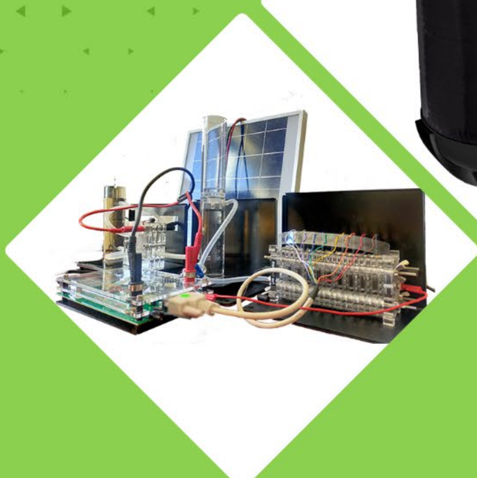
HYDROGEN LABORATORY SAFETY PROTOCOLS -GHLAB



GREEN HYDROGEN LAB

Green Hydrogen Lab
Department of Mechanical Engineering
Kathmandu University

DISCLAIMER

This safety manual is prepared by Green Hydrogen Lab, Kathmandu University with reference to international safety guidelines and standards. The document presents general safety information and a focused protocol to operate the equipment at the Green Hydrogen lab. The information is kept simple to make it understandable for all individuals visiting and operating the Lab. This document doesn't guarantee the complex and unseen safety risk that may occur. The laboratory equipment operator or an individual will be solely responsible for maintaining safety within the lab. The manual doesn't intend to violet the international code of conduct on safety procedures. The document is a dynamic document and can be updated as per the need.

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1. HYDROGEN PROPERTIES

Hydrogen is a colorless, odorless, tasteless, flammable nontoxic gas that is flammable over a wide range of concentrations from 4% to 75% by volume. Hydrogen burns with a nonluminous flame which can't be visible under day light.

Hydrogen gas can be a major threat to the health and safety of laboratory workers, first responders if it is not managed appropriately.

S.N.	Properties	Considerations
1.	Relatively low ignition energy (0.02 millijoules). *The ease of ignition creates a large portion of risk with the usage.*	➢ Keep away the sources of ignition ➢ Location of fire extinguishers, exits and water showers.
2.	Low density: 0.08375 kg/m³ at STP *Hydrogen is 14 times less dense than air.* *Hydrogen must be stored at a high pressure to achieve enough mass for practical use.*	➢ Location of the pressurized tank ➢ Location of vents and exhausts
3.	Specific gravity: 0.0696 Powerful buoyancy *The powerful buoyancy of hydrogen adds safety feature in unconfined areas allowing hydrogen to disperse quickly.*	➢ Location of vents and exhausts should be at height.
4.	Very low viscosity *Difficult to prevent leak. It also can attack, and damage to the point of leakage certain materials that are used for the construction of storage containers, piping, valves, and other apparatus. Hydrogen leakage may take place through welds, seals, gaskets, etc.*	➢ Air tight connections and fittings should be used. ➢ Joints and connections should be checked.
5.	Low boiling point (-423°F) *A large amount of energy is required to liquefy hydrogen and the liquid hydrogen presents hazards as a cryogenic fluid.*	➢ Heat sinks and cooling system ➢ Location of vents and exhausts
6.	High diffusivity. *Rapidly vaporizes and is not likely to reach the ground in a liquid state. Can sometimes cause shortness of breath.*	➢ Location of vent and exhaust
7.	Liquid density: 67.7581 kg/m^3 *It is a light liquid.* *The mass of hydrogen in a gallon of water is more than the mass in a gallon of liquid hydrogen.*	➢ Location of storage ➢ Location of vents
8.	Highest energy content by weight (120 MJ/kg) *Nearly three times the energy content of gasoline.* *Mixing up with air can cause the formation of extremely explosive mixtures.*	➢ Keep away from sources of ignition ➢ Check leakages, loose connections.
9.	High burning velocity of hydrogen-air mixture *Eight times that of the natural gas and propane mixture gases.* *Difficult to confine and arrest the hydrogen flames and explosions, particularly in a closed environment.*	➢ Keep away from ignition sources ➢ Leakage, loose connections should be prevented.

2. GENERAL HYDROGEN EQUIPMENT GUIDELINES AND SAFE HANDLING PRACTICES

The operators and the visitors at any hydrogen facility must be aware of general hydrogen properties and safety.

a. Physical, chemical, and specific hazardous properties and behavior of hydrogen.
b. Hydrogen equipment inspection, operation, and maintenance.
c. Emergency notification and evacuation/response policies and procedures.
d. Training on First aid procedures.

2.1. Hydrogen Experiment Guidelines and Safe handling requirements

Before performing any experiment on hydrogen gas, the following points shall be considered:

a. The facility or laboratory should be examined for the availability of resources for the conduction of the experiment and safety concerns.
b. Follow the laboratory checklists for safety protocols and implementation in each experiment. Documentation of every experiment performed with the results, and observations is required.
c. Appropriate personal protective equipment (e.g., safety glasses, laboratory coats, gloves face shields, and protective shoes) must be used for any experiment.
d. Check and calibrate the safety valves, gas detection system, alarm systems and maintain the natural vents and check the laboratory exhausts.
e. Identify the chemicals and equipment required. Remove all the unnecessary chemicals and equipment from the experiment location,
f. Check the emergency exit routes. Make sure you know where your lab's safety equipment including first aid box, fire extinguishers, eye wash stations, and safety showers is located and how to use them.
g. Do not work alone, work under the supervision of TL/RAs. Follow experiment steps and avoid horseplay. Report all injuries, accidents, and broken equipment or glass right away, even if the incident seems small and unimportant.
h. Avoid cell phones used during experiments. Cut power after use. If you are the last person to leave the lab, make sure to lock the doors and turn off all ignition sources.
i. Do not eat, drink or smoke in the laboratory.
j. After the experiment has been completed, rearrange the setup and materials. Dispose of waste solid or liquid once the experiment is completed. Clean the laboratory after the experiment.

2.2. Safety considerations in Production: Use of Electrolyzer

The points to be considered while using the generator include the following:

a. Ventilation should be checked for exhaust of oxygen.
b. Flammable objects, flame sources, and ignition sources should be removed.
c. Lab alarms, safety system, gas detection, and ventilation should be checked.
d. All the connections with the electrolyzer should be checked before operation for any loose connection, wire failure, possible chances of leakage etc.
e. Purging and water valve should be checked. Only deionized or distilled water should be used.

f. Level of aqueous solution (generally KOH) should be monitored.
g. Waste or extra hydrogen should be safely vented from the exhaust after experiment.
h. Automatic or manual shutdown of the system is a must in case of identification of any flaws and system malfunction.

2.3. Safety considerations in Storage: Use of Storage Tank

Type IV composite carbon fiber hydrogen tank are preferred for the high pressurized storage of hydrogen gas. The points to be considered while using the storage tank include:

a. Storage tank should not be carried horizontally. The tank shouldn't be held at the top neck from where the gas is injected.
b. Store the compressed gas cylinders in dry and well-ventilated areas.
c. Sparks, ignition, open flame, heat sources, and other sources of ignition should be stored away from cylinder.
d. Store hazardous gas cylinders away from electrical panes, safety showers, and eyewashes.
e. Fire extinguishers and fire suppression systems should be present in a flammable gas storage area.
f. No smoking sign should be posted where flammable gases are used and stored.
g. No gas other than hydrogen gas should be filled.
h. Temperature rise and variation during refilling of hydrogen should be minutely checked and considered. Avoid refilling if the temperature rises above 40^0C.

2.4. Safety Considerations at End-use: Use of Fuel Cell

The safety concerns to be considered during the end-use application and the application of fuel cells include the following:

a. Prevent unnecessary physical contact with the fuel cell to prevent the stack from physical contamination.
b. Do not wear jewelry near the fuel cell engine. To minimize conductivity, your hands and clothes should be dry.
c. Startup time should be checked before the fuel cell is operated.
d. The gas inlet to the PEM fuel cell should be clean and pure hydrogen. Most mixtures of hydrogen and air are potentially flammable and explosive and can be easily ignited by a spark or hot surface. Hydrogen flames are almost invisible in daylight.
e. The pressure of the gas inlet in the fuel cell should be considered while the fuel cell is in operation. High-pressure hydrogen shouldn't be passed in the fuel cell.
f. Fuel cell engines contain high DC and AC voltages. Exercise caution when accessing electrical components to prevent shock or electrocution.
g. Always assume that the fuel cell stacks are electrically charged. Do not touch the fuel cell stack, its graphite cells, or the cell voltage monitoring wires until you confirm that no voltage exists.
h. Exposure of fuel cells to different chemicals must be prevented.

2.5. Safety Considerations at Disposal: Waste Management

Waste disposal is a significant task in any laboratory after the experiment has been performed. All laboratory staff should take active participation in the disposal of laboratory waste management. The waste should be categorized and disposed of accordingly.

Categories of Waste:

a. General Waste
b. Biohazardous Waste
    - Chemical Waste
    - Biological Waste
    - Radioactive Waste

The basic norms to dispose of the waste material include the following:

a. Use of proper PPE and disposal of chemical waste.
b. Return, old, unused, or empty cylinders to vendors.
c. Do not store the waste material in a metal container. Waste associated with the generation of hydrogen gas, solutions, and by-products, must be collected in airtight containers.
d. Do not store chemical waste under the fume hood.
e. All the chemical waste generated in course of the experiment should be considered hazardous including the water rinsed from the container.
f. The rinse water from the decontamination of all non-disposable equipment must be collected and disposed as hazardous waste.
g. The hazardous waste must be located in a specified location.
h. The containers with different waste should be labeled properly. The waste containers should be leakproof with no chance of leakage and puncture due to sharp material.
i. Do not keep incompatible chemicals in the same container, such as acid and alkali should be kept in different containers.
j. Neutralize the acidic or basic solution.
    a. Acid Neutralization: Make a basic solution using a large volume of cold water and an appropriate inorganic base. Stir the solution while slowly adding diluted acid.
    b. Base Neutralization: First add the base to the large vessel containing water. Slowly add appropriate inorganic acid.
    c. Allow the content to react for 15 minutes and heat before testing pH. The container should not be hot and the contents should not be smoking. If the container is still hot, allow the reaction to continue until the heat is dissipated.
    d. Test the neutralized solution to confirm the pH between 5 and 9 and flush to sewer with at least 20 parts of water.
k. Segregate the waste from the incompatible materials.
l. Waste must be in control of the person generating and disposing of it.
m. All disposable materials contaminated must be disposed as hazardous waste.

2.6. Prevention of probable incidents

Actions should be taken to avoid probable accidents and incidents in any research laboratory. Planning and preparation shall be done to prevent any kind of incidents.

a. Identify the chemicals and equipment required. All the unnecessary chemicals and equipment from the experiment location should be removed.
b. Ensure the electrical sockets, and supplies are in good condition.
c. Frequently disposal of chemical waste and other waste which is not required in the laboratory.
d. Identify the ventilation spaces, emergency exits, and outlets in case of spills.
e. Post the emergency phone numbers, and first aid procedures for specific incidents (examples, chemical splitting on eye/skin, electric shock, etc.)
f. Plan the experiment, select the team members for documenting, and performing the experiment, and to take steps in case of failures.
g. Documentation of the procedure is a must. Checklist must be maintained for the completion of all pre-experiment setups.
h. The laboratory experiment checklist should be checked and updated periodically.
i. The safety policy, flaw points, loopholes and implementation techniques must be discussed within the team timely.

2.7. Prevention from Gas Leakage

Gas leakage is a serious concern in hydrogen laboratory. Hydrogen gas being odorless is difficult to detect in case of leakage. Following points should be considered to prevent from hydrogen gas leakage.

a. The gas valves should be monitored regularly for any leakage.
b. Vents and exhaust should be maintained.
c. Gas detection system and alarm system should be installed in the laboratory.
d. Turn off all the ignition sources, electrical equipment in operation that can cause sparks.
e. Call emergency in case of any incidents and emergencies (health emergencies, fire, explosion, etc.)
f. Evacuate the building.

2.8. Prevention from fire and explosion

To prevent and minimize the effects of fire and explosions, following steps should be considered.

a. Determine the non-flammable substitute for materials available for experiment. Reduce and eliminate the open flames and spark-producing equipment.
b. The electrical power sources, supplies, backup power, and switching system for any loose wiring and connection failures should be regularly checked.
c. Fire-resistant coats instead of plastic should be used during performing any experiment.
d. Eyewashes, emergency showers, and sprinkler heads should be operational in case of emergency.
e. Air vents and natural air flow should be checked for smoke in the laboratory. Exhaust fans should be used.
f. Heating systems, and refrigeration systems if available should be monitored.

g. Check and maintain the pipes, tubing, and fittings of electrolyzer and connections for leakage at regular intervals of time.
h. Gas cylinders should be kept out of the reach of any potential source of ignition. Fire extinguishers have to be available, checked frequently, and refilled.

2.9. Emergency Plans

Plans for emergencies should be incorporated for various circumstances. The points to be considered include the following.

a. Activate the visible and audible alarm system.
b. Automatic sensing, shutdown, ventilation, and fire suppression systems appropriate for the specific materials and hazards in the lab.
c. Power backup should be standby.
d. One performing the experiment should be aware of equipment shutdown procedures or applicable emergency operation.
e. Avoid breathing vapors, mists, fumes, dust, or gases present in the laboratory.
f. Everyone should be aware of evacuation and re-entry procedures. The entry and exit routes should be clearly identified. Signs for emergency exit should be used.
g. All visitors and personnel present at the time of the incident should be documented and recorded compulsorily.
h. Information must be provided to the first responders (normally the fire department) to allow emergency responders to develop response tactics as soon as possible.

2.10. Health Safety

Personal Protective Equipment (PPE) should be used while carrying out any experiment associated with hydrogen. PPE is used to protect students, employees, and visitors from laboratory risks and hazards. PPE includes gloves, glasses, eye protection, foot protection, protective aprons, and coats.

S.N.	Potential Hazards	Protection
1.	Explosion and Fire	➢ PPE: Helmet, lab coat, helmet and safety glasses, footwear ➢ Use of fire extinguisher. ➢ Respiratory and ear protection (earbuds) ➢ Electrical sockets should be located at safe location. ➢ Emergency exits should be present ➢ Exhaust and ventilation should be maintained regularly. ➢ Check pipes, tubing, and fittings regularly for leakage and failures at regular intervals of time.
2.	Chemicals Hydroxides: NaOH, KOH Ammonia (NH_3)	➢ PPE: Use of safety apron, chemical-resistant gloves ➢ Footwear in case of chemical spilling ➢ Check ventilations for outlets of gas

3.	Gases and other biohazards	➢ Gas-resistant masks, gloves, goggles

2.11. First Aid Procedures

First aid is a set of guidelines that can lessen the damage caused by exposure to chemicals or injury before the arrival of a medical expert or professional. Everyone working in the laboratory should be familiar with first-aid practices as these save valuable time and reduce the extent of human injury in case of laboratory accidents.

Guidelines:

a. The place should be evacuated immediately.
b. Start to aid the victim without waiting for medical personnel to arrive. If the victim is not exposed to smoke, fire, dangerous chemicals, or vapors, do not attempt to transfer him or her. Move to a secure spot with caution.
c. Remove chemical bottles from work areas of facilities personnel working in laboratories.
d. Ensure the victim is breathing. If breathing is stopped, try artificial mouth-to-mouth or mouth-to-nose respiration.
e. Do not remove deeply embedded glass or metal pieces or shreds. Rather bandage the wounds to control the bleeding till help arrives.
f. Prevent intense bleeding if any. Pressing the wound with the thumb can be helpful.
g. In case of fainting, turn the victim on the side with the face tilted towards the floor and prevent choking by the tongue.
h. In case of gas inhaling:
   Move the person to a fresh air zone. If not breathing, artificial respiration should be provided. Oxygen should be provided in case of difficulty in breathing. Medical aid should be provided.
i. In case of burns:
   Hold the skin affected under the stream of water for at least 10-15 minutes. Keep the wound open and do not apply any ointment without a medical expert's approval. In case of strong acid burns, after washing with water, rinse with dilute ammonia (1-2%) or sodium bicarbonate solution.

CAUTION!
Never apply acid or alkali to neutralize the corrosive liquid on the skin, Due to the heat of the reaction, matters may get even more complicated.

j. In case of Eye contamination
   Immediately flush eyes with plenty of water for at least 15 minutes. Cover or close the eyes for any foreign body (dust, metal, paint, or wood chips) in the eye.
k. In case of injuries and wound
   The wound should be cleaned with medicine and warm water. Bandage and cover the wound with a clean band or cloth to prevent infection. Take the victim to trained medical personnel immediately.

2.12. Environment Safety

Green Hydrogen being eco-friendly have little to no impact on the environment. However, improper disposal of waste and chemicals from the laboratory can cause significant harm in the environment including chemical fumes and foul smell.

The laboratory experiment handling and procedures should be checked. Following points should be considered so that the laboratory causes a minor impact on the environment include the following:

a. Proper disposal of chemical waste and other solid organic and inorganic waste generated from the laboratory experiments.
b. Decontamination of the waste generated especially chemicals.
c. Ventilation for the exhaust of gases and smoke.

3. INFORMATION ABOUT EQUIPMENT IN GHLAB

Green Hydrogen lab at Kathmandu University is a research laboratory that performs research activities in the field of Green Hydrogen. Various Equipment is present in the laboratory for experimentation and research. This chapter provides a brief insight into the various equipment of the laboratory.

3.1. Hydrogen Experimentation Stack

The experimentation stack is the model of a complete energy supply system in hydrogen production from electricity generation from a renewable source to end-use application through an electrolyzer, hydrogen storage tank, and fuel cell. The stack experimentation stack demonstrates the mode of operation of hydrogen technology in an interesting and step-by-step manner.

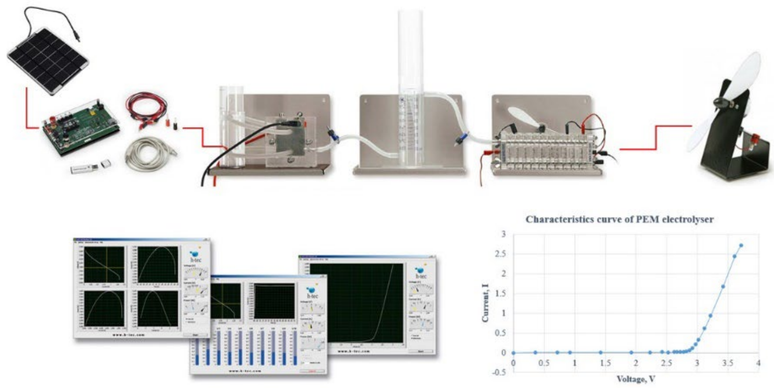


Figure 1: Experiment Stack system components

Components in 10W system

The components in the hydrogen experimentation stack include the following:

a. Solar Panel Module
b. Fuel Cell Monitor Pro (with power supply cord)
c. Double Cell PEM Electrolyzer Stack
d. Fuel Cell Monitor Pro 4.0
e. Hydrogen Storage Tank (Storage 80)
f. PEM Fuel Cell Stack (Fuel Cell Stack 10)
g. Test fan
h. Experimentation Lamp (Load)
i. Holder Set

Operating the Stack Experimentation Set

The DC supply is supplied to the electrolyzer either through the Fuel cell monitor pro or through the solar panel module. The water is fed to the electrolyzer from below, through the tubes from the storage tank. The electrolyzer splits the distilled water into hydrogen and oxygen. The oxygen is dissipated to the environment while the hydrogen produced is trapped in the hydrogen storage tank. The top outlet of the storage tank is connected to the fuel cell stack. The gases pass from the top end of the gas storage tank to the fuel cell in which the electricity, heat, and water are produced. The amount of heat generated is small. Water that is produced is condensed in the housing plates.

Manufacturer: H-Tec Education

Website: H-Tec Education

3.2. 1kW Alkaline Electrolyzer

1kW alkaline water electrolyzer system was procured from Light Bridge. The development of high-efficiency nickel electrodes based on the core technology reduces the system production cost and generates hydrogen through the high-yielding rate per input power, and this technology has a long-life cycle activating over 10,000 hours (for nickel-based electrodes). The estimated lifetime for the alkaline electrolyzer stack (or individual cells present in the stack hardware) is 6000 operational hours. This alkaline electrolyzer stack requires a caustic solution of 30 wt.% KOH for its efficient operation.

Hydrogen generated from the water electrolyzer is used as the energy storage medium for HESS (Hydrogen Energy Storage System). The water electrolyzer can be even powered by renewable energy such as solar, wind power, tidal, night-time electricity, and surplus power energy. When needed, hydrogen is converted to electricity by the fuel cell.

This product is a high-performance water electrolysis system and can be expanded according to the power desired by the customer. It includes the stack, process bath, cooling system, circulation system, hydrogen pressure control, regulation function electrolyte module, power module, and electronic control board.

Specification:
Size: 300 X 520 X 500
Power Consumption: < 500W
Gas Production
Hydrogen Gas: 200 l/hr.
Oxygen Gas: 100 l/hr.
Operating Temperature: 10~80^{0} C
Pressure: Maximum 10 bar
Purity: 99.5 – 99.9% Hydrogen Gas and 98% pure Oxygen gas

Use:

Alkaline Electrolyzer uses electricity to generate hydrogen gas and oxygen gas from alkaline solution.

Product Link: https://bit.ly/3qlgVxY

Figure 2: 1kW electrolyzer

3.3. Hydrogen Tank

Ultralight Type IV hydrogen tank from Doosan Mobility is available at the Laboratory. The tank has high storage efficiency with working pressure up to 350 bar pressure. The tank is based on verified technology already being used in hydrogen-powered vehicles.

Figure 3: Hydrogen Tank

Specification

Content Volume: 10.8 l

Working Pressure: 350 bar

Use: Stores Hydrogen gas

Product Link: https://bit.ly/3rQfGHw

3.4. 150W PEM Fuel Cell

The Protium-150 is an advanced hydrogen PEM fuel cell that is designed for tomorrow's unmanned vehicles. The Protium Series is the flagship suite of fuel cell systems and the culmination of more than a decade of cutting-edge R&D. Every Protium fuel cell is made of the best quality membrane electrode assemblies to ensure the highest power output in the smallest form factor.

Includes:

a. 20-cell graphite plate fuel cell stack with cell voltage monitoring ports
b. Electronic controller
c. Heat management system (cooling fan with integrated PWM control)
d. Fuel supply system (solenoid valves, gas pressure sensor, gas tubing and connector)
e. On-off push button with status LED and buzzer
f. Power and signal cable
g. RS232 to USB cable
h. Factory Acceptance Tests (FAT) report
i. Pelican storage case

Technical Specifications:

Rated Power: 150W

Rated Current: 12.5A

Voltage Output: 12-18V DC

Start-up Time: 5s

Operating Ambient Temp.: (0,40) °C

Operating Altitude: 1500m AGL

System Weight: 470g

Dimensions: 109 x 101 x 84 mm

Fuel Supply:

Hydrogen Gas: Dry, 99.999% purity

Delivery Pressure: 0.4-0.7 bar (6-10 psig)

Fuel Consumption: 1.9L/min


Figure 4: 150W PEM fuel cell

Gas Tubing: Silicone, 1.6mm ID
Supply & Purge Control: Solenoid valves with integrated pressure sensor

Electronic Controller:
Processor Board: FLY V3.1
PCBA Dimension: 85 × 55 × 25 mm
PCBA Weight: 105g
Output Connector: User specified
Warning & Protections: Low voltage, high temperature, low battery, low fuel
Communication: RS-232/USB
Data Acquisition (DAQ) Software: PC graphic user interface (GUI) application
GUI Capabilities: Live monitoring, graph plotting, data logging, snapshot

Use: PEM fuel cell converts the hydrogen gas into electricity.

Product Link: https://bit.ly/3bge2bE

3.5. Hydrogen Sensors

The professional hydrogen (H2) gas meter by FORENSICS. Detect hydrogen gas in vehicles, fuel cells, storage tanks, laboratory settings, or outgassing from batteries. H2 is a colorless, odorless, and tasteless gas which makes it very important to adopt detection instrumentation. It is the lightest gas and explosive in the air over 4%. When in contact with chlorine, oxygen, or other oxidizers, hydrogen is flammable and burns with a nearly invisible flame. Our H2 gas detector has high precision and provides robust measurements for fieldwork, inspections, occupational safety, industrial, and environmental applications. The instrument employs a high-quality electrochemical sensor.

Specifications:
Hydrogen (H2) detection: 0 - 1000 ppm with 1 ppm resolution
Accuracy: ≤ ± 5% F.S
Response time: T < 30 sec
Indication: LCD indicates the time, concentration, temp, and battery state
Alarm: Indication of alarm, fault, and low voltage with LED, sound, and vibration Operating temperature: 0F - 122F
Operating humidity: < 95% RH non-condensing
Voltage: DC 3.7V Li-battery 1500 mAh
Working time: > 24 hours
Charging time: 4 hours
Sensor life: 2 - 3 years
Protection category: IP65
Weight: about 130 g (including battery)

Figure 5: Hydrogen Sensor

Use: Hydrogen sensor detects the presence of hydrogen in confined area.

Product Link: https://bit.ly/3jRaPDf

3.6. Oxygen Sensor

Professional series O2 detector with pump by FORENSICS. High precision for accurate measurements, robust fieldwork, research, inspections, occupational safety, industrial, and environmental applications. The pump allows for point probe or continuous sampling. Comes factory-calibrated. The detection range of O2 is 0 - 30% within 30 seconds with an error less than +/- 5% full scale. Advanced features include temperature detection, alarm recording, alarm setting, backlight high-resolution LCD, and calibration.

The handheld pump has a gas input from a stainless probe (8.6-inch length). Gas output is a male 3.2 mm tube connector that connects to standard aquarium tubing with a diameter of 3/16 in. The pump has a rechargeable DC 3.0V Li-battery 1500 mAh, charged via a USB connector. Pump LCD shows temperature detection, time, and date with high-resolution backlight. The power load indicator of pump resistance is also clearly shown so the user has insight into the pump load. Ideal for point sampling of toxic gas or remote sampling (can operate up to 50 feet).

Detector Specifications:
Oxygen (O2) detection: 0 - 30% with 0.1% resolution
Accuracy: ≤ ± 5% F.S.
Response time: T < 30 sec
Indication: LCD indicates the time, concentration, temp, and battery state
Alarm: indication of alarm, fault, and low voltage with LED, sound, and vibration Operating temperature: -20°C ∼ 50°C
Operating humidity: < 95% RH non-condensing
Voltage: DC 3.7V Li-battery 1500 mAh
Working time: > 24 hours Charging time: 4 hours
Sensor life: 2 - 3 years
Protection category: IP65
Detector weight: about 130 g (including battery)

Figure 6: Oxygen Sensor

Use: Oxygen sensor detects the presence of oxygen gas.

Product Link: https://bit.ly/2ZmpMUs

3.7. Conductivity Meter

Figure 7: Conductivity Meter

A conductivity meter is an intelligent one-line chemical analysis equipment, widely used in continuous monitoring of temperature and conductivity value of the solution in thermal power, chemical fertilizer, metallurgy, environmental protection, pharmaceutical, biochemical, food and running water and so on. The continuous monitoring data is realized by remote transmission monitoring and recording through the transmission output connection recorder. It can also be connected to the RS485 interface and can be easily connected to the computer for monitoring and recording through the MODBUS-RTU protocol. Conductivity meter coupled to the electrode constant of 1.0 or 10.0 measurable general liquid; coupled with an electrode of 0.1 or 0.01, can accurately measure the conductivity of pure water or ultrapure water, especially suitable for steam power plants and boiler feed water On-line continuous monitoring of conductivity of high purity water such as condensate.

Use: Checks the conductivity of distilled and deionized water.

Product Link: https://bit.ly/3s0iX7i

3.8. Flash Arrestor

These re-settable flashback arrestors offer four safety devices in each unit. Safety features include protection against flashbacks with a wide range of mixtures of oxygen or air with flammable gases including hydrogen, acetylene, methane, and LPG gases. The design includes a built-in non-return (check) valve to stop reverse flow and a thermal shut off which stops gas flow in the event a of hose or pipeline fire. An easily re-settable pressure control stops gas flow in the event of reverse flow or a flashback that creates 10 psig back pressure. This feature alerts the user that a reverse flow or a flashback of greater than 10 psig has occurred. These units are easily re-set by pulling up on the pressure control ring (shown at right), no disassembly of the gas line or special tools are needed. The 8491 Series high flow capacity makes them suitable for a broad range of applications. Units are U/L listed and meet ISO 5175, EN 730, BS 6158, and AS 4603 standards.

Features:

a. Inlet: 1/4" NPT female
b. Outlet: 1/4" NPT female
c. 100% flashback tested after assembly
d. U/L listed and meets strict international standards
e. Alerts user by shutting off gas flow in the event of a reverse flow or flashback exceeding 10 psig back pressure (captures back pressure in the housing, no flame or gas is exhausted to the atmosphere)
f. Stainless steel flame barrier positively extinguishes flame within the housing
g. Checks reverse flow and provide positive shut-off of reverse flow over 10 psig
h. Thermal Cut-Off at 165°C
i. Built-in 100 microns stainless steel sintered filter on the inlet
j. High flow capacity
k. Working Pressure
    a. Oxygen: 143.0 psig
    b. Hydrogen / Oxygen: 50.0 psig
    c. Hydrogen / Air: 150.0 psig

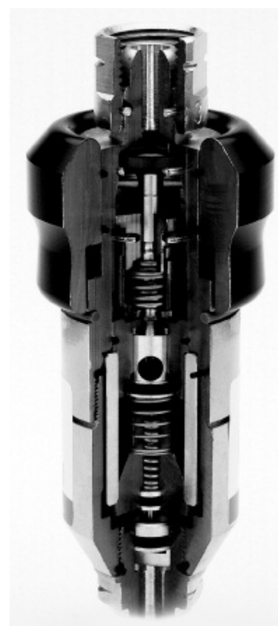


Figure 8: Flash Arrestor

Use: Used a safety component in the hydrogen value chain to squeeze the flame in case of accident.

Product Link: https://bit.ly/3ao2u6J

3.9. Pressure Gauge

The compact low-cost digital pressure gauge DM 10 is battery-powered and has an adjustable housing; it is thus extremely suitable for mobile pressure monitoring. The 4.5-digit LC display indicates the battery status, the measurement value as well as the unit, this enables a fast and precise reading. It is possible to switch between the most common units (bar, psi, Pa, MPa). Additional functions such as auto-zero, min/max values, and an automatic switching-off complete the DM 10 profile.

Figure 9: Pressure Gauge

Features

a. nominal pressure: 0 ... 1.6 bar up to 0 ... 250 bar
b. accuracy: 0.5 % FSO BFSL (class 0.5)
c. ceramic diaphragm
d. adjustable housing
e. LC display, 4.5-digit 7-segment display
f. standard battery CR 2450 operating period > 1.800h

Use: Measure the pressure of Hydrogen gas

Product Link: https://bit.ly/3s07hRW

3.10. Temperature Sensor

UTY8 digital temperature gauge is designed with whole electronic structure, it uses 3.6V high performance lithium battery as power supply. The display of UTY8 is 5-digit LCD, with high resolution and no reading error. With Pt100 resistor as a sensing element, UTY8 can measure and display the medium temperature precisely. The installation of UIY8 is very easy and simple.

UTY8 digital temperature gauge is widely used in such industries as water and electricity, chemical, and machinery, for the measurement and demonstration of fluid medium's temperature.

Features:

a. Measuring medium: Gas or liquid compatible to stainless steel
b. Temperature ranges: -200~ + 500^0 C
c. Temperature Sensor type: Pt100
d. Accuracy: 0.5% FS
e. LCD Display: 4 digit
f. Display Range: -1999~9999
g. Long term stability: <0.1% FS/year
h. Battery power supply: 3.6V battery
i. Ambient temperature range: -20~+70ºC
j. Display unit: ºC,F,K,Ra, Re
k. Sampling Time: 1 time/sec
l. Process correction: G1/2 or others
m. Housing materials: 304 SS
n. 1~15min automatic turn-off function

Figure 10: Temperature Sensor

Use: Measure the temperature of the hydrogen gas.

Product Link: https://bit.ly/3baA1Ar

3.11. Pressure Regulator

The pressure regulator is for regulating the input and output pressure of the hydrogen from electrolyzer and the hydrogen storage tank.

Features:

a. High Pressure 1-Stage Regulator
b. Max Inlet Pressure: 206 bar
c. Max outlet Pressure: 13 bar

Use: Regulates the pressure of hydrogen gas flow.

Product Link: https://bit.ly/2ZmkI2g

3.12. Compact-DAQ Chassis

8-Slot, TSN (Time Sensitive Networking)-Enabled Ethernet Compact DAQ Chassis—The cDAQ-9189 is a Compact DAQ Ethernet chassis designed for distributed sensor measurement systems. The chassis controls the timing, synchronization, and data transfer between C Series I/O modules and an external host. With this chassis, you can combine C Series I/O modules to create a mix of analog I/O, digital I/O, and counter/timer measurements. The chassis provides precise, synchronized timing over the network using TSN, ideal for highly distributed measurements over long distances. The chassis has an integrated network switch for simple daisy-chaining. The chassis also has four 32-bit general-purpose counters/timers, accessible through a hardware-timed digital C Series module for applications that involve quadrature encoders, PWM, pulse train generation, and more.

Figure 11: Compact DAQ Chassis

Specification:

a. 8 Slots
b. TSN Enabled Ethernet (Time Sensitive Networking)- Real time communication with real world over ethernet.
c. Control the Timing, Synchronization, data transfer via internet
d. Combine C series I/O modules to create analog I/O, digital I/O, and precise measurements over long distance
e. Transfers all the input to LabVIEW.

Use: Used for data acquisition of experiment

Product Link: https://bit.ly/3qvFSrD

3.13. C Series Temperature Module

4-Channel, 14 S/s Aggregate, ±80 mV C Series Temperature Input Module - The NI-9210 includes anti-aliasing filters, open-thermocouple detection, and cold-junction compensation for high-accuracy thermocouple measurements. The NI-9210 features NIST-traceable calibration and a channel-to-earth ground double isolation barrier for safety, noise immunity, and high common-mode voltage range.

Figure 12: C Series temperature module

Specifications:

a. Temperature input module
b. Includes filters, open thermocouple detection, and cold- junction compensation for high accuracy thermocouple measurements.
c. Channel to earth ground double isolation barrier for safety, noise immunity, and high common mode voltage

Use: Measures the temperature sensor signal from K type thermocouple.

Product Link: https://bit.ly/3qrniRm

3.14. C Series Voltage Input Module

Figure 13: Voltage input module

Measures input voltage signals for Compact DAQ or Compact RIO systems. Models also offer isolation and overcurrent protection for high-voltage applications. C Series Voltage Input Modules provide an effective combination of channel count, resolution, and speed designed to meet the needs of all types of voltage measurement applications. Isolation on the modules can separate channels from each other, from COM, or from earth ground for safety, noise immunity, and high common-mode voltage range. Models feature up to 100 V of overvoltage protection for errant signal connection or unexpected outputs to the individual channels. Options include configurable input ranges, output channels, various connectors, and enclosed or non-enclosed modules.

The NI 9205 is a C Series module for use with any Compact DAQ or Compact RIO system. Each channel has programmable input ranges of ±200 mV, ±1 V, ±5 V, and ±10 V. To protect against signal transients, the NI 9205 includes ±30 V of overvoltage protection between input channels and common (COM). In addition, the NI 9205 also includes a channel-to-earth ground isolation barrier for safety, noise immunity, and high common-mode voltage range.

Specifications:

a. Measures all types of input voltage signals and measurements
b. Configurable input range, output channels, various connectors and enclosed or non-enclosed modules.
c. Isolation for the signal transitions, and separation of channels.

Use: Measure voltage signals from sensors that provide voltage signal

Product Link: https://bit.ly/3vP074k

3.15. Hydrogen Pressure Transducer

Figure 14: Hydrogen Pressure Transducer

The AST2000/AST4000 H2 Hydrogen Pressure Transducers are now available and suitable for hydrogen pressure sensing applications. It has been tested to a variety of hydrogen and automotive standards. The AST2000/AST4000 H2 Hydrogen Pressure Transducer combines the best mechanical design for hydrogen measurement with high-performance digital compensation.

Features:

a. One-piece design
b. Measurement up to 20 bar Hydrogen Measurement with High performance digital compensation
c. All 316L wetted material for optimal compatibility

d. No oil-filled cavities leave no chance of containment
e. Non-welded diaphragm eliminates leak paths and weak points
f. Digitally compensated
g. Krystal Bond™ Technology

Use: Used in PEM fuel cells, hydrogen storage, hydrogen filling stations and back-up power stations to measure the pressure of hydrogen gas.

Product Link: https://bit.ly/2TWZmJ8

3.16. Smart IoT Gateway

SMART IoT GATEWAY (SIG) is versatile device which reads Modbus memory map of any RS-485 Modbus protocol device and sends the data to the cloud server. The stored data can be viewed as per the customer requirements on Dashboard. SIG mainly consist of GSM module and Microcontroller based control circuit. It supports generic Modbus RTU protocol for data acquisition and it can give output on Modbus RTU/ Modbus TCP/IP or Modbus RTU over TCP/IP (Optional) also uses MQTT protocol to communicate with IT applications like database on cloud. Multiple slave devices can be configured to SIG. It remotely monitors all industrial sensors data to the cloud server.

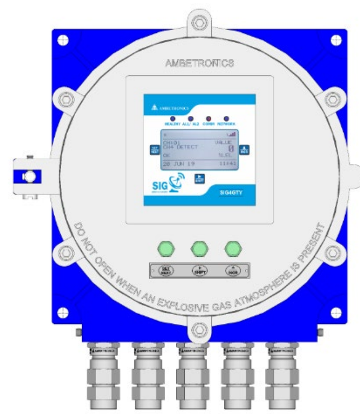


Figure 15: Smart IoT Gateway

SIG is very reliable and highly scalable solution for IoT deployment.

Features:

a. 48- Nodes (With GSM), 70 Nodes (Without GSM)
b. Global supporting GSM Module (2G,3G,4G), Dual Sim Slots
c. 128 x 6 GLCD Display
d. Two Settable Alarm Set points per channel
e. 4 Double Changeover Relays
f. Buzzer and Bicolor LED indications
g. SMS/TCP-IP connection
h. MQTT/TCP_IP Connection
i. Cloud-Based Support System
j. Pendrive Interface

Use: Used in refineries and petrochemical areas, emergency response to off-site leak detection, tank farms, power and industrial plants, leak detection in gas pipelines, coal mine and confined areas.

Product Link: https://bit.ly/3NtDSv7

3.17. Smart Gas Transmitter (Wall Mount)

The GT-2500 Smart Gas Transmitter is a microcontroller-based gas transmitter that continuously monitors hydrogen/oxygen gas in P PB/PPM/ %V/V /%LEL depending on the gas selected. It is ideally suited for harsh environment in industries where human interference is not possible in toxic or combustible gases area.

Figure 16: Smart Gas Transmitter

The GT-2500 is capable of displaying the gas concentration and transmits the data to control units through the standard 4-20mA output. It comes with optional relays allowing relay to direcly control the external devices such as fans, pumps, alarm hooters, warning lamps etc. It comes with optional RS-485 with MODBUS RTU protocol which allows the unit to communicate with the control devices.

All the user adjustable parameters can be accessed by using push button switches, magnetic switches or Remote control. The two setup modes allow you to display and change the setup and calibration settings.

Features:

a. Provides a fast and reliable output by using Electro Chemical/Pallister Sensor Technology.
b. Optimized for detection of smallest leak of Hydrogen/ Oxygen.
c. Highly resistant to poisoning and etching,
d. Capable of detecting down to PPM, %LEL, and % V/V.
e. Digital display of Gas Concentration on LED Display.
f. Standard 4-20mA signal output with configurable range
g. Easy handling and programming with 3 keys for weatherproof Models.
h. Non-intrusive programming for flameproof model using Magnetic Wand
i. Password protected programming with password changing facility
j. One-man Auto software gas calibration
k. Optional alarm relay contacts with two configurable alarm levels and one relay for fail safe relay
l. Optional STEL and TWA setpoints can be configured for Toxic gases
m. Optional RS-485 communication port with MODBUS RTU protocol

Uses: used in gas cylinder bank, gas pipeline project, stack monitoring, heat treatment plants, control atmosphere, automotive industries, gas metering station etc.

4. SYSTEMS AT GHLAB

4.1. Synthetic Natural Gas System

GHLab has established a cutting-edge SNG manufacturing unit capable of producing synthetic natural gas (SNG) with an impressive capacity of up to 1500 grams per hour. This facility incorporates advanced technology, utilizing a highly efficient Ni-Al2O3 catalyst. Operating under high-pressure conditions of 150 bars and elevated temperatures of 800 degrees Celsius, the plant demonstrates exceptional performance and durability by utilizing high-quality SS 316 material for construction.

The production process involves the integration of carbon dioxide captured from industrial emissions and hydrogen generated through water electrolysis at elevated temperatures. These components are ingeniously combined to yield methane, the primary component of SNG. To showcase the viability and efficacy of SNG as a clean and sustainable alternative to traditional fossil fuels, we will employ bottled carbon dioxide and hydrogen sourced from a 1 kW Electrolyzer within our laboratory.

Through this demonstration, the lab aims to emphasize the immense potential of SNG in addressing energy demands while significantly reducing carbon emissions. By harnessing locally available resources and scaling up production, Nepal can pave the way for a greener future, advancing towards a more sustainable energy landscape.

Figure 17: SNG System and Accessories

Key Salient Features of the System

a. Specially Designed Gas Inlet Line:

The gas flow control system includes essential components such as a block valve for pressure regulation, a de-hydration chamber to remove moisture, a bypass arrangement for troubleshooting, and instruments for monitoring gas conditions. Additionally, a gas pre-heater ensures rapid heating of gases before entering the reaction zone. These components ensure efficient and safe operation of the packed bed catalytic reactor.

b. Preheater and Mixer Zone:

The SS 316 distributor facilitates uniform mixing of feeds before they enter the packed bed reactor. It is designed to accommodate various components such as a pressure gauge, rupture disk, spring relief valve, electrically operated solenoid valve, electronic pressure transmitter, and a manual vent needle valve. The distributor also includes inlet lines for gases and liquids, ensuring proper arrangement for feeding into the reactor.

c. Reactor and Furnace:

The reactor is an SS 316 packed bed column designed to hold catalyst material. It features a removable retainer plate at the bottom for cleaning and 1.5mm diameter holes for holding the catalyst. The column has threaded openings at both ends for easy maintenance, filling, and removal from the system. The reactor can be operated safely at a very high pressure of up to 150 bars and an elevated temperature of up to 800℃.

d. Reactor Cooling System:

The cooling system consists of a ¼" tube coiled within the annular space of a double-walled pipe closure. The cooling fluid flows through this tube to regulate the temperature. The system is insulated to ensure the stability of the utility line temperature. Additionally, an electrically operated solenoid valve is incorporated to control the pressure inside the packed bed reactor. It allows for the release of excess pressure, maintaining the reactor pressure at the desired value.

e. Cyclonic Separator:

The conical vessel features a tangentially placed inlet nozzle and a dampener to effectively separate the gas and liquid, including any liquid droplets, during the flow to the GC unit. This design allows the liquid to collect at the bottom of the cone while enabling the gas to exit the cyclonic separator through a back pressure valve.

f. Gas Liquid Separator:

During this whole reaction process water is formed along with the methane gas. Hence a gas-liquid separator having a conical bottom body with a baffle in between is installed. The gas-carrying liquid bangs on the baffle plate which is been designed to flow in a circular or Tangential to the cone body thus allowing the liquid to coalesce and form droplets heavier than the gas-carrying force and separate.

g. Automated Control Panel:

The SS Control panel box is equipped with a glass window to prevent damage to instruments and accidental switching on/off of switches. An emergency press switch is located on top of the control panel to quickly stop all electrical supply to the unit without the need to open the panel door. The door is secured with magnet locks to avoid keyway opening and misplacement. A mains MCB switch ensures sequential power supply (R, Y, B, N, E) and incorporates a phase detector to prevent supply if the voltage falls below 200V or exceeds 250V for each phase. The panel includes various MCB switches for pre-heaters, reactor-mounted furnaces, and cooling functions. Digital temperature displays are available for controlling and monitoring temperatures in the pre-heaters, reactor furnaces, and various points throughout the system. The panel also features digital displays for pressure and gas flow, allowing for control and monitoring of these parameters.

h. Integrated Sensors and Safety Systems:

The plant is equipped with a range of sensors and safety equipment to ensure precise and safe operation. Notably, a gas venting system with a needle valve allows for the controlled release of gas or pressure before opening the system. To provide visual pressure indications, both a pressure gauge and a digital display on the control panel are present, ensuring operator awareness even during power outages. Accurate pressure measurement is facilitated by a pressure transmitter. For safety purposes, a spring-loaded pressure relief valve is set at 140BAR (adjustable) to prevent overpressure situations. Additionally, a PT-100 sensor is utilized to measure the temperature of the mass prior to its entry into the reactor.

Operation Manual

Catalytic Reactor

In chemical processing, a packed bed is a hollow tube, pipe, or other vessel that is filled with a packing material. The packing can be randomly filled with small objects like Rasching rings or else it can be a specifically designed structured packing or Catalyst as per the process requirement. Packed beds may also contain catalyst particles or adsorbents such as zeolite pellets, granular activated carbon, etc.

The purpose of a packed bed is typically to improve contact between two phases in a chemical or similar process. Packed beds can be used in a chemical reactor, a distillation process, or a scrubber, but packed beds have also been used to store heat in chemical plants. In this case, hot gases are allowed to escape through a vessel that is packed with a refractory material until the packing is hot. Air or other cool gas is then fed back to the plant through the hot bed, thereby pre- heating the air or gas feed.

KTL Group Packed Bed Reactors are solid-liquid-gas contacting devices wherein a liquid stream flows downward over a bed of catalyst with pressure difference serving as the driving force. The fluid flows over catalyst particles and forms fine films, rivulets, or droplets. The gas stream can either flow concurrent with the liquid or countercurrent to it through the bed. These types of bed reactors are primarily operated in continuous mode but are sometimes used in semi-batch processes.

KTL Packed bed Reactors are named as such for their operation in a trickle-flow regime. This regime is characterized by stable and continuous flow of the liquid and gas streams through the bed, like laminar flow in a single-phase system. The regime in which the system operates is dependent on the velocities of the liquid and gas streams. Trickle bed reactors can also be run in pulsing, spray, or bubble flow regimes depending on the application.

A large factor in the overall performance of a packed bed reactor is the type of packed bed used. The configuration of the bed, whether it be random packing or structured packing, as well as the shape of packing used, affect properties such as pressure drop and the catalyst coating area.

Depending on the application, alternatives to the standard packed bed reactor design might be necessary to attain different reactor characteristics. Some of them include:

i. Monolith packed bed reactors use a channeled slab of ceramic or metallic material coated in a catalyst layer. This design allows for a far lower pressure drop and eliminates diffusion as a limiting factor to the reaction.
ii. Micro-packed bed reactors use very small characteristic length scales to allow better control.

Usage of Bed Catalytic Reactor

Packed bed reactors play a large role in hydro-processing in the petroleum industry to generate cleaner fuels. Liquid petroleum flows with high-pressure hydrogen gas at relatively low speeds to prolong the residence time within the system. Reactions at the catalyst surface remove pollutants such as sulfur and nitrogen from petroleum. These are typically very large reactors that correspond to the large production scales in industry.

Advantages:

i. Can be used for three - phase reactions.
ii. Lower total energy consumption since solids are stagnant, not suspended in slurry.
iii. Simple to operate under high temperatures and pressures.
iv. Lower catalyst attrition.

Disadvantages

v. Hot spots may develop due to solvent evaporation.
vi. Channeling may occur, leading to inefficiencies (Hence the smaller the diameter the better)
vii. Difficult to control vessel parameters.
viii. Lower performance when liquid not uniformly distributed
ix. Difficult to scale up due to dependence on fluid dynamics of the system of reaction parameters and enhance process safety.

Fabrication of the System

Equipment Used:

i. Tubular Packed Bed Column around 300mm long with an electric heating media.
ii. Gas flow line with Mass controller and NRV system…x 2 Nos.
iii. Gas Pre-Heaters with Controller system
iv. Pre-Mixer Zone for mounting instruments like PG, Pressure Transmitter, Relief Valve, Electronic Solenoid Valve and Vent Needle Valve.
v. Product Cooler
vi. Gas – Liquid Cyclone Separator
vii. Product Receiver
viii. Back Pressure Valve for Vent gases to GC
ix. Digital Display of each sensor and instruments required to generate data.

Equipment Design

KTL Packed bed reactor consists of a tubular tank with a sieve plate or wire mesh near its bottom to support the packed bed, and inlets and outlets for the liquid stream at the top and bottom of the reactor, respectively. The gases & Liquid or (Liquid in Vapor state) acting as inlet, is located at the top, with the outlet located at the opposite end. A bubble cap, sieve plate distributor, or fine layer of non-reacting particles are placed at the top of the bed to ensure a uniform liquid distribution throughout the bed.

The Packed Bed is in tubular structure with top and bottom having threaded open able adaptors for filling of catalyst, or removable after exhaust. At the bottom of Tube reactor there is a provision to mount wire mesh which can be removed for maintenance purposes.

This Tube Reactor is placed in a Heating medium which is an electric band heater which has a range of 500 to 800 0C. Now the feeds for this Reactor can be gases and Liquids depending on the process used.

KTL Packed Bed provides two gas inlets and two Liquid inlets for a particular Tubular Packed Bed Catalytic Reaction, so that one can use any combination as Gas-Gas-Liquid, Gas-Liquid-Liquid or Gas- Gas-Vapor system as per custom use.

The Gas Line typically consists of:

i. A block Valve the entry of gas from any source to control the pressure, so that the MFC's are not damaged.
ii. A de-hydration chamber absorbs any moisture content in the flowing gas, so that MFC's do not malfunction.
iii. A bypass arrangement to MFC via Needle Valve assembly, to work in the process even if MFC is not working or by-passed for Troubleshoot, without effecting the On-going process.
iv. A set of instruments to monitor the gas like, Pressure gauge, needle valve to control the flow, non-Return valve, etc. are placed accordingly.
v. A Gas-Pre-Heater is provided to heat the gases so as to attain the reacting temperature before the mixing zone.
vi. A Gas-Pre-Heating chamber consists of a tube in tube structure where in the gas is passed through an annular region having film heating, to attain temperature in a very less time.

The Liquid Line typically consists of:

i. A feed vessel with a Glass level indicator and valves.
ii. A metering pump (of specified flow rate)
iii. A back pressure monitoring arrangement with Relief Valve and Pressure Gauge.
iv. A Non-Return valve before the Pre-Heating Zone, so that Vapor does not block the liquid flow line.
v. A Pre-Heater (Vaporizer)
vi. A Pre-Heater chamber consists of a tube in tube structure where the liquid is passed through an annular region having film heating, to attain temperature in a very less time.

The Heater Cum Mixer Zone Consists of:

i. A SS316 Distributor which mixes the feeds in a uniform way, prior to the feed to Packed Bed Reactor.
ii. This Also has provision for mounting of Pressure Gauge, Rupture Disk, Spring Relief Valve, electrically operated Solenoid Valve, Electronic Pressure Transmitter, and A manual Vent Needle Valve. And finally, the inlet line feeds from Gases and Liquid arrangements to the Reactor.

The product cooler consists of:

i. A ¼" Tube coiled and placed in an annular space of a two walled pipe closure, through which the cooling fluid passes.
ii. This is typically insulated so that the temperature of the utility line is maintained.
iii. This has an Electrically operated Solenoid Valve which can be set to a desired pressure, so that it releases the excess and maintains the Packed bed Reactor Pressure to the desired value.

The Cyclonic Separator consists of:

i. A Conical Vessel which has the inlet nozzle tangentially placed and a dampener, to separate the gas and liquid, or gas carrying liquid droplets along with the flow to the GC unit. Such that the liquid is collected at the bottom of cone and gas is ready to vet off the cyclonic separator via back pressure Valve.

Control Panel

Figure 18: Control Panel of SNG System

The control panel consists of:

i. SS Panel box with Glass window for precaution of Instrument from damage and accidental ON / OFF of Switches.
ii. An Emergency Press Switch on top of Control Panel for Stopping of all electrical supply to the unit.
(One need not have to open the control panel door to OFF the Mains)

iii. The door has been provided with Magnet Locks to avoid KEYWAY opening and its misplacement.

iv. A MAINS MCB switch to ON the Control Panel, this will TRIP OR will not get ON if the power supply, which is 3 Phase, Neutral and Earthling is not in sequential manner. (I.e., R, Y, B, N, E).
We have provided a Phase detector in the panel which will prevent the supply if the voltage is below 200V and above 250V for each Phase and its sequence.

v. A MCB Switch to ON the Pre-Heaters for respective Gas Supply.

vi. A MCB Switch to ON the Reactor Mounted Furnace.

vii. A Two-way switch for cooling the Reactor mass with an Indication lamp. *(This switch is by default placed in AUTO Mode so that the Temperature is maintained in the Reactor as per set Value and will be in FORCED mode if one needs to cool down the Reactor to ambient Temperature. The Utility lines are not in scope of supply. An Electronic Solenoid Valve is provided on top of the Reactor which will do the operation.)*

Digital Display of Thermometer

Figure 19: Digital Display of Thermometer

i. There is Digital Display of Temperature for Controlling the Pre-Heater for Each Gas. This is a Controller which will control the Pre-Heater power supply based on the set value in Controller. Whereas there is a Display for Temperature of Pre-Heater just below it, which will show the temperature of electric heating element, which will just confirm that the heater is working by giving some value above ambient, one has not to get confused with the value showing to the set value in Controller as it may vary, since the sensor is placed near the electric element.

ii. There is Digital Display of Temperature for Controlling the Reactor Furnace Heater and a Display for Furnace Temperature with working just same as above. In this the sensor is placed before the Reactor Packed bed on the Manifold while the Furnace Temperature sensor at the back of it. These sensors which have yellow connectors are of "K" Type which have higher range up to 7000C. but are not as accurate as that of White connectors which are "PT-100" Type having range up to 350 0C.

iii. There is Digital Display Temperature Indicator which shows the Temperature at the Port before or after the Product cooler, one can use this common sensor to get either of the data of temperature of mass going to the Product cooler or temperature of mass coming out of the product cooler.

iv. There is Digital Display Temperature Indicator which shows the Temperature at the Port before or after the Product cooler, one can use this common sensor to get either of the data of temperature of mass going to the Product cooler or temperature of mass coming out of the product cooler. The Same Type of Digital Display Temperature Indicator on the GAS-LIQUID Separator.

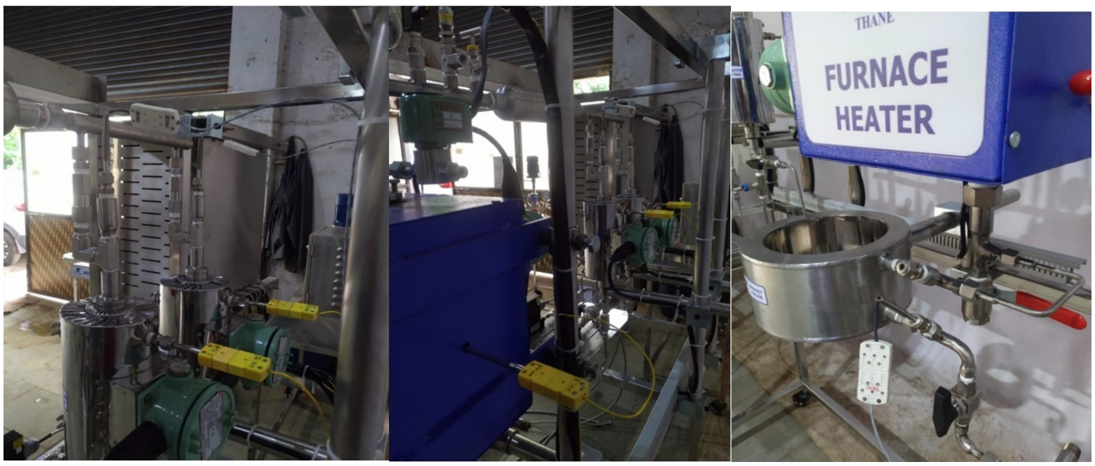


Figure 20: Temperature Measurement at different places

Digital Display of Pressure

A Digital Display of Pressure in Bar, of the Entire unit under pressure which gets the value from the Pressure Transmitter mounted on the Manifold on top of the Reactor. We have provided one more Pressure Indicator which gets the value from the Pressure Transmitter mounted on the Liquid Receiver, *this is just in case if Differential Pressure is formed in the system due to chock up of catalyst material in the Packed bed.*

Digital Display of Flow of Gases

The system is provided with Digital Display of Flow of gases for each gas respectively. This Flow of gases can be controlled by A POT provided and its respective value will be displayed on the Controller. Since these MFC's are volume-based display, one needs to convert to Kg/m3 by multiplying it with its respective density. The maximum range for both the gases is 30LPM. One can vary the flow value by the POT; it has a ratio of 10 turns to display max flow.

Gas Mass Flow Control Assembly

There are two MFC provided in this system, one for *Hydrogen Gas* and the other for *Carbon-Dioxide*. Each MFC has been provided with By-Pass Line so that one can run the system on manual mode without MFC by controlling the flow of gases manually by Needle Valve provided just before the gas enters the Gas Pre-Heaters. While Ball Valve is provided at the MFC line so that the valve opening is full bore as compared to needle valve, which can be manipulated and never known to the operator. The Ball Valve *ARROW Handle* does the job, hence assuring that the flow set in MFC is going to the system.

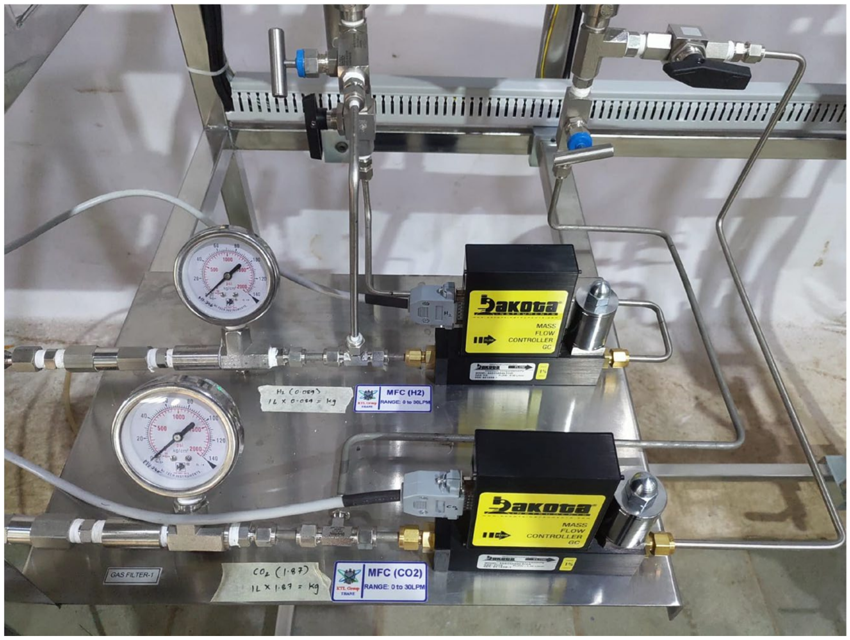


Figure 21: Gas Mass Flow Assembly

Figure 22: Mass Flow Controller Setup

The Gas Lines are provided with NRV, then Gas Filter and Pressure Gauge just before the MFC for protection of the same. We have also provided SS flexible Hose Pipes along with respective Gas Flow control valve. MFC needs cable to display its value, hence specific cables have been provided with nomenclature on it. One cannot interchange these cables as they are calibrated for the respective gases.

Figure 23: Gas Flow Control Valve

Gas Pre-Heaters

Figure 24: Gas Pre-heater

These are Electric Heaters having range up to 200^0C *(Its limitation due to heating element area so as its wattage).* These Heaters are removable *without disturbing the unit*, by hinge operated locks. It has provision for mounting sensor to display the temperature of the outer surface of the metal through which the gases pass. Hence may not be accurate as the controller, *this is just to assure that the heater is working.*

This Metal Assembly is designed such that a *very thin film of gas is created on the walls* of which heater is heating on the outer body, so that rapid heating is achieved in a very less retention time. A Sensor is provided on other side of the assembly to read the temperature of gas just before passing to the Mixer, followed by Non-Returning Valve (NRV).

Gas Mixer

Figure 25: Gas Mixer

It's a closed equipment made of SS 316 having SS 316 Mesh Packing. It is designed to thoroughly mix the Gases and OR Liquids in gaseous phase passing through it. Thus, making the mass material ready before it enters the Catalytic bed (Reactor).

Manifold

Figure 26: Manifold of the System

It consists of devices and instruments to control and display the Pressure and Temperature of the entire assembly. It consists of a Needle Valve to vent off the gas or pressure before opening the system. A Pressure Gauge to show the pressure apart from digital display in control panel just in case power goes OFF and the operator is unknown. A Pressure Transmitter to read the system Pressure and display on control panel. A Pressure Relief Valve, which is a spring-loaded safety Valve set at 140BAR (Can Be varied by adjusting the nut). A PT-100 Sensor to read the Temperature of the mass before entering the Reactor.

Reactor and Furnace Assembly

Figure 27: Reactor and Furnace Assembly

The Reactor is an SS316 column for placing catalyst, hence known as packed bed column. This Column has a retainer plate at the bottom, which can be removed for cleaning. It has 1.5mm dia holes as sleeve plate to hold the catalyst, *one can even use micron size filter cloth or mesh on top of it if the catalyst is of fine grain size*. This column has threaded opening at both its ends for maintenance, and ease of filling or removal from the system. This column is also provided with cooling coil, to cool the mass either by controlling it through Temperature controller or by forced cooling, via an electronic Solenoid Valve which is operated by the signal given by the controller or by manual switch provided on control panel. To this valve a tap water line needs to be provided (Not in scope of supply) through which the water passes and comes out from the bottom nozzle in the form of steam. A Drain Ball Valve has also been provided at the bottom of Column.

Figure 28: Drain Valve

Product Cooler

Figure 29: Cooler

This is an Annular Heat Exchanger. It consists of an outer Body and an inner ring body through which SS316 Coil has been passed, through which the reactor mass passes, while in the annular space utility fluid passes. A Temperature port has been provided at the entry and exit of the Heat Exchanger. One can use these ports to place a sensor to get the data. A Ball Valve has been provided at the outlet, through which one controls the flow of mass passing through it with a desired temperature.

Gas-Liquid Separator

A Gas – Liquid Separator is an equipment which separates Gas carrying Liquid droplets along with it through the vent line. It has a conical bottom body with a baffle in between, the gas carrying liquid bangs on the baffle plate which is been *designed to flow in a circular or Tangential to the cone body thus allowing the liquid to coalesce and form droplets heavier than the gas carrying force and separate*. A SS jacket has been provided to maintain the Temperature so that the liquid does not get carried out again with the gas.

Figure 30: Gas-Liquid Separator

Liquid Receiver

It's a SS 316 Receiver Tank in which the Liquid Droplets separated from gas in the GLS has been collected. It has a needle valve provision for Venting OFF the left-over gasses. A Pressure Transmitter mounting to read the Pressure in the system. And a Drain Ball Valve to collect the liquid. We have provided Nozzles to mount Level Indicator if the process requires so.

Figure 31: Liquid Receiver

5. HANDLING OF EQUIPMENT AT GHLAB

In this chapter, the various safe handling procedures for the equipment available in the laboratory are discussed briefly.

5.1. Hydrogen Stack Experimentation Set

The safety instructions enlisted below for the smooth operation of the stack experimentation are based on the manufacturer's safety guidelines and laboratory protocols.

a. The setup can only be operated by a supervisor, researcher, or TA at the laboratory. Students are not allowed to use the kit without the supervision of TA/RAs.
b. The operating instructions should be studied before use. The instructions should be followed during the experiment.
c. The setup can be used only with the system modules (H-TEC education Solar Module, H-TEC Education battery box, H-TEC Education power supply). Equipment other than the stet-up shouldn't be integrated into the system.
d. Protective goggles, gloves, and PPE should be used during the experiment.
e. The equipment and gas should be used and stored safely after use.
f. The power supply and the solar module should be disconnected before cleaning the liquids. This can cause short-circuiting in the system. The connection terminals shouldn't be short-circuited or reverse-connected.
g. Deionized water should be used for operation. Sufficient water in the tank should be ensured. The setup should not be run with empty water tanks.
h. Flammable gases, vapors, and liquids from the area surrounding the fuel cells and electrolyzer should be removed. The catalytic chemicals involved may cause spontaneous ignition.
i. Hydrogen and oxygen may escape from the units. The experiment set-up should be operated in a well-ventilated room so that the gases do not accumulate to form explosive mixture.
j. Anything that could ignite the hydrogen (e.g., open flame, materials that can combine change with static electricity, substance with catalytic action) should be removed.
k. Anything that could ignite in the increased concentration of oxygen gas should be removed.
l. Smoking, and flames should be completely restricted.
m. Horse pipe, plugs, and gas tanks should be used for pressure compensation. They must be fixed or secured with clamps, adhesives, etc.
n. The gas storage tanks associated with or supplied with the units should only be used for the storage of gas.
o. The units may only be operated at room temperature and ambient pressure.
p. Minimum separation distances must be observed when using solar modules and artificial lights. These are 30 cm between H-TEC solar modules and the H-TEC Video light and 50 cm in the case of the H-TEC Spotlight. When using lights from other manufacturers, the minimum distance specified by them should be observed before use.
q. The temperature of the solar module when in use can rise. Any potential danger as a consequence should be carefully supervised.
r. There can be electric charges in the live electric contact surface of the product. Connecting to an

impermissible operating voltage may result in fire hazard, possible chances of electric shock and damage to components.

5.2. 1 kW Alkaline Water Electrolyzer

The safety instructions enlisted below for the smooth operation of the alkaline electrolyzer are aligned with the manufacturer's safety guidelines and laboratory protocols.

a. KOH concentration should be 30% by weight.

b. Make sure electrolyte solution (KOH) does not contact the skin.

c. Do not lay the electrolyzer by the side or upside down.

d. Do not disassemble or open the product. The electrolyzer must be covered when in use.

e. Open the hydrogen gas, and oxygen gas outlet and also the hydrogen and oxygen gas vents.

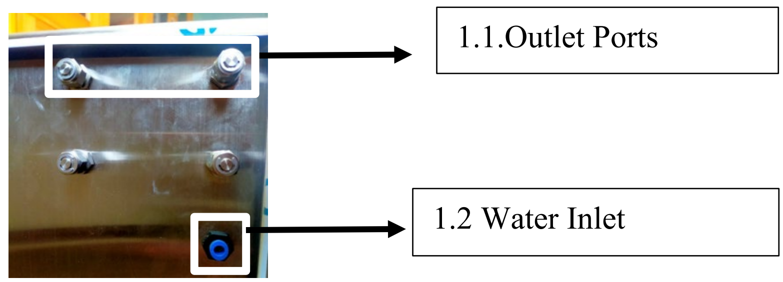


Figure 32: Outlet ports and Water Inlet

f. Connect power supply to the electrolyzer with the help of power cord. And turn the switch on.

Figure 33: power supply cord

g. Set the generation pressure of hydrogen and oxygen at least to 10 bar from the display.

Figure 34: Display Board

h. Do not allow the setting of the electrolyte temperature to be above 80°C.

i. Check the gas detection system if it is turned on.

j. The outlet of the tank and the purge should not be blocked by any means.

k. The hydrogen gas should be vented outside the laboratory if left in the open air.
l. Ensure the electrolyzer is being operated in a well-ventilated area.
m. After the use, turn off the system by setting the pressure to 0 after venting hydrogen and oxygen.
n. If the electrolyte solution leaks, stop the operation and ask for customer support.

5.3. Hydrogen Storage Tank

The safety instructions enlisted below for the smooth operation of the hydrogen tank are aligned with the manufacturer's safety guidelines and laboratory protocols.

a. Storage tank should not be carried horizontally. The tank shouldn't be held at the top neck from where the gas is injected.

Figure 35: Tank shouldn't be carried from neck.

b. The tank should be kept vertically all the time.
c. No gas other than hydrogen gas should be filled.
d. Temperature rise and variation during refilling of hydrogen should be checked timely and considered. Avoid refilling if the temperature rises above 40^0C.
e. Store the compressed gas cylinders in dry and well-ventilated areas.
f. Flammable gas should not be stored near the exit or any location where it can block an exit.
g. Sparks, ignition, open flame, heat sources, and other sources of ignition should be avoided.
h. Gas shouldn't be stored in any room with insufficient ventilation.
i. Store hazardous gas cylinders away from electrical panes, safety showers, and eyewashes.
j. Fire extinguishers and fire suppression systems should be present in a flammable gas storage area.
k. No smoking sign should be posted where flammable gases are used and stored.

5.4. Spectronik Fuel Cell

The safety instructions enlisted below for the smooth operation of the Spectronik fuel cell are aligned with the manufacturer's safety guidelines and laboratory protocols.

a. **Safe Handling:**
PROTIUM-150 requires as is made of thin sheet metal, graphite, and plastic and has a sensitive electrochemical membrane and components inside that require safe handling. PROTIUM-150 is not designed for extreme conditions, rough handling, vibration, shock, or drop. PROTIUM-150 should be stored away from heat, flame, strong sunlight, water, dust, soil, or mud. Damaged PROTIUM-150 should not be used.

b. **Repairing and Maintenance:**
PROTIUM-150 should not be repaired, dismantled, and disassembled by own. Component replacement shouldn't be performed.

c. **Hydrogen:**
High purity (99.999%) dry Hydrogen gas should only be used with PROTIUM-150. All rules and regulations for safe handling, storage, and usage of Hydrogen gas should be followed. Smoking, fire, and burner ignition should be avoided when the fuel cell is in use.

d. **Connectors, ports, and buttons:**
Forcing a connector into the port and applying pressure to a button should be avoided. If the connector and port do not join with reasonable ease, they probably do not match. Obstructions in the pipe should be checked and the correct size of connector for the tubing should be ensured.

e. **Disposal and recycling:**
As PROTIUM-150 contains electronic components and a battery, it must be disposed of separately from household waste. When PROTIUM-150 reaches its end of life, all laws and regulations for proper disposal and recycling options should be followed.

f. Power more than the rated power of the fuel cell should not be drawn from the fuel cell.

g. All gas tubing and electrical wire connections should be ensured firm and secure.

h. The purge outlet should not be blocked and open passage for the flow of gas should be ensured. The outlet should be placed in an open space.

i. Check the delivery pressure of the hydrogen gas supply. Insufficient pressure will affect PROTIUM-150's performance while excessive pressure might rupture its membrane electrode assembly and cause permanent damage.

j. The fuel cell must be kept within casing when not in use.

Figure 37: Spectronik Fuel Cell Casing

Figure 36: Spectronik Fuel Cell (PROTIUM 150)

5.5. Hydrogen and Oxygen Sensor

The safety instructions enlisted below for the smooth operation of the gas sensors are aligned with the manufacturer's safety guidelines and laboratory protocols.

a. The sensors should be kept within the casing when not in use.

Figure 39: Sensor Casing

Figure 38: Sensor

b. Keep the sensors away from dust and particulate and never expose them to exhaust gas or concentrated vapors, harsh chemicals, or extremely high concentration levels as they may poison the sensor.
c. Keep the sensors away from electromagnetic and magnetic interferences (i.e., phones and magnets)
d. Do not open the sensor unit.
e. The sensors should be charged regularly even if not used.
f. To ensure accuracy, calibrate the device at least once every six months.
g. Do not charge in dangerous test locations to avoid fire or explosions.

5.6. Conductivity Meter

The safety instructions enlisted below for the smooth operation of the conductivity meter are aligned with the manufacturer's safety guidelines and laboratory protocols.

a. The coil of the conductivity meter should be thoroughly cleansed.

Figure 40: Coil of Conductivity meter

b. The conductivity meter should be calibrated timely.
c. Immerse the cell in the sample such that the electrode plates are completely submerged in the liquid.
d. If air bubbles remain in the outer cylinder and supporting tube, remove them by shaking the cell.

5.7. Pressure Gauge

The safety instructions enlisted below for the smooth operation of the pressure gauge are aligned with the manufacturer's safety guidelines and laboratory protocols.

a. The startup time should be considered while using the gauge.
b. Blockage in the passage of gauge should be prevented. The sensor or the pressure measuring tip should be cleaned timely.

5.8. Temperature Sensor

The safety instructions enlisted below for the smooth operation of the temperature sensor are aligned with the manufacturer's safety guidelines and laboratory protocols.

a. The startup time should be considered while using the temperature sensor.
b. The sensor should be kept in a closed box after use.
c. The sensor tip should be cleaned after use with chemicals to measure the temperature.

5.9. National Instruments Components

The compact DAQ chassis, voltage module, and temperature module come under the national instrument's components. The safety guidelines in handling the components includes the following.

a. The power supply wires and connectors from the controller should not be disconnected unless power has been switched off.
b. The I/O-side wires or connectors should not be disconnected unless power has been switched off or the area is known to be non-hazardous.
c. The modules should not be removed unless power has been switched off or the area is known to be nonhazardous.
d. The system must be installed in an enclosure certified for the intended hazardous (classified) location, having a tool secured cover/door, where minimum protection of at least IP54 is provided.
e. Observe all instructions and cautions in the user documentation. Using the model in a manner not specified can damage the model and compromise the built-in safety protection. Return damaged models to NI for repair.

5.10. Smart IOT Gateway

SMART IoT GATEWAY (SIG) is a versatile device that reads the Modbus memory map of any RS-485 Modbus protocol device and sends the data to the cloud server. The system is used in various applications of leak detection-prone zones of industries and gas pipelines, coal mines, storage areas power plants and off-site leak detection zones.

Before operating the instrument, the user manual shall be read. The warnings and cautions shall be checked carefully. Instructions and procedures in this section may require special precautions to ensure the safety of the personnel performing them. All warnings and cautions are listed here and repeated at appropriate place according to the relevant subjects of the user manual. Information that may raise safety concerns is indicated by a warning symbol (⚠).

The following safety messages mentioned with (⚠) symbol before performing any tasks shall be referred.

a. The instrument is meant to be used in safe and controlled environment only.
b. Accessing the interior of the instrument to carry out any repair work the qualified personnel only or in presence of Researcher or TA.
c. Opening the box for changing to programming mode for editing the configuration should be done in a clean and dust free environment. This shall not be performed as possible.
d. The device must be used in an RF free environment to reduce the errors in the operation.
e. To minimize the risk of fire or electric shock, the unit must be protected against atmospheric precipitation and excessive humidity.
f. The unit should not be used in areas with excessive shocks, vibrations, dust, humidity, corrosive gases and oils.

5.11. Smart Gas Transmitter

The GT-2500 Smart Gas Transmitter is a microcontroller-based gas transmitter that continuously monitors hydrogen/oxygen gas in P PB/PPM/ %V/V /%LEL depending on the gas selected. The operating manual shall be read before installing, operating, and maintaining the instrument. Warnings can be observed when not operated properly.

Following are some safety guidelines to be ensured before the installation and operation of the system.

a. The interior of the instrument shall be configured and carried out by trained professional only or in presence of RA and TA.
b. To reduce the risk of ignition of hazardous atmosphere, declassify the area or disconnect the instrument power supply before operating the instrument enclosure, the enclosure should be kept tightly during operating.
c. The enclosure shouldn't be opened or replaced in a potentially hazardous atmosphere while power is still supplied.
d. Earthing should be connected
e. The replacement of sensor must be disposed in an environment-friendly manner when the life of the sensor is over.
f. The unit must be protected from electric shock hazard, vibration prone zones, dust, atmospheric precipitation and excessive humidity.

5.12. SNG System Safety Guidelines

The safety procedures to be followed while operating the SNG System include the following.

a. Personnel Training: Ensure that all operators and personnel working with the SNG system are properly trained on its operation, safety procedures, and emergency protocols.
b. Personal Protective Equipment (PPE): Operators and personnel must wear appropriate PPE, including safety goggles, heat-resistant gloves, lab coats, and closed-toe shoes, to protect against potential hazards.
c. Emergency Shutdown: Familiarize all personnel with the location and operation of emergency shutdown switches, especially the Emergency Press Switch on top of the control panel to stop all electrical supply to the unit in case of emergencies.

d. Gas Venting: Use the gas venting system with the needle valve for controlled release of gas or pressure before opening the system. Never vent gas directly into the lab environment.
e. High-Pressure Handling: Exercise extreme caution when handling high-pressure gas lines (150 bars). Follow proper procedures for connection, disconnection, and pressure regulation to prevent accidents.
f. Temperature Hazards: Be cautious of elevated temperatures (up to 800°C) in the system. Avoid direct contact with hot surfaces and use heat-resistant gloves when necessary.
g. Reactor Cooling: Monitor the cooling system to avoid overheating of the reactor. Make sure the cooling fluid flow is well-maintained and the electrically operated solenoid valve controls the pressure inside the reactor.
h. Catalyst Handling: When working with the reactor and packed bed column, be careful with catalyst material. Avoid direct contact and use protective measures, such as micron size filter cloth or mesh, to prevent inhalation.
i. Gas Mixing: Ensure that the gas mixer is securely closed during operation and that gas and liquid feeds are accurately mixed before entering the catalytic bed.
j. Gas and Liquid Leak Prevention: Regularly inspect all gas and liquid lines, connections, and valves for leaks. Use leak detection systems or soapy water tests if necessary.
k. Proper Instrument Operation: Understand the functionality of all instruments on the control panel. Confirm that pressure, temperature, and flow readings are accurate and calibrated correctly.
l. System Monitoring: Continuously monitor the SNG system during operation, including pressure, temperature, gas flow, and other critical parameters.
m. Adherence to Design Specifications: Operate the system within its specified limits and adhere to design recommendations to prevent overpressure, overheating, or other hazardous situations.
n. Safe Startup and Shutdown: Follow proper startup and shutdown procedures to prevent sudden pressure surges or unexpected reactions.
o. Fire Safety: Keep fire extinguishing equipment nearby and ensure that the lab has a comprehensive fire safety plan in place.
p. First Aid and Emergency Response: Establish clear emergency response protocols and ensure that first aid supplies are readily available.
q. Regular Maintenance: Schedule regular maintenance and inspections of the SNG system to identify potential issues and ensure safe and efficient operation.
r. Keep Work Area Clean and Organized: Maintain a clean and clutter-free work area to minimize the risk of accidents and improve overall safety.
s. Emergency Preparedness: Have a well-defined emergency response plan in place, including evacuation procedures and contacts for emergency services.
t. Compliance with Regulations: Ensure compliance with all relevant safety regulations and guidelines related to the handling of gases, high-pressure systems, and hazardous materials.

6. EMERGENCY CONTACT NUMBER

A list of Emergency contact numbers is provided below:

Personnel	Contact Number
Team Leader	9861936212 *(Dr. Biraj Singh Thapa)*
Research Assistant	9862785638 *(Mr. Abhishek Subedi)*
Department of Mechanical Engineering, Kathmandu University	011-5526974
Security Chief KU	9841109827
Kathmandu University	011-415200
Dhulikhel Hospital	011-490497
Dhulikhel Ambulance	9801002359
Fire Brigade Dhulikhel	9851066310

ANNEX I: Laboratory Experimental Evaluation

Green Hydrogen Laboratory
Department of Mechanical Engineering
Kathmandu University

Date: **Time:**

Location:

Experiment Code:

Experiment Name:

Experiment Associated with:

Objective:

Experiment Performed By:

1. …………………………………………………………
2. …………………………………………………………
3. …………………………………………………………

Assistants:

1. …………………………………………………………
2. …………………………………………………………
3. …………………………………………………………

Theory (Assumptions, reasons, Initial conditions)

Safety Guidelines Checklist

Safety Protocols	Yes	No	Comments
Shoes, Full-sized pants, and Apron (for the chemical-associated experiment)			
Electrical connections and switches test			
Ventilation and window			
Experimental glasses, earbuds, and face shields			
Fire Extinguisher			
Secured Ignition sources, flammable components, and heating components (heater, lighters, etc.)			
Gas Detection Systems (Turned ON)			
Protective globes (considering chemical components used)			
Purging and Water			

Procedure:

Observation:

S.N.	Description of Activity	Outcomes	Remarks

Results:

Problem Encountered	Possible Reasons	Possible mitigation/solutions

Conclusion:

Prepared By:

Name:
Signature
Date:

Approved By:

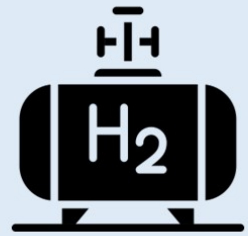
Name:
Signature:
Date:

ANNEX II

Laboratory Setup Safety Protocols and System in GHLab

Hydrogen is a colorless, odorless, tasteless, flammable nontoxic gas which is flammable over a wide range of concentrations from 4% to 74.2% by volume. Hydrogen has a relatively low ignition energy (0.02 millijoules). It has a very low density and therefore must be stored at a high pressure to achieve enough mass for practical use. The ease of ignition and high storage pressure of hydrogen gas create a large portion of the risk associated with hydrogen usage.

Hydrogen burns with a nonluminous flame which can be visible under bright light. Hydrogen has the highest energy content by weight of any chemical fuel-three times higher than gasoline, thus mixing up with air can cause the formation of extremely explosive mixtures. It also the ability to attack, and damage to the point of leakage to certain materials that are used for construction of storage containers, piping, valves, and other apparatus.



Precautions

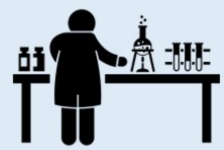
Before performing any experiment, the **safety guidelines** shall be studied.

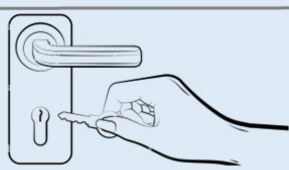
Appropriate **personal protective equipment** (e.g., safety glasses, laboratory coats, gloves face shields, and protective shoes) should be used for any experiment.

Observe the **safety valves, gas detection system, alarm systems** and maintain the natural vents and check the laboratory exhausts.

Check the **emergency exit routes**. Make sure you know where your lab's safety equipment including **first aid box, fire extinguishers, eye wash stations, and safety showers** is located and how to use them.

Do not work alone, work under the **supervision of TL/RAs**. Follow experiment steps and avoid horseplay. **Report all injuries, accidents, and broken equipment or glass right away**, even if the incident seems small and unimportant.





Avoid cell phones usage during experiments. Cut power after use. If you are the last person to leave the lab, make sure to **lock the doors** and **turn off all ignition sources**.

Emergency Contact Numbers:

Team Leader: 9861936212 *(Dr. Biraj Singh Thapa)*
Research Assistant: 9862785638 *(Mr. Abhishek Subedi)*
Department of Mechanical Engineering, Kathmandu University: 011-5526974
Security Chief KU: 9841109827
Kathmandu University: 011-415200
Dhulikhel Hospital: 011-490497
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