GREEN HYDROGEN 2023

"HYDROGEN SAFETY – STANDARDS AND REGULATIONS"

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6th

JULY 2023

PESO 125
YEARS OF SERVICE TO NATION

GASEOUS HYDROGEN - HAZARDs

- **HYDROGEN IS LIGHT –** To be precise with a density of 84 g/m3 at 15°C and 1 bar(a). It is the lightest of all gases and is 14 times lighter than air – VENTILATION.
- **IGNITION TEMPERATURE –** In Air, this is 585°C. This is higher than ignition temperature of Methane (540°C), the main component of NG.
- **HYDROGEN IS EXTREMELY FLAMMABLE –** Minimum Auto-ignition energy is 20uJ, which is extremely low – IIC CLASSIFIED.
- **HYDROGEN FLAME IS COLORLESS –** Fires can go unnoticed under certain circumstances in day light
- **EXPLOSIVE RANGE –** Extremely wide. It touches from 4 vol% to 77 vol% LEL.

LIQUID HYDROGEN - HAZARDs

- Liquid Hydrogen (LH2) poses unique explosion hazards. At -253°C, it is so cold that any impurities it contains (except Helium) freeze solid. This applies in particular, to air that enters a container of liquid hydrogen. A mixture of solid air and LH2 acts like an explosive.
- In addition, the low temperatures mean that air condenses on the external surfaces of uninsulated pipes or system parts. Little by little, nitrogen evaporates from this liquid air, meaning that the concentration of liquid oxygen in the mixture increases. If it comes into contact with combustibles substances, for instance if the liquid oxygen drips onto wood, this can also lead to an explosion. If this occurs near a pipe containing hydrogen, the consequences could be devastating.

HYDROGEN SAFETY AND REGULATIONS

- **Safety is seen as a paramount concern by many relevant bodies in relation to the regulation of the Indian hydrogen industry. While they do not expressly refer to hydrogen, existing safety standards and regulations are arguably broad enough to capture most aspects of the hydrogen industry. Nevertheless, it would be prudent to adopt standards and regulations specifically dealing with hydrogen to ensure that all aspects of the hydrogen industry are dealt with.**
- **Hydrogen safety is regulated by Explosives Act 1884, Gas Cylinder Rules 2016 ,Static and Mobile Pressure Vessels (Unfired) Rules 2016 and MSIHC Rules 1989.**

HYDROGEN VESSEL

- **Hydrogen Vessels requires a license in Form LS1A required under Rule 50, 54 and 55 of SMPV (U) RULES 2016.**
- **Transportation of compressed gas in a pressure vessel laden vehicle requires a license in Form LS2 as required under Rule 50, 54 and 55 of SMPV (U) RULES 2016**

HYDROGEN DISPENSING

Approvals for R&D activities accorded to IOCL R&D Division, University of Petroleum and Energy Studies for Hydrogen dispensing station at Gurgaon and at Tata Motors

PESO has already approved Type 3 (Aluminium lined composite cylinders) and Type 4 (all composite cylinders) cylinders for CNG applications which can also be approved for Hydrogen applications as per Gas Cylinders Rules 2016

HYDROGEN DISPENSING

As far as Hydrogen dispensing is concerned, a robust design and equipments confirming to international standards are the requirement.

PESO is in the process of formulating standards, design criteria, safety regulations and fire fighting system requirements for hydrogen dispensing facility.

PESO has given Consent in JUNE 2022 to Hydrogen dispensing facility for filling Hydrogen in cylinders/cascades and dispensing in Fuel Cell Buses attached with M/S IOCL, Gujarat Refinery.

PESO has given Consent in APRIL 2023 to Hydrogen refueling station of RIL at Jamnagar for filling Hydrogen in cylinders/cascades and dispensing in Fuel Cell Buses attached with RIL.

HYDROGEN STORAGE

- **The most challenging part in this process is storage of hydrogen, as hydrogen is very low density gas & must be stored at high pressures ranging from 350 Bar to 700 Bar to get required quantity & mileage of vehicles.**
- **The development of Type 4 high pressure composite cylinders which are very light in weight and safe compared to steel cylinders made it possible to use Hydrogen as fuel in the vehicles which is future of auto industry.**
- **The storage of hydrogen is different in different type of vehicles at different pressures.**

HYDROGEN STORAGE

- For passenger cars, size of cylinder is in between 40 to 120 Ltr water capacity at working pressure rating of 500 bar to 700 bar. One passenger car can store 5-6 Kgs of Hydrogen depending upon the pressure and typically travel 600 – 650 Km in one filling. The development of Type 4 high pressure composite cylinders which are very light in weight and safe compared to steel cylinders made it possible to use Hydrogen as fuel in the vehicles which is future of auto industry.
- The transport vehicles need more gas to be stored as consumption is more, are using number of cylinders of water capacity between 150 to 350 Ltr and can store upto 16-20 Kgs of hydrogen which can travel approx.. 500 Kms in one filling. The pressure of hydrogen is approx. 350 bar.

COMPOSITE CYLINDERS

- The composite cylinders for vehicle applications are designed as per European standard EC-79, ECER-134, ISO 19881 etc. The vehicles can be filled at dispensing unit in similar fashion as CNG is filled presently. Since hydrogen is very light in nature and having high explosion behavior, lot more precautions needed to be taken while handling the hydrogen gas.
- The working pressure of such Type 4 composite cylinders cascade is 300-350 bar. The cylinders for the Cascade are designed as per European standard EN-12245. The water capacity of one 10 ft cascade shall be approx. 8750 Ltrs which can accommodate about 250 Kgs of hydrogen gas.

CHALLENGES IN STORAGE AND TRANSPORTATION

- **Big challenge is to storage & transportation of hydrogen gas to filling station. Since it is the beginning of hydrogen era in India it is not practically possible to lay the pipeline in all the places for transportation of Hydrogen to dispense. The best alternative of storage and transportation of hydrogen in cascades of Type IV composite cylinders. The cascades of hydrogen are being used in many countries which comes in the standard sizes like ISO containers of 10 ft, 20 ft & 40 ft.**
- **Presently these type 4 of composite cylinders for Hydrogen are being manufactured by companies like Hexagon, Quantum, Iljin etc. These companies are marketing the cylinders all over the world.**

RECENT DEVELOPMENTS

- **Recently our Road Transport Minister Mr. Nitin Gadkari has launched a vehicle manufactured by Toyota which is working on hydrogen fuel cell for storage of hydrogen they have used two cylinders of 60 Ltrs water capacity which can store 5 kgs of hydrogen at 700 bar pressure of gas and can travel approx. 600 Kilometers in single filling.**
- **In India presently no body is manufacturing Type IV composite cylinders for hydrogen gas. M/s. Time Technoplast Ltd, Mumbai is engaged in manufacture of Type IV composite cylinder for LPG & CNG. They are successfully launched Type IV composite cylinder under AtmaNirbhar Bharat for transportation & storage of CNG gas with very efficient space utilization of transport vehicle helping in reduction on transportation cost and carbon emissions.**

RECENT DEVELOPMENTS

- **Time Technoplast is in advanced stage of development of Type IV composite cylinders for Hydrogen for automobile and also for cascade i.e. transportation of gas to dispensing stations. The cylinder shall be designed as per international standards ECER-134 & EN-12245. The working pressure of these cylinders shall be upto 700 bar for automobile and 350 bar for cascades.**

OTHER STATUTES

- **Manufacture, Storage and Import of Hydrogen also comes under the purview of MANUFACTURE, STORAGE AND IMPORT OF HAZARDOUS CHEMICAL (MSIHC) RULES, 1989.**
- **In MSIHC Rules 1989, PART II, LIST OF HAZARDOUS AND TOXIC CHEMICALS. Sl. NO.314 is Hydrogen**
- **GROUP 3-HIGHLY REACTIVE SUBSTANCES, Sl.No. 143, Hydrogen is mentioned. In this, Threshold Quantity for application for application of Rules 5, 7-9 and 13-15 is 2 Tons and threshold quantity for application of Rules 10-12 is 50 T**

REQUIREMENTS AS PER MSIHC RULES 1989

- a) Notification of major accident as per rule 5;
- b) Approval and notification of sites as per rule 7;
- c) Safety report and safety audit reports as per rules 10 to 12;
- d) Acceptance of On-site Emergency plans as per rule 13

Rule 5 of MSIHC Rules 1989

- **Notification of major accident**

Where a major accident occurs on a site or in a pipe line, the occupier shall [within 48 hours notify] the concerned authority as identified in Schedule 5 of that accident, and furnish thereafter to the concerned authority a report relating to the accidents in installations, if necessary, in Schedule 6

Rule 7 of MSIHC Rules 1989

APPROVAL AND NOTIFICATION OF SITES

An occupier shall not undertake any industrial activity unless he has been granted an approval for undertaking such an activity and has submitted] a written report to the concerned authority containing the particulars specified in Schedule 7 at least 3 months before commencing that activity or before such shorter time as the concerned authority may agree and for the purpose of this paragraph, an activity in which subsequently there is or is liable to be a threshold quantity or more of an additional hazardous chemical shall be deemed to be a different activity and shall be notified accordingly.

Rule 10 of MSIHC Rules 1989

SAFETY REPORTS AND SAFETY AUDIT REPORTS

Subjects to the following paragraphs of this rule, an occupier shall not undertake any industrial activity to which this rule applies, unless he has prepared a safety report on that industrial activity containing the information specified in Schedule 8 and has sent a copy of that report to the concerned authority at least ninety days before commencing that activity.

Rule 11 of MSIHC Rules 1989

- **UPDATING OF REPORTS UNDER RULE 10**

Rule 12 of MSIHC Rules 1989

- **REQUIREMENT FOR FURTHER INFORMATION TO BE SENT TO THE AUTHORITY**

Rule 13 of MSIHC Rules 1989

- **PREPARATION OF ON-SITE EMERGENCY PLAN BY THE OCCUPIER**

APPROVAL FOR HYDROGEN DISPENSING STATION – IOCL GUJARAT

- **PESO HAS GIVEN APPROVAL FOR IOCL GUJARAT REFINERY for Hydrogen Dispensing Facility of Indian Oil Corporation Limited, Gujarat Refinery, at Koyali, Vadodara, Gujarat.**
- **PESO HAS GRANTED Conceptual agreement for Hydrogen generation and filling in cylinders /cascades and dispensing installation attached with IOCL Gujarat Refinery.**
- **PESO has granted license to import 6 Gas cylinders for High Pressure Cylinder Storage to IOCL.**
- **PESO has given Consent in APRIL 2023 to Hydrogen refueling station at Jamnagar for filling Hydrogen in cylinders/cascades and dispensing in Fuel Cell Buses attached with RIL. (There is no high pressure storage, chiller and heat exchanger at RIL because of reduced compressor capacity.**

IOCL Hydrogen Purification & Dispensing Facility at Gujarat

Hydrogen Initiative by IOCL, Gujarat Refinery

HYDROGEN PURIFICATION & DISPENSING FACILITY

POINTS CONSIDERED BY PESO AT HYDROGEN DISPENSING STATIONS TO MITIGATE HAZARDS

- **MECHANICAL INTEGRITY –** Selecting compatible materials and components, Welded connections, Relief devices, Pressure Testing, Regular Maintenance, Expansion & Contraction
- **SAFE INSTALLATION LOCATION –** Safety setback distances, Fire barrier walls, Impact prevention from Trucks by provision of bollards, Canopy design – Weather protection and adequate ventilation
- **VENTILATION –** Naturally ventilated design (should not obstruct passive airflow)
- **DETECTION –** Leak checking during preventive maintenance, leak detectors & hydrogen gas detectors
- **SYSTEM CONTROLS –** Emergency Shutdown system, Isolation valves, Venting to safe location
- **IGNITION AND ELECTRICAL DESIGN –** Classified and Intrinsically Safe Electrical equipment. All equipment must be bonded and grounded to mitigate charge accumulation and electrostatic discharge
- **PURGING –** Required if maintenance is needed
- **PPEs –** Fire Resistant clothing, Face shields
- **TRAINING AND EMERGENCY RESPONSE PLAN**

HYDROGEN DISPENSING FACILITY

Fuel Cell Grade Hydrogen is being sourced IOCL, Gujarat Refinery. This will be further purified using a PSA (Pressure swing adsorption) facility in one of the HGU (Hydrogen Generation Unit)

Fuel cell grade hydrogen is transported through 4" above ground carbon steel pipeline (designed as per ANSI B31.12) to Hydrogen dispensing facility.

This Fuel cell grade Hydrogen is then compressed from 18 Kg/cm2 to 550 Kg/cm2 using water cooled, reciprocating diaphragm, triple metallic diaphragm compressor with a capacity of 35 Kg/Hr. This two-stage compressor discharge pressure is 500 Bar – 550 Bar. (RIL capacity is 2.5 kg/hr)

The High-pressure hydrogen from compressor is routed to high pressure cylinder storage with 6 tubes in cascade with a storage pressure of 500 – 550 Bar and a capacity of 24 Kg per tube.

A pressure reducing station for filling hydrogen gas to tube trailer is also constructed. The pressure reducing station reduces the pressure from 550 Bar to 200 Bar for filling the tube trailer.

HYDROGEN DISPENSER

02 nos of Hydrogen Dispenser with dispensing pressure of 350 bar has been installed

To maintain the temp of Hydrogen Gas at dispensing/delivery nozzle point, the Hydrogen gas after pressure reduction exchanges heat with coolant in a exchanger inside dispenser. The supply & return of coolant to & from dispenser is governed by 2 number of Chiller units (1 for each dispenser). Any fault detection in chiller will stop the dispenser. Each Chiller unit comprises of a refrigeration system, coolant storage tank (1000L) & pump. Each chiller package is 13 HP stand-alone unit.

02 nos. hydrogen Gas detectors have been provided inside the Dispenser Cabinet (1 in lower & 1 in upper cabinet). Upon detection of gas leakage, Gas supply to dispenser shall be cut-off.

The breakaway coupling is installed between the dispenser and the filling/venting hose. In the event of accidental deployment, e.g. driving a vehicle from the dispenser with the nozzle remaining in the vehicle fuel port, the coupling will separate the connections between dispenser and hose sealing both ends

Critical Equipment - Dispenser

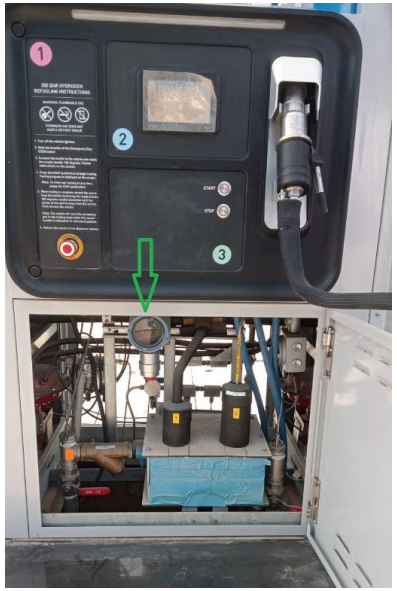
No of Dispenser	2
Compatible Pressure for Nozzles	350 bar
Pre-Cooling/ Chilling System	Provided
Standards	ISO Codes (ISO 19880-1, ISO/DIS 19880-2, 19880-3, 19880-5, 19880-6)
Inlet Pressure of Hydrogen from Storage System	550 bar g
Temperature of Hydrogen from Storage Section	50°C
Total Number of Nozzles	4 (2 nozzles on each dispenser)
Heavy Duty Vehicle Nozzle	3 no.
Maximum Dispensing Pressure	350 bars
Flow rate	3.6 kg/min (minimum)
Light Duty vehicles and HPIT Nozzle	1 no.
Maximum Dispensing Pressure	350 bars
Flow rate	1.8 kg/min (minimum)

- Supplier - Powertech, Canada
- Total number of nozzles- 4 (3 Heavy Duty Vehicle Nozzles + 1 Light Duty vehicles and HPIT Nozzle)
- Maximum dispensing pressure- 350 bar

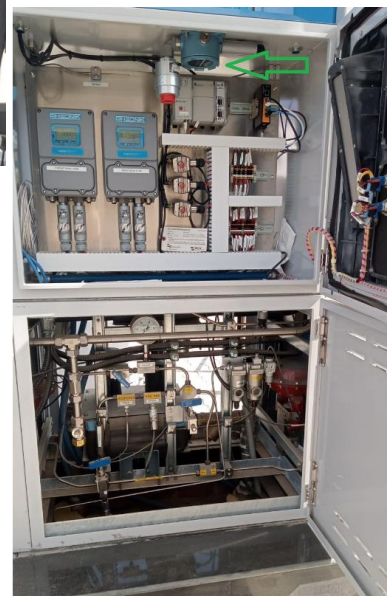
The hydrogen dispensing system shall have capacity of 1.5 tons/day of hydrogen that shall be capable filling 75 bus per day with 24 hours basis operation. Each bus shall have filling capacity of 20 kg/ bus

DISPENSER PROTECTION

Dispenser- Chillers installed at Site



Dispenser- Gas Detector (Bottom Cabinet)



Dispenser- Gas Detector (Top Cabinet)

Dispenser-Hose Breakaway Coupling

STANDARDS AND CODES REFERRED

Following standards and codes are referred for approval of hydrogen dispensing facility

- **Explosives Act 1884**
- **Gas Cylinder Rules 2016**
- **SMPV(U) Rules 2016**
- **MSIHC Rules 1989**
- **ISO 13849: Safety of Machinery**
- **ISO 19880-1, Gaseous Hydrogen – Fueling Stations – Part 1: General Requirements**
- **ISO 19880-3, Gaseous Hydrogen – Fueling Stations – Part 3: Valves**
- **ISO 19880-5, Gaseous Hydrogen – Fueling Stations – Part 5: Fueling Station Hoses**
- **ISO 19880-6, Gaseous Hydrogen – Fueling Stations – Part 6: Fittings**
- **SAE J2601, Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles**

HYDROGEN SYSTEM ISO CODES

- HYDROGEN SAFETY
- **ISO/TR 15916, Basic Considerations for the safety of Hydrogen Systems**
- **ISO 26142, Hydrogen Detection Apparatus – Stationary Applications**
- HYDROGEN PRODUCTION
- **ISO 22734, Part 1and 2 Hydrogen Generators using water Electrolysis process**
- **ISO 14687, Hydrogen fuel Quality- Product Specification**
- HYDROGEN STORAGE
- **ISO 16111,Transportable gas storage devices –Hydrogen absorbed in reversible metal hydride.**
- **ISO 19884, Gaseous Hydrogen- Cylinders and tubes for storage (Under Development)**

- HYDROGEN DISPENSING
- **Explosive atmospheres CODE:**
- **IEC 60079-0:2011, IEC 60079-0:2017, IEC 60079-1:2007-4, IEC 60079-1:2014-06, IEC 60079-11:2011, IEC 60079-15:2010, IEC 60079-15:2017, IEC 60079-18:2017**
- **NFPA 2 – Hydrogen Technologies Code**
- **NFPA 70 – National Electrical Code**
- **SAE J2600 – Compressed Hydrogen Surface Vehicle Fueling Connection Devices**
- **SAE J2601-1 – Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles**
- **SAE J2601-2 – Fueling Protocols for Gaseous Hydrogen Powered Heavy Duty Vehicles**
- **SAE J2799 – Hydrogen Surface Vehicle to Station Communications Hardware and Software**
- **ISO/TS 19880 – Gaseous Hydrogen – Fueling Stations**
- **ASME B31.3 – Process Piping**
- **ASME B31.12 – Hydrogen Piping and Pipelines**
- **API 520 – Sizing, Selection, and Installation of Pressure-Relieving Devices**

HYDROGEN SYSTEM ISO CODES

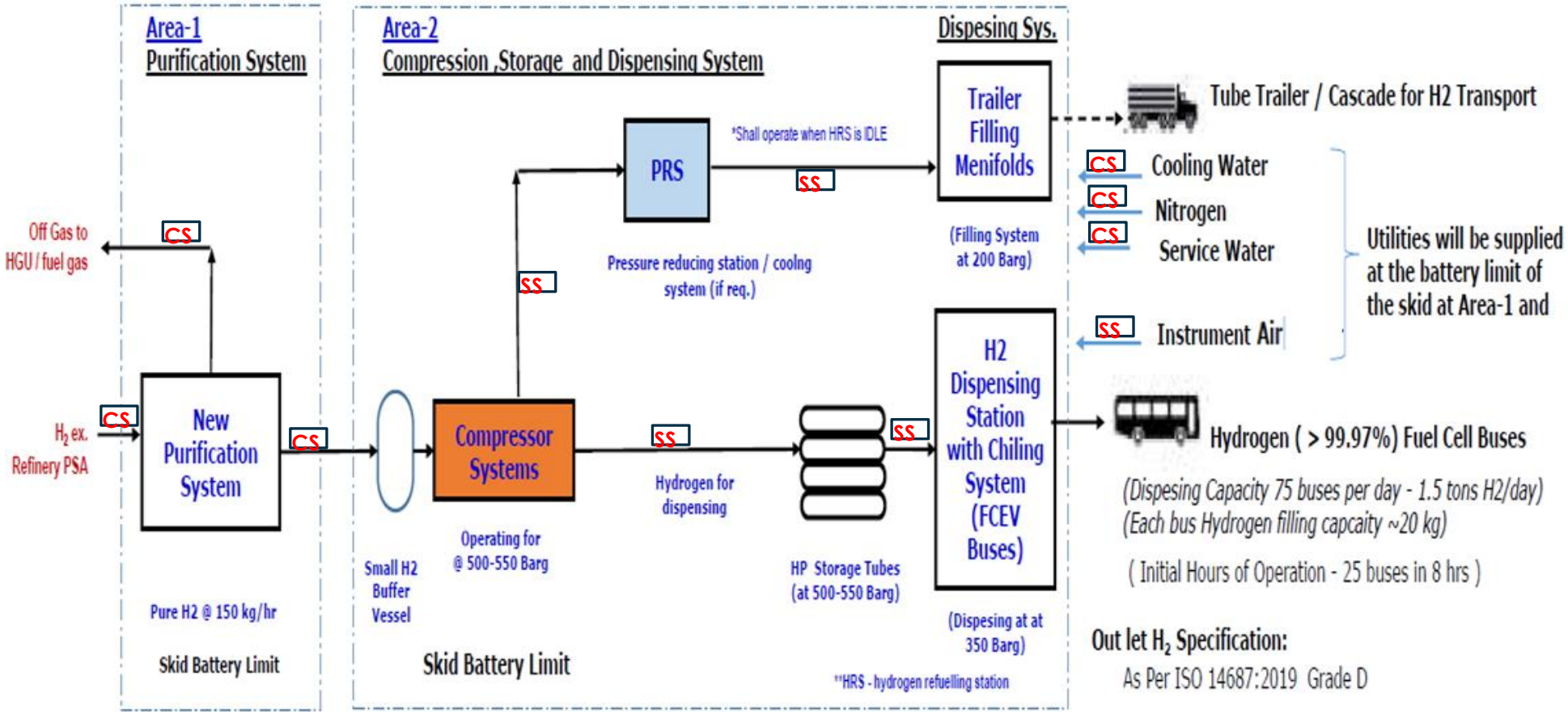
- HYDROGEN TRANSPORTATION
- ISO1111-4, Transportable gas cylinders – Compatibility of cylinder and valve materials with gas contents-part 4: Test methods for selecting steels resistant to Hydrogen embrittlement.
- UNE –EN 17339-Transportable Gas Cylinders –Fully Wrapped carbon composite Cylinders and tubes for e bundle o –Intended to be permanently mounted in a frame bundle or Trailer with test pressure of not less than 300 bar
- HYDROGEN MOBILTY
- IEC 62282-3-200, Fuel Cell Technologies-Part 3-200: Stationary Fuel Power Systems – Performance Test Methods
- IEC 62282-3-300, Fuel Cell Technologies-Part 3-300: Stationary Fuel Power Systems –Installation
- ISO/DIS 19880, Gaseous Hydrogen Fuelling stations – Series.
- ISO 19880-1:2020, Gaseous hydrogen — Fuelling stations — Part 1: General requirements
- ISO 19880-3:2018, Gaseous hydrogen — Fuelling stations — Part 3: Valves
- ISO 19880-5:2019, Gaseous hydrogen — Fuelling stations — Part 5: Dispenser hoses and hose assemblies
- ISO 19880-6,1 Gaseous hydrogen — Fuelling stations — Part 6: Fittings
- ISO 19880-82, Gaseous hydrogen — Fuelling stations — Hydrogen fuelling quality
- ISO 19881 Gaseous Hydrogen – Land Vehicle Fuel Containers

PROJECT DETAILS

- **Capacity- 1.5 tons/day of hydrogen**
- **Objective- Produce Fuel Cell grade hydrogen (ISO 14687: 2019 type D) from the hydrogen product of existing HGUs**
- **Provision for the tube trailer filling exists and will be operated only when the hydrogen dispensing is idle.**
- **Two Dispensing Stations are used for refueling of the Vehicles with fuel cell grade hydrogen.**
- **Capable of filling 75 buses per day with 24 hours basis operation. Each bus shall have filling capacity of 20 kg/ bus.**
- **PLC control system is provided for automatic and easy operation of the Hydrogen Dispensing Station.**

Project	Hydrogen Purification & Dispensing Facility
Capacity	25 Buses per 8-hour shift
Date of Approval	2nd Dec'2020

HYDROGEN DISPENSING FLOW DIAGRAM



(Conceptual Scheme for Hydrogen Purification , Compression and Dispesing Station)

Pipe spec

FACILITIES AT HYDROGEN DISPENSING FACILITY

- **SALES ROOM**
- **PMCC**
- **CONTROL ROOM**
- **TOILETS**
- **COMPRESSOR HOUSE**
- **CHILLER UNIT- 2 NO**
- **HYDROGEN DISPENSING UNIT – 2 NO**
- CANOPY – 1 NO (18 M x 13.5 M)
- PUMP ISLANDS – 2 NO
- AIR FACILITY – 1 NO
- WATER FACILITY – 1 NO
- RVI WITH UNIPOLE & BUFFER STRIP
- HOARDING – 2 NO

CRITICAL EQUIPMENTS PSA

- Supplier - Xebec, Canada
- Number of beds – 6
- Design Gas flow rate- 150 Kg/hr
- Guaranteed Parameters
  - Hydrogen Recovery -Expected : 83%, Guaranteed : 80% (minimum) at 100% nominal design capacity, 75% (minimum) at 30% capacity
  - Pressure Drop across PSA System 1.0 Kg/cm2 (maximum)

Hydrogen (99.9 % purity) will be sourced from existing Hydrogen Generation unit (HGU-III) of Gujarat Refinery, which will be further purified, through new proposed Pressure Swing Adsorption (PSA) facility, to 99.97 % with total non-hydrocarbon gases maximum limit of 300 µmol/mol.

Hydrogen operating conditions are as follows:

Pressure:	**18-22 Kg/cm2g**
Temperature:	**~45 o C**
Flow:	**150 Kg/Hr**

CRITICAL EQUIPMENTS COMPRESSOR

Supplier - Sundyne, USA	Number- 1 working + 1 Standby	Type- Water Cooled, Reciprocating Diaphragm, Triple Metallic diaphragm
Capacity- 773.5 (with 2 units working)	Suction Pressure ((Nor/Min/Max)- 17.5/16/22 kg/cm2	Suction Temperature ((Min/Max)) - 35/45 Deg C
Discharge Pressure- 500 Barg to 550 barg	No of Stages- 2	Motor rate power- 132 KW

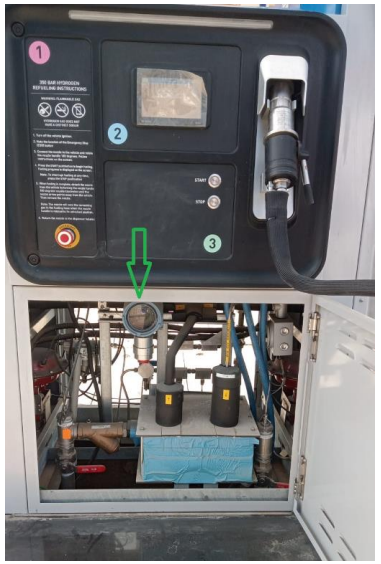
Buffer Vessel make	Nuberg Engineering limited
Designed Capacity	3.1 KL
Design pressure	23.1 Kg/cm2g
Design Code	ASME SEC-VIII, Div-1
MOC	SA 516 Gr 70

Pure hydrogen (99.97%) from Gujarat Refinery shall be routed to high pressure compressors through buffer vessel. At compressors section, hydrogen shall be compressed from 20 Kg/cm2g to 550 Kg/c2g in 2 stages. The buffer vessel has been provided to avoid cavitation in the compressor. Below are the details of the buffer vessel and compressors.

Critical Equipment- Dispenser +Chiller

Dispenser-Hose Breakaway Coupling

The breakaway is **installed between the dispenser and the filling/venting hose**. In the event of accidental deployment, e.g. driving a vehicle from the dispenser with the nozzle remaining in the vehicle fuel port, the coupling will separate the connections between dispenser and hose sealing both ends



Dispenser- Gas Detector (Bottom Cabinet)

2 Gas detectors have been provided inside the Dispenser Cabinet (1 in lower & 1 in upper cabinet). Upon detection of gas leakage, Gas supply to dispenser shall be cut-off

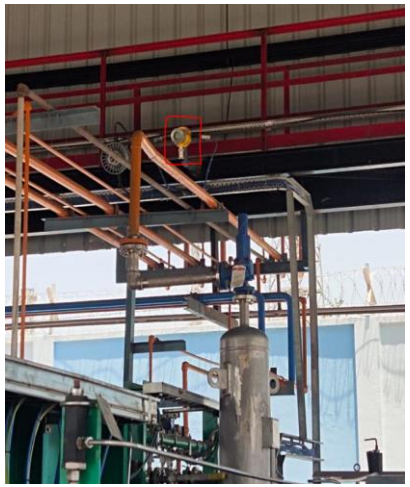
Dispenser- Gas Detector (Top Cabinet)

Dispenser- Chillers installed at Site

To maintain the temp of Hydrogen Gas at dispensing/delivery point, the Hydrogen gas after pressure reduction exchanges heat with coolant inside dispenser. The supply & return of coolant to & from dispenser is governed by 2 number of Chiller units (1 for each dispenser). Any fault detection in chiller will stop the dispenser. Each Chiller unit comprises of a refrigeration system, coolant storage tank (1000L) & pump. Each chiller package is 13 HP stand-alone unit.

Critical Equipment- Hydrogen Gas Detectors

Gas Detector – Compressor A



Gas Detector – Compressor B

Apart from the Gas detectors inside the Dispenser Cabinets (2 GD's in each Dispenser Cabinet), the Dispensing Area is equipped with 6 number of Hydrogen Gas detectors

- **2 installed in Compressor shed (1 for each compressor)**
- **2 installed near Dispensers (1 for each dispenser)**
- **1 installed at High pressure Storage Tubes**
- **1 installed in Tube trailer/ Cascade filling point**

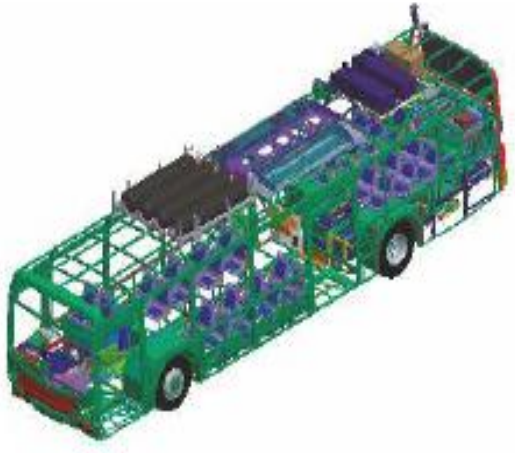
Gas Detector – Dispenser 1

Gas Detector – Dispenser 2

Gas Detector – HP Storage Tubes

Gas Detector – Trailer/Cascade filling

Hydrogen Fuel Cell Bus



The fuel stack is fitted on the rear module of the bus, as shown below:

Technical Specifications

TATA Starbus FUEL CELL

Bus	LPO 1625 Hydrogen Fuel Cell Bus
Seating Capacity	30
Fuel Cell Power System	Hydrogen Fuel Cell
Fuel Cell Gross Peak Power	85 kW
Air Compressor for Fuel Cell	Single Stage Twin Screw Type
Fuel System	Roof-mounted Hydrogen Cylinders; 4 nos. (205 l capacity each)
Total Useful Amount of Fuel	14.5 kg
Electric Propulsion Motor	2 Rear - AC Induction Motors with Summation Gearbox
Peak Power Output of Motor	186 kW
Rated Speed	Idle: 600 r/min; Max.: 2100 r/min
Rated Torque	1050 Nm @ 600 r/min
Energy Storage System	Li - Ion Battery
Steering	Hydraulic Power Steering
Suspension	Pneumatic Suspension & Hydraulic Double Acting Telescopic-type Shock Absorber at Front & Rear
Brakes	Full Air Dual Circuit SCAM with ABS
Tyres	11 R 22.5 Radial Tubeless; 7 nos.
Electrical System	System Voltage - 24 V DC; Battery - 2 x 12 V, 150 Ah; Alternator - 75 A
Max. Speed	70 km/h
Gradeability	17%
Wheelbase	6300 mm
Body Dimensions (LxWxH)	12000 mm x 2600 mm x 3500 mm
Floor Height	390 mm

Basic Safety facilities for Dispensing facility

- **Safety is a significant priority for both people and property.**
- **Product of this plant is Hydrogen, and falls in the Grade A Category in the GB50016-2006 Fire Prevention Code for Building Design.**
- **Hydrogen is colorless, tasteless, inflammable and explosive gas gas under atmospheric pressure and room temperature. Its boiling point is low (-225°C) and it is noncorrosive. Explosive proportion against air is 4.0 - 75.0%. The gas is not for breathing and would thus suffocate in high concentration condition. Its flame point is 570°C.**
- **<u>Following basic safety facilities have been considered in plant design:</u>**
- **In design of automatically controlled instrument system, once the power is cut off, the plant will automatically turn in to safe mode.**
- **Special requirements of Hydrogen contained media transfer have been met in design of process pipelines, valves and fittings.**

Process Alarm Safety

Following alarms are provided in the Hydrogen dispensing system:

HYDROGEN COMPRESSOR SECTION

- **Pressure Indication (PIA-5001) on Buffer Vessel gives alarm, when it becomes High (H) or Low (L).**

HYDROGEN TUBE TRAILER FILLING FACILITY

- **Pressure Indication PIA-2403 in downstream line of Pressure Reducing Valve (PRV-2403) gives alarm, when it becomes High (H)**

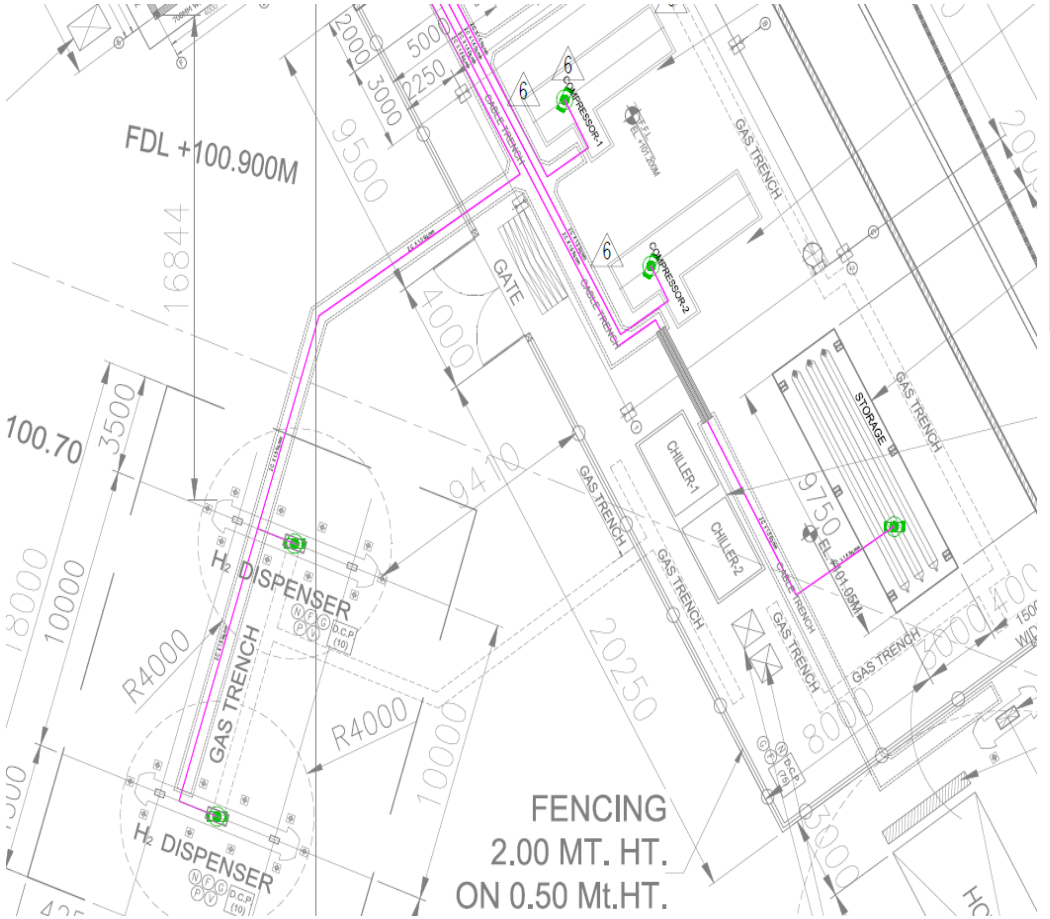
HYDROGEN STORAGE AND DISPENSING STATION

- **Pressure in High Priority storage banks is monitored by Pressure Indicators (PIA-2404) and High (H) / Low (L) alarm is provided at 550 barg / 400 barg**
- **Pressure in Medium Priority storage banks is monitored by Pressure Indicators (PIA-2405) and High (H) / Low (L) alarm is provided at 550 barg / 350 barg**
- **Pressure in Low Priority storage banks is monitored by Pressure Indicators (PIA-2406) and High (H) / Low (L) alarm is provided at 550 barg / 200 barg.**

Gas Detector System

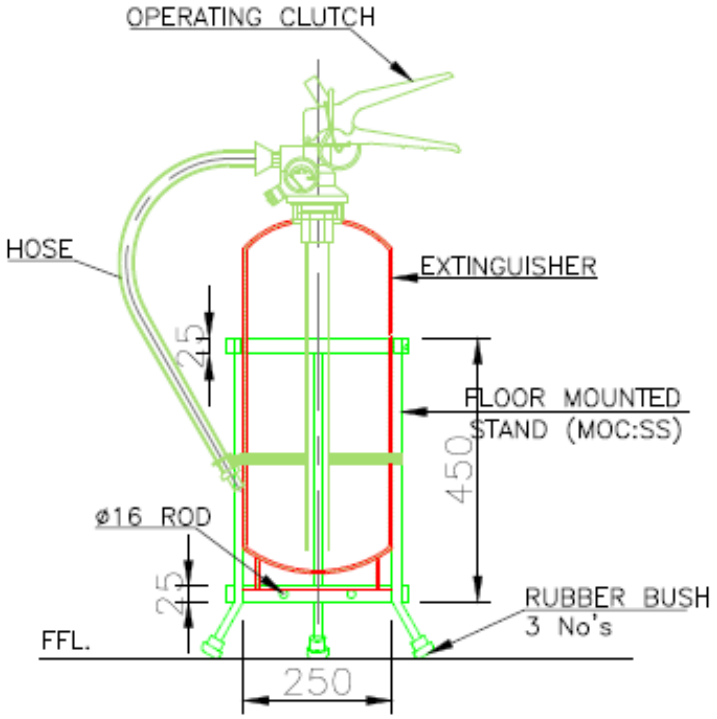
- Hydrogen gas Detector AZ-1002 provided near Hydrogen Compressor K-2200 A
- Hydrogen gas Detector AZ-1003 provided near Hydrogen Compressor K-2200 B
- Hydrogen gas Detector AZ-1004 provided near Tube trailer facility
- Hydrogen gas Detector AZ-1005 provided near Hydrogen Dispensing Unit (D-2400A)
- Hydrogen gas Detector AZ-1006 provided near Hydrogen Dispensing Unit (D-2400A)
- Hydrogen gas Detector AZ-1007 provided near High pressure tubes HT-2301-A/B/C

Gas Detector Layout



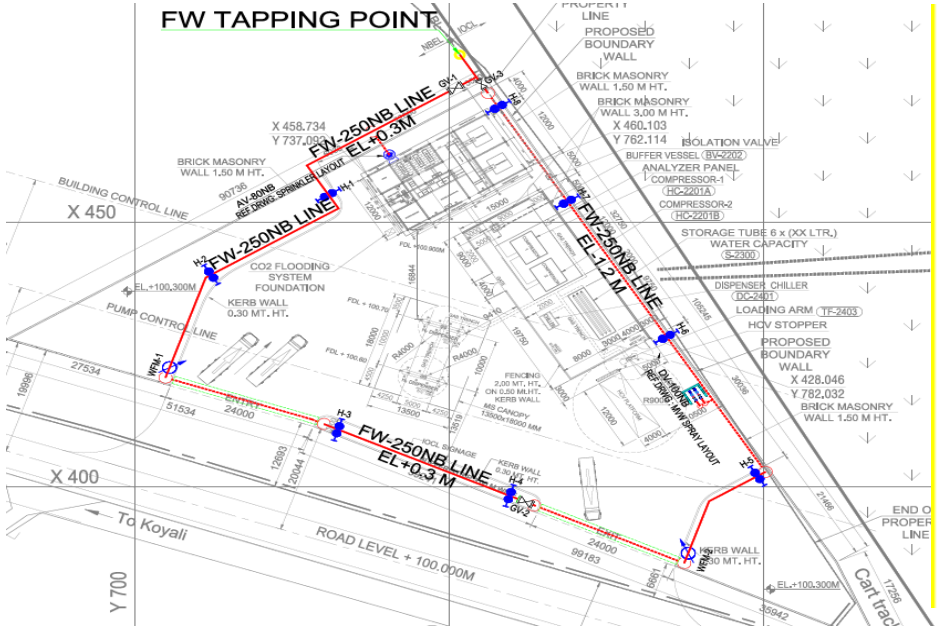
Fire Extinguisher system

SYMBOL	CAPACITY	DESCRIPTION	QUANTITY
	4.5 kg	CARBON DIOXIDE EXTINGUISHER	04 NOS
	22.5 kg	CARBON DIOXIDE EXTINGUISHER	1 NO
	6 kg	DRY CHEMICAL POWDER EXTINGUISHER	08 NOS
	25 Kg	DRY CHEMICAL POWDER EXTINGUISHER	05 NOS
	50 Kg	DRY CHEMICAL POWDER EXTINGUISHER	01 NOS
	@9 Ltrs	SAND BUCKET	02 Set



DETAIL OF FIRE EXTINGUISHER
FLOOR MOUNTED WITH STAND

Fire Fighting system



SYMBOL	ABBREVIATION	DESCRIPTION
	H–X	DOUBLE HEADED FIRE HYDRANT VALVE
	AV–X	ALARM VALVE
	FWM–X	FOAM WATER MONITOR
	GV–X	GATE VALVE
	DV–X	DELUGE VALVE HOUSING
	--	ABOVE GROUND FIRE LINE HEADER
	--	UNDER GROUND FIRE LINE HEADER
	--	HUME PIPE

Following fire fighting equipments /facilities are provided:

- Hydrant: 8 nos.
- Foam Water Monitor: 2.0 Nos.
- Deluge system: 1.0 no.
- Alarm Valve: 1.0 nos.
- MVWS : 2.0 locations (Compressor & Tube)
- Gas flooding : MCC room

PERFORMANCE ANALYSIS:-HDF

HYDROGEN COMPRESSOR SECTION

No. of compressor:	2	
Compressor Tag no	K-2200 A/B	
Type of compressor:	Water Cooled, Reciprocating Diaphragm, Triple Metallic diaphragm	
Make	M/s Sundyne/PPI LLC.	
Capacity, each	35 Kg/Hr	
No of Stages	2	
Performance Parameters	**Design value**	**Actual**
Compressor in operation	Compressor tag	Compressor A &B
Suction Pressure ((Nor/Min/Max)	17.5/16/22 Kg/cm2g	18.5
Suction Temperature ((Min/Max)	35/45 Deg C	36DegC
Discharge Pressure	509.8 - 560.8 kg/cm2g	550 kg/cm2g
Compression Ratio	5.5	5.5
Stage 2 discharge Temperature (Max)	202 Deg C	175 Deg C
Discharge Temperature after cooler	40 + 5 Deg C	43 Deg C

HYDROGEN STORAGE TUBE

Make:	Fiba, USA			
Sr. Nos.	2225, 2202, 2203, 2227, 2226 & 2228			
Capacity of each tube	680.2 Liter			
Total Capacity	4081.2 Liter			
Performance Parameters		Low priority	Medium Priority	High Priority
No. of cylinder/tubes:	6	2	2	2
Design/ Operating Pressure	552 Kg/cm2g	550 Kg/cm2g	550 Kg/cm2g	550 Kg/cm2g

HYDROGEN COMPRESSOR OPERATON

- Compressor start-up and Shutdown happens as per approved PLC logic Sequence.
- Able to achieve desired discharge pressure of 550 Bar from 19 Bar.
- No abnormal sound.
- Vibrations are within design range.
- All parameters like discharge temperature, are within designed operating range.
- No leaks or any process aberrations observed.

PERFORMANCE ANALYSIS:-HDF

HYDROGEN DISPENSING SECTION

Make	M/s Powertech, Canada	
No of Dispenser	2	
Model Number	H-3520-HH-04/H-3520-LH-03	
Compatible Pressure for Nozzles	350 bar	
Pre-Cooling/ Chilling System	Refrigeration System by M/s Keep Rite	
Inlet Pressure of Hydrogen from Storage System	550 bar g	
Temperature of Hydrogen from Storage Section	50°C	
Total Number of Nozzles	4 (2 nozzles on each dispenser)	
Heavy Duty Vehicle Nozzle	3 no.	
Performance Parameters	Design	Actual
Maximum Dispensing Pressure	350 bars	350 bars
Flow rate	3.6 kg/min	3.6 kg/min
Total Duration of filling including automatic leak test	8 -10 min (approx.)	
Hydrogen filled	20-22.2 Kgs	

HYDROGEN DISPENSING OPERATION

- Continuous trial and filling of buses is going on since 23.12.2022 as and total 25 nos. of FCEV Bus Fuelling operations were carried out till March 2023 Successfully.
- Operation of dispenser was done through HMI Interface and performance was found satisfactory.
- After completion of the dispensing, a summary report was displayed at the dispenser screen, showing total mass dispensed, final pressure at vehicle.
- Alarms or tripping if any, displayed at dispenser screen and upon rectification or acknowledge, the system enables dispensing.
- Hydrogen dispensing was done without any interruption.
- No leakages has occurred during dispensing operation since commissioning.

FINAL THOUGHTS

- **The development of a hydrogen regulatory framework in India will be a complex process, involving many different industry stakeholders and international counterparts. It is promising therefore that each of the state Governments appear to be collaborating with one another and liaising with a vast range of industry stakeholders to develop uniform laws concerning hydrogen across the country.**
- **This will be an interesting space to watch within the coming years.**
- **The promotion of hydrogen use is expected to become an important part of achieving a carbon neutral society. In order to promote the development of various infrastructures necessary as preconditions for such a change, clarification and rationalization of the relevant laws and regulations will be important, in addition to technological innovation.**

Thank You