electrolytic cell, which contains two electrodes and an electrolyte solution.
- Compressor:it is used to increase the pressure of a gas or air by reducing its volume . Hydrogen gas is typically produced at low pressure, and it needs to be compressed to a higher pressure for use in various applications.
- Heat Exchange :A heat exchange involves the transfer of heat energy from one fluid to another through a thermally conductive surface or barrier.In hydrogen production plants for heat recovery and to cool the hydrogen gas.
- Moisture Trap: A moisture trap is a device used to remove moisture or water vapor from a gas or air stream.
- Dryer: A dryer is an essential component of a hydrogen production plant because it is used to remove moisture from the feed stock or process gas.

II. Control and Instrumentation

DM water is important for the production of hydrogen gas through electrolysis. Electrolysis is a process where an electric current is passed through water to split it into hydrogen and oxygen. During this process, the mineral ions in water can cause problems by interfering with the process or contaminating the final product. When DM water is used for electrolysis, it ensures that the water is free of minerals and other impurities that can interfere with the process. This helps to ensure the efficiency of the electrolysis process and to produce high-quality hydrogen gas that is free of impurities. The Closed loop operation is suitable for the water tank process. Feedback signal process control to be compared with the reference input, thereby providing controlled action. The DM water storage tank is used to store water which will be used in the H2 plant for the electrolysis process.For level measurement level switch – Vibrating Fork Switch (LE). This LE sends an electronic signal to an indicator and LAH and LAL, according to the alarm operator, will get to know the level of the storage tank. For the final control element, the ball valve is suitable.

The hydrogen plant system involves two main equipment, the hydrogen generator and power supply. The hydrogen generator consists of mechanical equipment and piping systems supporting the electrolysis process.The power supply consists of equipment to convert AC power input into DC power in the electrolysis process. The power supply at the installation is separate from the hydrogen generator.In the electrolysis process, two products will be produced, namely hydrogen (H2) and oxygen (O2). Here we are mainly focusing on hydrogen and its Control Process. The hydrogen we receive from the process will be stored in a hydrogen storage tank. . This hydrogen gas will not be in 100% pure form to get into a pure and desirable state. further processing and control is needed here. For storage monitoring, level and pressure parameters are integrated.

Water vapor can be problematic in a hydrogen production plant because it can cause corrosion of the equipment, reduce the efficiency of the process, and lower the quality of the hydrogen gas.a moisture trap is used to remove water vapor from the hydrogen gas stream before it is compressed and stored. The gas which enters the moisture trap removes water and other impurities from hydrogen.The purified gas is discharged from the moisture trap to the moisture separator. compression allows a low-pressure well to produce higher volumes of natural gas—in some instances, well production may be entirely dependent upon gas compression. Multi-stage compressors can regulate air temperature. Because they cool air as it passes between each chamber, the output air has a lower temperature.

As gas is compressed, the gas temperature increases. to maintain the temperature, this compressed gas will be passed through shell and tube heat exchanges.This heat exchanger is used to heat up to process fluid at desired outlet temperature. Therefore, action must be taken to correct any deviation so as to maintain the outlet process temperature at its desired value. Here, we have to maintain the range of the temperature at 25°C. For temperature measurement, RTD can be used as TE. RTD has a temperature measurement range of -200°C to 850°C. It is a 4wire Pt100 element type. It gives an output of 4-20mA.It possesses high accuracy of measurement, it responds quickly, it gives stable and accurate performance over many years. temperature compensation is not required.

After Heat Exchanger the Hydrogen Gas will pass through dryer.In the drying process, all the leftover moisture will get cancelled out and thus this passes to the hydrogen storage. A FT and a FI along with FAH and FAL are to be provided to measure and indicate flow. With Flow control, we need to monitor and control the pressure parameters as well.

A. *Abbreviations and Acronyms*

DM - Demineralized Water

H2- Hydrogen

O2 - Oxygen

LE- Level Element

TE- Temperature Element

LAH- Level Alaram High

LAL- Level Alarm Low

FT- Flow Transmitter

FAL - Flow Alarm Low

FAH - FLow Alarm High

FI - FLow Indicator

Mpa- Mega pascal

RTD- Resistance Temperature Detector

mA- Miliampere

III. Hydrogen Hazards and safety

Hydrogen is a colorless, odorless, tasteless gas that is lighter than air. Hydrogen is extremely flammable and can be ignited by the cylinder valve being opened to air and by heat , sparks and static electricity. Constantly contact with hydrogen can cause acute health effects, chronic health effects. Hydrogen is lighter than the air and can accumulate in upper sections of enclosed spaces. Hydrogen may form an ignitable vapor/air mixture in closed tanks or containers.

A. Hydrogen Leak Detection

If a hydrogen leak does occur, it is important to follow proper safety procedures, such as evacuating the area, ventilating the space, and avoiding any sources of ignition. It is also important to repair the source of the leak as soon as possible to prevent further releases of hydrogen gas.two technologies suitable for detecting hydrogen: pellistor sensors and electrochemical sensors. Pellistor, or catalytic bead, sensors rely on the use of a catalyst that causes flammable gas within the sensor to ignite at a much lower temperature than usual.When combustion occurs, heat is produced in proportion to the amount of flammable gas present. The concentration of flammable gases can then be derived from this measurement and expressed as a percentage of the lower explosive limit (%LEL). Pellistor sensors are typically used as a general "catch-all" technology for flammable gas detection. Pellistors respond to any flammable gas, measuring 0-100% LEL. Since a 4% concentration of hydrogen is explosive, this corresponds to 100% LEL.

Ultrasonic (acoustic) gas leak detection technology functions through the constant monitoring of wide areas by advanced acoustic sensors specially tuned to process ultrasound emitted from pressurized gas leaks.

Thermal Conductivity Detectors,The temperature of the sensing element depends on the thermal conductivity of the gas flowing around it.Thermal conductivity leak detectors have cells that contain coils in bridge circuits.

Infrared absorption sensors These sensors use infrared light to detect the presence of hydrogen gas. They are relatively accurate and can detect hydrogen at concentrations as low as 1% in air.

Thermography involves the detection of temperature differences by scanning in the IR region of the spectrum.Leaking valves and steam traps are easily located through the use of this technique.

B. Final Control Element

Final Control Elements are control valves which are an essential part of the process as they are are part of the total control of the process and manipulation of the outcomes.Valves can be placed at the beginning and end of the pipeline to control the flow of hydrogen in and out of the pipeline. This can be useful for isolating the pipeline for maintenance or emergencies, or for diverting the flow of hydrogen to another location.The specific placement of valves will depend on the design and operation of the pipeline, and it's recommended to consult with experts and literature for the best options for a particular pipeline and application.Valve sensors are instruments used to indicate the position of a valve. For example, when installed on a shutoff valve like a ball valve, sensors such as limit switches are used to indicate whether the valve is fully opened or fully closed.Valve position sensor readouts can be displayed via lights, dials with hands or digital screens.A UV/IR flame detector consists of ultraviolet (UV) and infrared (IR) sensors that are joined together in a single apparatus.The location of the detectors are set looking at the leakage points at the inlet and outlet connections and around the storage tank surroundings.to prevent over-pressure in the plant, the device used is the safety or safety relief valve.The safety valve operates by releasing a volume of fluid from within the plant when a predetermined maximum pressure is reached, thereby reducing the excess pressure in a safe manner. As the safety valve may be the only remaining device to prevent catastrophic failure under over-pressure conditions.

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