[Open]

FIRE SAFETY SYSTEMS GUIDELINE FOR

HYDROGEN REFUELLING STATION

[Open]

COMMITTEE REPRESENTATION

ADVISORY

Jabatan Bomba dan Penyelamat Malaysia

Dato' Ir. Ts. Ahmad Izram Bin Osman
Datu Khirudin Bin Drahman @ Hussain

COMMITTEE MEMBERS

Jabatan Bomba dan Penyelamat Malaysia

Dr. Ts. Mohd Zaid Bin Abd Ghani
Muhamad Zahin Bin Ishak
Mohd Fazwan Bin Mohd Nawi
Mohd Tauffieq Bin Mohd Shari
Amiruddin Shukri Bin Omar

Petroliam Nasional Berhad (PETRONAS)

Kairul Zaman Bin Mohamed Noh
M Shaik Fareed Bin M Naja Buddin
M Rosli Bin Abu Seman
Abd Ghani Kumar Bin Abd Aziz Ramasamy
Humaidah Khalidah Binti Wahid
M Firdhaus Bin Abd Razak

FOREWORD

Malaysia' Government states that the National Energy Transition Roadmap (NETR) ambition to achieve 70% Renewable Energy (RE) share of installed capacity by 2050. Hydrogen energy has become one of the potential substitutes for the conventional oil and gas sector. Hydrogen research and development in Malaysia has long been started since 2001, however rapid hydrogen production development was set back in 2023 in pursuant to Malaysia's Hydrogen Economy and Technology Roadmap establishment.

As Malaysia embark on a journey towards a greener, more sustainable future, hydrogen refuelling stations play a pivotal role in enabling the widespread adoption of hydrogen fuel cell vehicles. Hydrogen refuelling stations have become increasingly integrated into our infrastructure which presents new challenges for firefighters and fire safety protocols. While hydrogen fuel offers numerous environmental and economic benefits, they also introduce unique considerations for firefighting operations, ranging from fire and explosion hazards to structural integrity concerns.

Fire Safety System Guidelines for Hydrogen Refuelling Station provides the guidance and good practices on options that are appropriate to be implemented in order to satisfy risk drivers such as safety, environmental protection, asset protection, reputation, and business continuity. This document covers for hydrogen refuelling station including elements in designing and implementing fire risk reduction measures from prevention through engineering and design of the facility, operation safety, detection, and protection systems to reduce the risk from potential hazards.

The guidance in this document should assist process safety engineers, fire safety engineers, safety advisors, fire safety consultants, designers and JBPM officers, emergency planners or others with responsibility for fire hazards management to meet the pertinent requirements which includes design concepts, design codes and standards, diagrams, and illustrations for better understanding. This will be used as a basis for establishing a consistent and optimum fire hazards policy for players in the hydrogen industries.

This document was prepared by the Working Group formed to collaborate in strengthening the standard of fire safety for the operation of hydrogen refuelling station in Malaysia.

The information and requirement stipulated in this document is implied for minimum requirement for HRS design.

Whilst the Working Group have applied reasonable care in developing this guideline, no representations or warranties, express or implied are made by the Working Group concerning the applicability, suitability accuracy or completeness of the information contained herein, and the Working Group shall not be liable in any way for any liability, loss, cost or damage incurred as a result of the receipt or use of the information contained herein.

Based on changing trends, technology and knowledge development in fire safety, this guideline may be further reviewed from time to time to charter new knowledge and development in hydrogen technology and industry best practices.

Director General
Jabatan Bomba dan Penyelamat Malaysia
Malaysia

TABLE OF CONTENT

1. INTRODUCTION

Hydrogen energy has become one of the potential substitutes for the conventional oil and gas sector. Hydrogen research and development in Malaysia started in 2001. However, hydrogen production development was kickstarted in 2023 in pursuant to Malaysia's Hydrogen Economy and Technology Roadmap establishment. Despite huge potential of hydrogen in Malaysia, challenges remain when it comes to safety aspect regarding hydrogen production, storage, and utilisation. To date, there is no fire safety guideline established in Malaysia for safe hydrogen operation.

In response to this gap, this document has been crafted to provide comprehensive guidelines and reference pertaining to fire safety requirements for Hydrogen Refuelling Station (HRS) in Malaysia. It encompasses all pertinent aspects, including applicable codes and standards, hazards identification and risk assessment, fire prevention and protection management as well as people.

1.1 Objectives

This document is developed as a technical guidance to ensure:

i. Adequacy of fire prevention and protection design for Hydrogen Refuelling Station (HRS) facilities in Malaysia
ii. Compliance with Regulatory, Codes and Standards

1.2 Terms and Definitions

CAS	Chemical Abstracts Service
CGA	Compressed Gas Association
CHSV	Compressed Hydrogen Service Vehicle
ERP	Emergency Response Plan
ESS	Emergency Shutdown System
GH_2	Gaseous hydrogen
H-Code	Hazard statements code
Hazard Identification	Identification of the possible hazards and their sources which may result in a fire risk resulted from the proposed project storage, processes, and production.

HRS	Hydrogen Refuelling System
ICOP	Industry Code of Practice
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
JBPM	Jabatan Bomba & Penyelamat Malaysia.
LH_2	Liquified Hydrogen gas
LFL	Lower Flammability Limit
LOPC	Loss of Primary Containment
LPS	Low Pressure Storage
NFPA	National Fire Protection Association
SMR	Steam Methane Reforming
UBBL	Uniform Building By-Laws
UFL	Upper Flammability Limit

2. OVERVIEW OF HYDROGEN REFUELLING STATION

Hydrogen gas can be generated on-site via electrolysis or delivered through tube trailers and metal hydride storage trailers. A typical Hydrogen Refuelling Station which an integration of On-site Hydrogen Generators, Hydrogen Gas Supply via trailers and Hydrogen Dispensing facilities is illustrated in Figure 2.1 and 2.2 accordingly below.

2.1 Hydrogen Gas Supply via On-Site Hydrogen Generator

On-site hydrogen production is typically established through the water electrolysis process. The equipment required for the process, including the cell(s), electrical, gas processing, ventilation, cooling, monitoring equipment, and controls.

Hydrogen generators consist of the following process/ facilities:

i. Water Purification
ii. Electrolysis
iii. Hydrogen (H_2) and Oxygen (O_2) Separation
iv. Low Pressure Storage (LPS)
v. Compression (if required)
vi. High Pressure Storage (if required)
vii. Utilities and Offsite Facilities

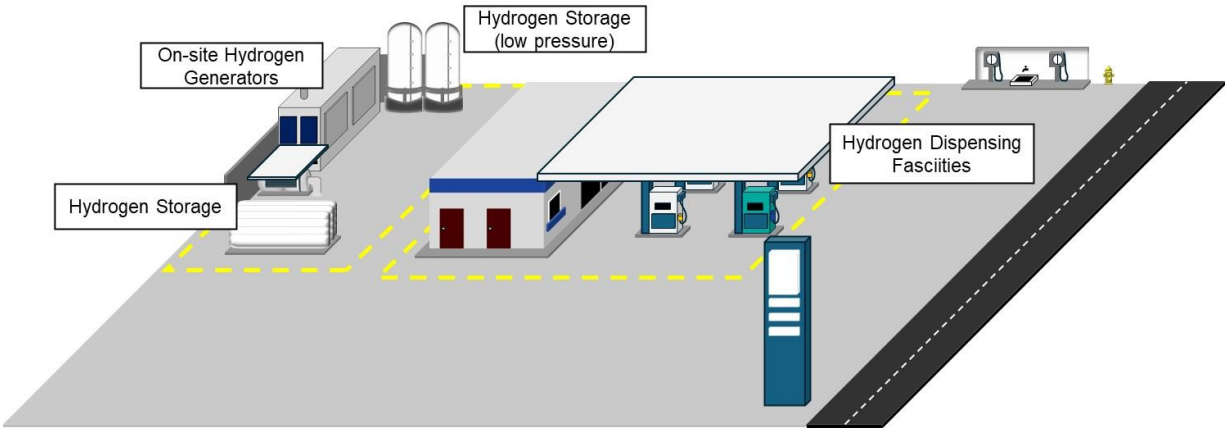

Figure 2. 1 Typical arrangement of On-site Hydrogen Generator with Hydrogen Dispensing Facilities

2.2 Hydrogen Gas Supply via Trailers

If not produced on-site, hydrogen gas can be supplied to the HRS externally via tube trailers and metal hydride storage trailers in the form of compressed gaseous. Trailers can either deliver to on-site hydrogen storage vessels at the refuelling station site or remain at the site and be replaced when the inventory of the hydrogen product in the trailer is low.

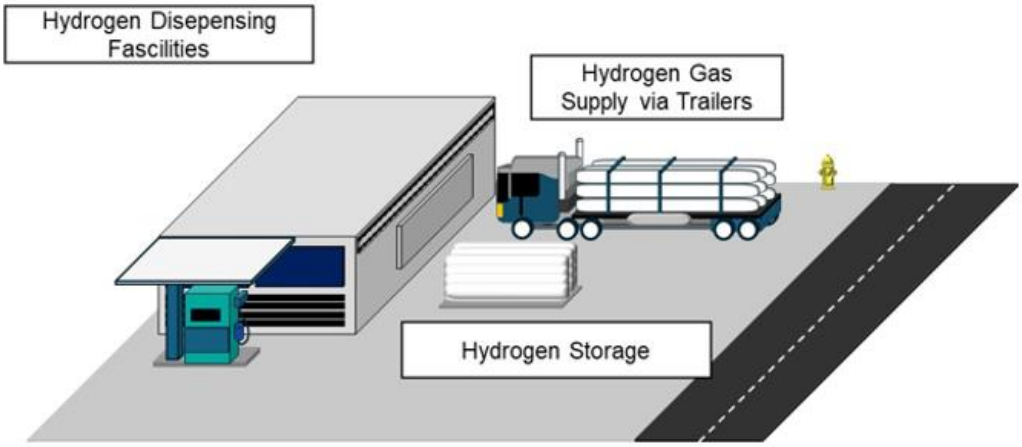

Figure 2. 2 Typical arrangements of Hydrogen Gas Supply via Trailer with Hydrogen Dispensing Facilities

2.3 Hydrogen Dispensing Facilities

Hydrogen gas dispensing facilities may receive gaseous hydrogen supplied by on-site hydrogen generators or via trailers. These Facilities consist of following main equipment:

i. Low Pressure Hydrogen gas storage
ii. Compressors
iii. High Pressure Hydrogen gas storage
iv. Chilling system
v. Dispenser

The low-pressure gaseous hydrogen supply is compressed and stored at pressures above the maximum vehicle pressure (either 350 or 700 bar). When a vehicle arrives to be filled, this high-pressure hydrogen gas flows into the vehicle through a dispenser. To ensure safety and efficiency, a chiller is typically used to pre-chill the high-pressure gas before it is dispensed into the vehicle. The typical arrangement for Hydrogen Dispensing Facilities can be referred to Figure 2.1 and 2.2 above accordingly.

3. SCOPE

This document provides technical guidance on the requirement of fire safety systems for the following:

i. On-site hydrogen generators
ii. Hydrogen dispensing facilities
iii. Hydrogen gas supply via trailers

The following process or systems are not covered under this guideline:

i. Liquified hydrogen gas system (LH_2)
ii. Vehicle/ truck refuelling receptacle
iii. Other type of hydrogen generation e.g. SMR, ammonia
iv. Hydrogen gas supply transportation e.g. tube trailers, tankers

4. REGULATORY COMPLIANCE

4.1 Applicable Regulatory requirements, Codes and Standards

4.1.1 Applicable Malaysian Laws and Regulations:

i. Akta Perkhidmatan BOMBA 1988 (Akta 341)
ii. Uniform Building By-Law (UBBL)1984
iii. Sarawak Building Ordinance 1994
iv. Occupational Safety and Health Act 1994 (Act 514)
v. Other Regulations approved by JBPM.

4.1.2 Other recognized Codes and Standard applicable for Hydrogen production and dispensing facilities:

i. NFPA 2 Hydrogen Technologies Code
ii. NFPA 55 Compressed Gases and Cryogenic Fluids Code
iii. ISO 22734 Hydrogen generators using water electrolysis — industrial, commercial, and residential applications.
iv. ISO 19880-1 Gaseous hydrogen – Fuelling Stations
v. ISO/ Technical Report 15916 Basic Considerations for the Safety of Hydrogen Systems
vi. CGA G-5.5 Hydrogen Vent Systems
vii. IEC 60079-10-1, Explosive atmospheres- Part 10.1: Classification of areas - Explosive gas atmospheres
viii. MS 2558:2022 – Safety and health signage used in the workplace – Specification
ix. SAE J2600, SAE J2601, SAE J2601-2, SAE J 2799

4.1.3 Other acceptable Codes and Standard.

Project team comprises of Submitting Person, Manufacturer, Owner and PMT are advised to present Project Brief and justification to obtain JBPM feedback and direction on the fire protection and prevention system requirement.

5. HYDROGEN HAZARDS

5.1 Hydrogen Properties

Hydrogen Properties and ICOP classification are summarized in Table 5.1 and Table 5.2 below.

Table 5. 1 Hydrogen Properties

Property	Criteria
General characteristic	• Colourless, odourless and tasteless gas • Non-toxic • Non-corrosive • Does not support life (asphyxiant)
Density	0.0838 kg/m^3 *Note:* *1. 14 times lighter than air* *2. Rises quickly under atmospheric conditions*
Specific Gravity	0.0696 *Note:* *1. Air Specific Gravity is 1.0*
Autoignition Temperature	585 °C
Flammable Range	LFL: 4%; UFL: 75%
Minimum Ignition Energy	0.02 mJ *Note:* *1. Minimum ignition energy in air (one of the lowest among substances)*
Size/Diffusivity	1.697 m^2/hour *Note:* *1. 4x smaller than Natural Gas* *2. Diffuses through many "gas tight" or "impermeable" materials.* *3. Smallest molecule*

Table 5.2 Hydrogen ICOP Classification (1)

CAS No	Classification		Labelling		
	Classification Code	H-Code	Signal Word	H-Code	Hazard Pictogram
1333-74-0	Flam. Gas 1 Press. Gas	H220 H280/281	Danger	H220 H280/281	

(1) Industry Code of Practice on Chemical Classification and Hazard Communication (Amendment) 2019

5.2 Risk Management

Appropriate hazard identification and risk assessment shall be conducted to evaluate design of HRS and adequacy of barriers, in accordance with Codes and Standard in Section 4 e.g. ISO 19880, NFPA 2.

A risk assessment shall be performed for the hydrogen fuelling station except when the stations comply with prescriptive regulations that address relevant risks.

Table 5.3 below tabulated the typical hazards associated to component of a HRS facilities, as a reference during hazard identification and risk assessment exercise.

Table 5. 3 Typical Hazards and Operating Parameters for Each Component in HRS

Components	Example of Hazards	Example Operating Parameters (System Pressure/ Temperature)
On-site hydrogen generator	• hydrogen gas • oxygen gas • high pressure/ temperature • flammable mixture in enclosures	Up to 25 MPA/ −18 °C to +40 °C
Hydrogen delivery via trailers including mobile storage and remote fill points	• flammable mixture in atmosphere	Up to 25 MPa/ −18 °C to +40 °C
Low pressure storage	• High pressure/ temperature • flammable mixture in atmosphere/ enclosure	Up to 25 MPa/ −18 °C to +40 °C
Compressors	• High pressure/ temperature • flammable mixture in atmosphere/ enclosure	Up to 97.5 MPa/ −18 °C to +40 °C
High Pressure Storage	• High pressure/ temperature • flammable mixture in atmosphere/ enclosure	Up to 97.5 MPa/ −18 °C to +40 °C
Pre-cooling	• High pressure/ temperature • flammable mixture in atmosphere/ enclosure	Up to 97.5 MPa/ −18 °C to +40 °C
Dispensers	• High pressure/ temperature • flammable mixture in atmosphere	Up to 97.5 MPa/ −18 °C to +40 °C

6. FIRE PREVENTION MANAGEMENT

By addressing fire prevention requirements during the design phase, hydrogen refuelling facilities can minimize the risk of fire incidents and ensure the safety of personnel, vehicles, and surrounding properties. This section describes some of the fire prevention features to be considered in the design.

6.1 Fire Prevention Measure

6.1.1 Fire prevention measures shall form an integral part of the design, engineering, and construction of the HRS.

6.1.2 **Separation distance** requirement shall be in accordance with the applicable Codes and Standards e.g. NFPA 2 and ISO 19880 for the types of hydrogen storage handled by the facility. Adequate separation distance shall be provided to minimize the impact of fire or an explosion to the surrounding facilities which can cause escalation and harm to public.

6.1.3 **Ignition Control** – Equipment shall be classified in accordance with IEC 60079-10-1. An average hydrogen gas concentration in enclosed areas within the enclosure shall be maintained below the LFL level of hydrogen. Design requirements for hydrogen refueling stations involve implementing measures to prevent the accidental ignition of highly flammable hydrogen gas. This includes selecting equipment and materials that minimize the risk of electric sparking or heat generation, selection of explosion-proof electrical equipment, ensuring proper ventilation to disperse hydrogen leaks, and implementing safety protocols such as bonding and grounding to prevent static electricity buildup. According to NFPA 2, paved surfaces should have a resistance of 1 megohm or less to allow static charge to safely dissipate, preventing buildup before refuelling begins.

6.1.4 **Emergency Shutdown System (ESS).** The main approach to extinguish hydrogen fire is through isolation and pressurization. ESS play an important role in preventing fire hazards for hydrogen facilities. The ESS shall operate upon activation of a manual or automatic emergency shutdown device (ESD). The detailed requirement of ESS shall be in accordance to Codes and Standards at section 4.0 e.g. ISO 19880, NFPA 2.

6.1.5 **Means for emergency venting of hydrogen storage vessel.** Relief of hydrogen from depressurization system shall be routed to a safe location. Means to extinguish vent fire and flash back into the system may be provided.

6.1.6 **Pressure Relief Device** - All pressurized systems and equipment shall be protected from overpressure by means of one or more pressure relief devices (PRD) or pressure safety system. Hydrogen vents shall be designed in accordance with the Codes and Standards at section 4 e.g. ISO 19880, NFPA 2.

6.1.7 **Isolation or shut-off valve** shall be provided for equipment and systems where the isolation of process flow is necessary during emergency

conditions. Requirement for the isolation valve shall be in accordance with the Codes and Standards in Section 4 e.g ISO 19880, NFPA 2.

6.1.8 **Ventilation of enclosures or buildings** containing hydrogen equipment (with hydrogen concentrations at or below 25% of the Lower Flammable Limit) shall be achieved either through natural ventilation or mechanical ventilation e.g. blower, extractor as per Codes and Standards in Section 4 e.g ISO 19880, NFPA 2.

6.1.9 **Oxygen Venting for On-site Hydrogen Generator** - Oxygen can be vented either indoors or outdoors of the enclosure. If oxygen is vented outdoors, it should be done in a way that does not create a hazardous condition i.e. vented at a safe location. If it is vented indoors, the enclosure should be diluted by a ventilation air stream to a volume fraction of oxygen less than 23.5% before being exhausted from the enclosure. The design of Oxygen venting shall be in accordance with ISO 22734.

7. FIRE PROTECTION MANAGEMENT

7.1 Passive Fire Protection

7.1.1 Passive fire protection prevents spread of fire and protect structure integrity. Consideration shall be given on passive fire protection to protect critical structures, equipment, and people against direct fire impact.

i. Fire wall shall be provided at strategic location at the hydrogen generation and storage area to prevent direct impact to the surrounding such as dispensing unit and public area. The requirement of fire wall can be further justified through consequence modeling or Fire and Explosion Risk Assessment (FERA) in accordance with the Codes and Standards in Section 4 e.g. ISO 19880

Note:

- Based on industrial practices, emergency procedures/mitigation are focused on isolation of hydrogen release through emergency shutdown system.
- The likelihood of emergencies come from tubing & piping leak and are unlikely for tank incident.

7.2 Active Fire Protection

7.2.1 Design, siting and installation requirements for applicable active fire protection for HRS e.g. fire hydrant and portable fire extinguisher (ABC type) shall be in accordance with MS1489 and MS1539 as shown in **Appendix 1**. Fire protection for building shall comply with UBBL requirement.

7.2.2 **Detection**. A leak detection system shall be provided and shall cause the hydrogen generator to alarm where possible and, where possible, change the operating parameters to minimize the inventory of release.

The hydrogen fire and gas detector(s) shall be installed at optimum location(s) e.g. hydrogen generator enclosure, compressor skid, etc to provide the earliest detection of presence of hydrogen gas and fire.

The alarm set points are:

- A lower activation limit set at maximum value of 10% of the LFL (0.4% by volume) for a High-level alarm.
- A higher activation limit, set at maximum value of 25% of the LFL (1.0% by volume) for a High-High level alarm, indicating a more urgent danger.

The 25% LFL threshold is a precaution, as hydrogen levels at this point pose a high risk of becoming flammable if they continue to rise.

7.2.3 **Communication and alarm system** should be installed at appropriate location(s) in accordance with the Codes and Standards at Section 4 with distinctive audible and/or visual to give notification as to the status of the facilities and emergency responses.

8. PEOPLE SAFETY MANAGEMENT

8.1 Safety Precautions and Considerations

This section describes the safety precautions and considerations to ensure the safe operation of the HRS facility as well as timely and effective response during emergency.

8.1.1 Emergency Response Plan

Dedicated Emergency Response Plan (ERP) shall be established and shall be readily available to operations personnel. The ERP shall include the information below in accordance with the Codes and Standards in Section 4.

i. Type of Emergency Scenario
ii. Type of emergency equipment available and its location
iii. A brief description of any testing or maintenance
iv. Maintenance programs for the available emergency equipment
v. An indication that hazard identification labelling is provided for each storage area.
vi. A safety data sheet (SDS) or equivalent for stored or used on the site.
vii. Site emergency response team
viii. List of emergency contacts, emergency services and phone numbers
ix. Emergency chain of command
x. Duty list
xi. Site plan and equipment operating manuals

8.1.2 Escape Route and Muster Area

Escape route for the HRS facility shall be designed in accordance with UBBL requirements.

Safe area shall be identified and located outside of hazardous areas i.e. fire exposure, and provide adequate occupancy requirements, such as accessibility and space of the facility.

Suitable roadways or other means of access for emergency equipment, such as fire department apparatus shall be provided in accordance with UBBL 1984.

8.1.3 Safety Signage

Safety signages shall be provided for HRS facilities in accordance with MS 2558, NFPA 55, NFPA 2, ISO 3864-1, and ANSI Z535.1 including the shapes, colour, size and position of the signage. The safety signages are used for warning against hazards, and for providing safety-related information. Table 8.1 below shows examples of Safety Signage that can be used for HRS facility.

Table 8. 1 Example of Safety Signage

Example of safety signs from MS 2558	Description
	• No open flame. • Fire • Open ignition source and smoking prohibited
	• Personal protective equipment required. • Keep Well Ventilated
	• Warning: Explosive • Hydrogen Flammable Gas
	• Fire Exit • Assembly Area
	• Firefighting equipment • Fire extinguisher • Fire alarm call point

8.1.4 Ignition Control

The facility must be designed, constructed, and maintained in a way that prevents unintended explosions and fires that could damage adjacent compartments, emergency life safety systems, adjacent properties, adjacent outside storage, and the facility's structural elements. Additionally, operations associated with the facility must also be conducted in a way that prevents such incidents.

This can be achieved through the prevention of ignition. Potential ignition sources are:

i. Mechanical Electrical Sparks
ii. Hot Surfaces, flames
iii. Frictional Heating
iv. Adiabatic Compression and Shock Wave
v. Electrical Equipment, especially non-flameproof motors
vi. Static Electricity
vii. Radio Waves

These ignition sources shall be identified and prohibited from being located within the refuelling area. Ignition control for HRS facilities shall in accordance with the applicable standards.

8.1.5 Vehicular Impact Protection Measures

The site layout and the selection for the vehicular impact protection shall be taken into account as part of the Hydrogen Refuelling facility. The protection measures shall be in accordance with ISO19880 in preventing vehicular from potentially colliding into the dispenser at the HRS facility.

8.1.6 Operation Procedures

Operating procedures shall be developed for managing the HRS facilities. As a minimum, the following procedure shall be developed and trained to the operator:

i. Start Up and Shutdown Procedure
ii. Normal Operating Procedure
iii. Emergency/ Abnormal Procedure

8.2 Hydrogen Fuelling Protocol

Hydrogen dispensing protocol and process limit for gaseous hydrogen dispensers intended to fuel light-duty and heavy-duty hydrogen motor vehicles shall be in accordance with the acceptable standard for safe dispensing protocol of hydrogen powered vehicles e.g. SAE J2600, SAE J2601, SAE J2601-2, SAE J 2799.

The manufacturer shall ensure that the pressure drop between the dispenser fuel pressure sensor, which monitors vehicle pressure, and the nozzle stays within the limits defined in the fuelling protocol during hydrogen flow, as outlined in ISO 19880-1:2020. The system must detect potentially hazardous leaks, such as hose failures, and limit the volume of leaked flammable gas. Possible methods for detecting leaks include:

- Detecting low dispenser fuel pressure and triggering an emergency shutdown
- Identifying an unexpected drop in fuel pressure and activating the shutdown.
- Detecting a higher-than-expected flow and initiating the emergency shutdown.

8.3 Inspection, Testing and Maintenance

Inspection, testing and maintenance program shall be established to ensure integrity of HRS facilities. The program shall focus on safety critical equipment such as safety interlock system, pressure safety valves, high pressure piping and vessel containing hydrogen, fire detection and protection system, etc.

Procedures shall be established for the expected service and maintenance activities. These procedures shall address proper isolation of the system, worker safety, measures required during the maintenance or service activity, and steps required to return the system to operation. The procedures are meant to prevent contamination or air ingestion into the dispensing system.

Frequency of the periodic inspection, testing and maintenance shall be established in accordance with Codes and Standard in Section 4 e.g. ISO 19880 and comply with recommendation from manufacturer.

Appendix 1 Active fire protection for Hydrogen Refuelling Station facilities.

Facility	Components	Type of Firefighting	
		Fire Extinguisher (ABC Type)	Hydrant
Hydrogen Onsite Generator and Dispensing Facilities	On-site hydrogen generator	X	X Note 1
	Hydrogen mobile storage and fill points	X	
	Low/ High pressure storage	X	
	Compressors	X	
	Dispensers	X	

Note 1: Hydrant provided for overall fire protection coverage to Hydrogen Refuelling Station facilities.

(This Page Intentionally Left Blank)