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Description:	Describes the fire protection and fire and gas detection philosophy and guidelines to be implemented to ensure life, health, and safety, and to protect the environment and assets during operations. Complies with the California Fire Code and provides guidelines for fire prevention, active fire protection and fire and gas detection and alarm systems and personnel safety measures.
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Appendix P

Fire Protection Philosophy

INTERSECT POWER RENEWABLE ENERGY HOLDINGS

Fire Protection Philosophy

IP Darden Facility

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PROJECT 418123-47718 - Fire Protection Philosophy - IP Darden Facility

Rev	Description	Originator	Reviewer	Worley Approver	Revision Date	Customer Approver	Approval Date
Rev A	Issued for Information	N. Compton	E. Tahouri	J.Scherrer	11 October 2023		Approval Date

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1. Introduction

This document is developed to define the fire protection and fire and gas detection philosophy of the Darden Hydrogen project. This document describes the fire protection and fire and gas detection philosophy and guidelines to be implemented to ensure life, health, and safety, and to protect the environment and the Company's assets during operations.

This philosophy provides guidelines for fire prevention, active fire protection and fire and gas detection and alarm systems and personnel safety measures.

The Fire Protection Philosophy should comply with the requirements of the California Fire Code and applicable referenced codes and standards. As more information becomes available for the facility, the philosophy should be further developed in the next phase of the project.

1.1 Project Overview

IP Darden I, LLC and Affiliates, subsidiaries of Intersect Power, LLC, proposes to construct, operate, and eventually repower or decommission the Darden Clean Energy Project (Project) in western Fresno County.

The Project consists of a 1,150 megawatt (MW) solar photovoltaic (PV) facility, a 4,600 megawatt-hour battery energy storage system (BESS), an up-to 1,200 MW green hydrogen generator configured as three (3) independent trains, a 34.5-500 kilovolt (kV) grid step-up substation, a 10- to 15-mile 500 kV generation intertie (gen-tie) line, a 500 kV utility switching station along the Pacific Gas and Electric Company (PG&E or Utility) Los Banos- Midway #2 500 kV transmission line, and appurtenances.

1.2 Objective

This fire protection philosophy provides the basis for design of active fire protection systems (AFP), fire and gas detection (F&G) and alarm systems, and personnel safety measures for the Darden Hydrogen Project.

The objectives of this philosophy are listed as follows to ensure:

- Protection of life, health, and safety of personnel from potential consequences of any loss of containment
- Protection and mitigation of potential property loss and environmental impacts.

This philosophy should be used to develop the Project Emergency Response Plan to ensure best practices for operators and emergency response team are in place.

1.3 Scope

The scope of this philosophy is intended to include fire protection requirements for the Darden Hydrogen Project, including but not limited to:

- Fire Prevention
- Active Fire Protection/Suppression
- Fire and Gas Detection and Alarm System
- Personal Protection

1.4 Definitions

Active Fire Protection (AFP): A group of systems that require some amount of action or motion in order to work efficiently in the event of a fire.

Class A Fire: A fire of ordinary combustible materials, such as wood, cloth, paper, rubber, and many plastics.

Class B Fire: A fire of flammable liquids, combustible liquids, petroleum greases, tars, oils, oil-based paints, solvents, lacquers, alcohols, and flammable gases, (e.g., Hydrogen fire).

Class C Fire: A fire that involves energized electrical equipment.

Combustible Liquid: A liquid having a flash point at or above 100 °F (37.8°C). Combustible liquids are subdivided as follows:

- Class II liquids are those having flash points at or above 100 °F (37.8°C) and below 140 °F (60°C);
- Class III-A liquids are those having flash points at or above 140 °F (60°C) and below 200 °F (93.3°C); and
- Class III-B liquids are those having flash points at or above 200 °F (93.3°C).

Consequence: An outcome from an incident which may occur immediately or over an extended period. The consequence could include impacts/effects on people, assets, environment, property, or a combination of these. There could be several incidents leading to one single consequence or one incident causing multiple consequences.

Critical Equipment: Equipment is considered critical when the loss of the equipment shall result in significant capital and/or business interruption cost.

Electrical Area Classification: Classification of locations within a facility for the selection and installation of electrical equipment.

Fire Zone: A physical area by which the plant is segregated into individual areas for the purpose of fire protection to ensure impacts of fire from one fire zone would not impact any adjacent zones.

Flammable Liquid: Per NFPA 30, a liquid having a flash point below 100°F (37.8°C) and having a vapour pressure not exceeding 40 psia (276 kPa) at 100°F (37.8°C). Flammable liquids are classified as Class I liquids and are subdivided as follows:

- Class I-A liquids include those having a flash point below 73°F (22.8°C) and having a boiling point below 37.8°C.
- Class I-B liquids include those having a flash point below 22.8°C and having a boiling point at or above 37.8°C.

- Class I-C liquids include those having a flash point at or above 22.8°C and below 37.8°C.

Flash Point: The minimum temperature at which a liquid gives off vapours in sufficient concentration to form an ignitable mixture with air near the surface of the liquid within the vessel as specified by appropriate test procedures.

Foam Concentrate: A concentrated liquid foaming agent as received from the manufacturer.

Hazard: The potential to cause harm including adverse health effects or injury; damage to property, plant products, or the environment; production losses or increased liabilities.

High Fire Potential Equipment: Process equipment which contains flammable liquids or combustible liquids heated above their flash points, which are subject to leakage due to the presence of seals, gauge glasses, moving parts, etc. Equipment is not considered to be high fire potential if it is remote from other process equipment and ignition sources. Examples of high fire potential equipment are pumps, compressors, fired heaters, vessels, and exchangers.

Jet Fire: The combustion of material emerging with significant momentum from an orifice.

Pool Fire: The combustion of material evaporating from a layer of liquid at the base of the fire. Pool fires may occur after the ignition of a spreading or shrinking liquid pool.

1.5 Acronyms

Acronyms	Definitions
AFP	Active Fire Protection
API	American Petroleum Institute
BOP	Balance of Plant
EIV	Emergency Isolation Valve
ERT	Emergency Response Team
ESD	Emergency Shut Down
F&G	Fire and Gas
FZ	Fire Zone
HDPE	High Density Polyethylene
IP	Intersect Power
IR	Infrared
LEL (LFL)	Lower Explosive Limit (Lower Flammability Limit)
PHA	Process Hazard Analysis
PIV	Post Indicator Valve
PPE	Personal Protective Equipment
UV	Ultraviolet

2. Applicable Standards and Publications

All fire protection and equipment shall comply with the applicable standards and publications listed in this section. If an applicable standard or publication is revised and re-issued during the execution of the project this should be brought to the attention of the Customer. The Customer will determine which revision shall apply.

The applicable regulation, government acts, national/ international and industry standards and publications include:

Table 2 1: Applicable Acts, Regulation and Standards

Number	Title
ANSI ISEA Z358.1	American National Standards Institute Emergency Eyewash and Shower Standard
API RP 500	Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1, and Division 2
API RP 521	Guide for Pressure-Relieving and De-pressuring Systems
API RP 2001	Fire Protection in Refineries
API RP 2218	Fireproofing Practices in Petroleum and Petrochemical Product Processing Plants
API RP 2030	Application of Fixed Water Spray Systems for Fire Protection in the Petroleum and Petrochemical Industries
NFPA 2	Hydrogen Technologies Code, 2020 Edition
NFPA 10	Standard for Portable Fire Extinguishers, 2022 Edition
NFPA 11	Standard for Low, Medium and High Expansion Foam, 2005 Edition
NFPA 13	Standard for the Installation of Sprinkler Systems, 2022 Edition
NFPA 14	Standard for the Installation of Standpipe and Hose Systems, 2019 Edition
NFPA 15	Standard for the Installation of Water Spray Fixed Systems for Fire Protection, 2022 Edition
NFPA 16	Standard for the Installation of Foam Water Sprinkler and Foam Water Spray Systems, 2019 Edition
NFPA 20	Standard for the Installation of Stationary Pumps for Fire Protection, 2022 Edition
NFPA 22	Standard for Water Tanks for Private Fire Protection, 2023 Edition
NFPA 24	Standard for the Installation of Private Fire Service Mains and their Appurtenances, 2022 Edition
NFPA 30	Flammable and Combustible Liquids Code, 2021 Edition
NFPA 45	Standard on Fire Protection for Laboratories Using Chemicals, 2019 Edition
NFPA 55	Compressed Gases and Cryogenic Fluids Code, 2023 Edition
NFPA 72	National Fire Alarm and Signaling Standard, 2022 Edition
NFPA 101	Life Safety Code®, 2021 Edition
NFPA 101A	Guide on Alternative Approaches to Life Safety, 2022 Edition

Number	Title
NFPA 600	Standard on Industrial Fire Brigades, 2020 Edition
NFPA 1081	Standard for Industrial Fire Brigade Member Professional Qualifications, 2018 Edition
Title 24, Part 9	California Fire Code, 2022 Edition
	https://h2tools.org

3. Basis of the Philosophy

This philosophy provides guidelines and information regarding fire prevention and protection to minimize potential loss of life and/or assets due to unexpected fire at the Darden Hydrogen Project, located in western Fresno County.

The availability of a well-trained fire brigade or Emergency Response Team (ERT) as per requirements of NFPA 1081, Standard for Industrial Fire Brigade Member Professional Qualifications is crucial to design the fire protection systems in a facility.

A fire hazard risk assessment should be conducted to evaluate the potential fire hazards and mitigations of the Darden Hydrogen Project.

A fire response plan shall be prepared by the owner to document how the fire protection systems outlined in this philosophy shall come into service by intervention of fire brigade as soon as possible and with minimum travel distances.

Available information in this stage of the project as well as code requirements have been used for development of this fire protection philosophy. The fire protection philosophy shall be revisited in next phase once the fire hazards, liquid and vapour release scenarios, fire zones, fire intensities, and the location of ignition sources are more defined.

3.1 Fire Zones

The basis for fire protection systems design for the Darden Hydrogen Project is that of a single risk area concept, which assumes that only one credible event (fire) is occurring at any one time. Fire zones (FZ) are used to limit the consequences of hazardous events to support this basis. By dividing the plant into individual areas as fire zones, it is assumed the consequences of a hazardous event, i.e., fire or explosion, are limited to only that fire zone and do not impact other fire zones to an extent where their integrity could be put at risk. This rationale for determining fire zones is very useful for grouping process units and equipment with similar levels of risk, providing functional independence between fire zones (i.e., fire and/or gas detection, isolation, ESD logic, and fire protection), and ensuring single credible events.

Fire zones at the Darden Hydrogen Project should be determined according to either the results of a fire and blast risk analysis (consequence analysis/ QRA) or following the guidelines mentioned below:

- A clearance of at least 15m (50ft) on all sides of the fire zone from other process areas or equipment (with no equipment or piping in the clear space) is preferred. However, if the spacing cannot be met between two adjacent fire zones, fire walls shall be considered as a mean of segregation between fire zones. Other acceptable means of segregation for fire zones include:
  - Pipe bridges (pipe racks) between process areas that are necessary to link two neighboring fire zones. (Note: it is recommended to fireproof the pipe racks within fire hazardous areas up to the height exposed to high thermal radiation)
  - Fire barriers, fire walls or fireproofed structures
  - Buildings (each building is assumed to be a separate fire zone)

3.1.1 Considerations for Fire Zones

- Sloping and Drainage: The sloping and drainage in each fire zone shall be designed in a way to remove away the fire water from fire zone which is on fire as soon as possible.
- Isolation: Fire zones shall be isolated in case of an emergency via Emergency Isolation Valves (EIV) to quickly isolate a process circuit to prevent leakage or prevent flow from one fire zone to another. Isolation is critical for controlling and limiting the flammable inventories within piping and process equipment in one fire zone which could contribute to a fire, and also for limiting the duration of a fire.
- Fireproofing: Jet fire rated fireproofing may be required between fire zones if adequate spacing is not met or the structures and/or equipment are within fire hazardous area originating from adjacent fire zones and shall be evaluated in more detail on a case-by-case scenario.

3.2 Fire/Explosion Hazards

The results of Project's Process Hazard Analysis (PHA) reviews and the fire and blast study results should be used to determine the credible release and subsequent fire and explosion scenarios in the Darden Hydrogen Project. The appropriate type of active and passive fire protection should be identified according to code and regulatory requirements, fire zones, fire intensities, and the location of ignition sources.

The types of major hazard materials for the Darden Hydrogen Project are summarized as below:

- Hydrogen (Since hydrogen is one of the main processing materials in this facility, early detection of this gas is crucial in preventing subsequent fire and especially explosion hazards. See Appendix A for the hydrogen characteristics)
- Oxygen (See Appendix B)
- Nitrogen
- Diesel

4. Fire Prevention

The goal of fire prevention is to use proactive strategies to prevent potentially harmful fires within each fire zone. Special characteristics of flammable/combustible materials present in each zone should be taken into consideration for fire prevention strategies as outlined below.

4.1 Plant Layout

Due to the handling of flammable hydrogen and combustible liquids such as Diesel and potential presence of ignition sources i.e., trucks and cars, electrical equipment etc., plant layout is one main aspect of fire prevention. The layout philosophy should consider adequate spacing between sources of flammable/combustible release and occupied (or safety critical) buildings as well as between fire zones.

The basic objectives of the spacing design criteria provided in this philosophy include the following:

- To minimize involvement of adjacent fire zones in a fire or explosion due to undesired release of flammable/combustible materials
- To permit access for firefighting
- To ensure that critical emergency facilities are accessible for operators to perform emergency shutdown actions in the event of a fire or explosion
- To segregate higher-risk facilities or equipment from less hazardous operations and equipment
- To separate continuous ignition sources from equipment that may have a higher potential to be a source of release of flammable materials
- To permit access by plant personnel for normal operation and maintenance of equipment
- To avoid danger or nuisance to persons or facilities beyond the adjacent property lines
- To minimize equipment damage from a fire or explosion to the immediate area

A facility siting study with major accident hazards should be conducted to evaluate the potential consequences to occupied buildings from hazards.

International and local codes, regulations, and guidelines such as California Fire Code and NFPA shall be followed with regards of processing, transportation, and storage of Hydrogen, as applicable.

4.1.1 Access/Exit

Areas within each fire zone should be designed with adequate two-way access roads for maintenance, emergency evacuation/escape and emergency response. Length of dead-end corridors inside the modular structures should not exceed 15 m (50 ft). There should be roads with adequate turning radius which provide access for fire trucks and other mobile equipment in case of an emergency.

Reserved space and access should be considered for the fire truck(s) entering the plant, near hydrants/monitors. Building exits shall be designed as per local building code. Sufficient emergency lighting shall be provided to allow for escape under all emergency conditions during night.

An egress plan should be developed and included in the plant emergency response plan with adequate signage for escape and evacuation during emergency situations.

A Risk Assessment shall be conducted and the location of personnel and muster locations and embarkation areas against hazard zones shall be reviewed. When identifying muster locations, the following shall be considered:

- Prevailing wind direction and potential blast scenarios
- Muster locations for construction activities shall be addressed separately
- Egress/Access routes inside modular structures shall be evaluated

Plans showing the locations of escape routes, muster locations, and emergency equipment shall be located at strategic points along the main access routes of the facilities. Refer to NFPA 101 “Life Safety Code” for more details on access/exit.

4.2 Drainage and Grading

The spread and impact of fire can be effectively managed by the provision of an appropriate drainage system. The drainage system should provide quick collection and safe disposal of rain, fire water, and minor spills.

Liquid spills from transformers, Diesel pumps, pipes and tank shall be directed away from sources of ignition and drained to a safe location. Each transformer containing insulating mineral oil shall be located in a suitably sized concrete containment dike. Any oil overflow caused by rain or by application of firewater shall drain into an area topped with crushed stone to mitigate its flow.

Area near diesel pumps and tank and adjacent pipe racks should be sufficiently crowned or sloped to prevent liquid accumulation under the pipe rack or near Diesel tank.

Firewater should be removed away from the fire zone which is on fire and from adjacent higher fire risk zone soon as possible to avoid fire reoccurrence.

4.3 Ignition Source Control

Where there are areas within the facility with potential for accumulation of flammable vapours, such as hydrogen and oxygen, ignition source control technologies should be in place to avoid and/or to minimize the risk of fire and explosion. The following methods are some of the recommendations for ignition source control:

- Declaring areas surrounding Hydrogen, Oxygen and light ends handling as “hazardous” in Electrical Area Classification and considering provisions such as traffic lights for these areas
- Electrical equipment, instrumentation, and material conformity with area classification
- Static discharge elimination and control measures, i.e., grounding and bonding
- Elimination or segregation from hot surface ignition sources, i.e., furnaces
- Lightning protection systems
- Bonding and grounding
- Controlled vehicle entry/access
- Use of non-sparking tools and enforcing hot work permit

- Enforcement of "no ignition source" rule around equipment handling Hydrogen and other flammable vapours, such as compressors

4.4 Hazardous Area Classification

Hazardous area classification shall be used to classify areas in which flammable gases or vapours are present in the air in quantities sufficient to produce explosive or ignitable mixture. The purpose of electrical area classification is to select the appropriate electrical equipment to be installed within any classified area. The electrical area classification shall be developed for new facilities, or extensions/additions to existing facilities.

All areas shall be classified as either Classified or Unclassified Area. The definitions for the classifications of hazardous locations in the Division System are as per API RP 500: Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1, and Division 2.

4.5 Process Safety Systems

The primary defense against fires and explosions is to prevent accidental releases of flammable materials from occurring, preventing the formation of flammable mixtures of fuel and air/oxygen. These loss of containment events are prevented at a fundamental level by employing:

- Robust equipment design
- Regular inspection and maintenance of piping and equipment
- Development of procedures and training of personnel

4.5.1 Process Hazard Analysis

Process Hazard Analysis (PHA) Studies shall be conducted to ensure that all the necessary safeguards are in place to reduce the likelihood of loss of containment scenarios that could result from credible events.

4.5.2 Shutdown and Depressurization

When there are large amounts of flammable materials being handled at higher temperatures and pressures, there is the risk of escalation due to impingement of fire on an adjacent equipment or structure. Emergency shutdown provisions and isolation of process equipment are examples of process mitigations which may, to a great extent, determine the type and duration of the fire protection appropriate for a facility. Normally flammable vapours such as hydrogen fires are not extinguished until the supply of hydrogen has been shut off or exhausted since there is a danger of re-ignition and explosion. If the hydrogen streams cannot be isolated and de-inventoried or depressurized in a timely manner, a fire can have a longer duration. Hydrogen sources can lead to jet fires, any fire water that is applied will be used to cooldown nearby equipment but not extinguish the fire.

The vapor phase fuels (i.e., hydrogen) shall have their respective shutoff valves located outdoors to minimize the volume of fuel available to leak inside the buildings thereby minimizing the magnitude of any potential vapor cloud explosion. Reliable ESD system backed up by remote, manually operated valves shall limit the duration of hydrogen gas release or fire.

5. Active Fire Protection

5.1 General

Active fire protection systems appropriate to each fire hazard present in the Darden Hydrogen Project shall be implemented in each unit.

The objectives of the active fire protection systems are:

- To provide means of extinguishing fire
- To provide cooling of equipment and structures and limit fire escalation by controlling the fire
- To limit the effects of a fire and allow safe emergency escape, evacuation, and rescue activities.

It is assumed that active fire protection will be supported by a fire brigade team as part of the plant's Emergency Response Team (ERT). The location of Fire Hall, ERT number and their apparatus and response time shall be verified and taken into consideration in further development of this fire protection philosophy during next engineering phase.

The fire protection design at the Darden Hydrogen Project should meet the NFPA 30, NFPA 2, California Fire Code, and any other applicable codes and standards.

5.2 Fire Water System

Water is considered as the default agent to be used in active fire suppression systems of the Darden Hydrogen Project against Class A fires, as well as for cooling and control of Class B fires. Water can be used alone to provide cooling and exposure protection. The Fire Water System shall be designed in compliance with NFPA Standards.

5.2.1 Fire Water Supply

The fire water will be supplied by the fire water tank and two fire water pumps. The fire storage tank capacity shall be sized to provide a minimum of four hours continuous operation of the fire pumps at rated capacity per industry common practices and NFPA guidelines. The firewater tank shall be designed as per NFPA 22 "Standard for Water Tanks for Private Fire Protection". The tank filling system shall be sized to fill the tank in a maximum time of eight hours as per NFPA 22 requirements. The tank shall be kept filled, and the water level shall never be more than 102 mm (4 inches) below the designated fire service level. The firewater tank shall be protected against freezing during cold weather. The thermometer shall be observed daily, and the supply of heat shall be regulated to maintain the temperature at minimum 5.6 °C (42 °F), as lower temperatures are dangerously near the freezing point and shall not be permitted.

A fire water assessment and preliminary hydraulic calculations should be performed during next engineering phase to verify the flow and pressure requirements.

5.2.2 Fire Water Demand

The worst-case single fire scenario concept shall be used to determine the maximum fire water demand at the Darden Hydrogen Project. The following steps should be used for this purpose:

- Divide the Darden Hydrogen Project into individual fire zones, either based on minimum spacing of 15m (50 ft), between two fire zones or the fire and blast study consequence analysis results. The fire zones are individual areas within the plant so the consequences of a hazardous event, i.e., fire or explosion, are limited to only that fire zone and do not impact other fire zones to an extent where their integrity could be put at risk.
- Based on the amount of flammable/combustible materials being handled in each fire zone, congestion and accessibility determine the fire protection method (i.e., manual, fixed, semi-fixed, deluge, etc.) and fire water coverage in each fire zone.
- Calculate fire water demand for each fire zone by defining the fire water consumers in each zone and determine worst case fire water requirement.

Note- each fire zone may be divided in deluge zones to optimize the fire water amount. One or more deluge zones may be required to activate in worst case scenario fire water demand.

The design of the fire water systems should be revisited as the project progresses and develops to accommodate any design and/or layout changes.

5.2.3 Fire Water Pumps

It is recommended to use the combination of both electric and diesel fire water pumps in the Darden Hydrogen Project fire water system design. Electric Jockey Pumps shall be also provided in order to maintain the pressure in fire water network when the system is not flowing water.

5.2.4 Fire Water Network

Fire water mains are used for transporting fire water from fire water pumps to the fire zones. Fire water mains shall be arranged in the form of a loop around fire zones, so each loop and area within the fire zone will have fire water available from two opposite directions. The fire water mains should be underground below the frost line, or otherwise protected from freezing or damage.

The fire water main shall be equipped with sectional valves (e.g., PIVs), hydrants, monitors, hose reels, etc. Providing adequate number of sectional valves (isolation valves) in fire water main will limit the number of hydrants, monitors or other fire water consumers which are out of service in case of maintenance or blockage of a section in the fire water main. Division valves shall be located so that any section of the grid can be taken out of service and the grid still supply water through adjacent sections to protect all plant areas. No more than six fire protection devices (hydrants, monitors) or systems shall be removed from service at any one time. For buried piping, division valves shall be the indicating type, identified by permanent signs as to purpose, and protected against damage from vehicles. Recommended practice is to install a sectional valve after each take-off to the hydrant, monitor, or other fire water equipment (such as deluge or sprinkler).

Fire water mains shall be designed to provide the required flow to the protected areas with a pressure at the most hydraulically remote location not less than 100 psig, while the pipe flow velocities shall not exceed 3 m/s (10 feet per second) in any area of the piping distribution system.

The underground fire water ring should be sized hydraulically based on fire water requirement of each fire zone within the facility. Hydraulic Calculation shall be performed to confirm the fire water sizes and fire water pump sizing.

A fire water coverage plan shall be developed, with location of fire water ring main, hydrants, monitors, connections to deluge system and sprinkler and PIVs.

Underground fire water mains should be HDPE, UL listed for use as fire service main/underground piping, FM approved and shall be designed, installed, and tested to meet the minimum requirements of NFPA 24.

5.2.5 Fire Water Hydrants

Fire hydrants shall be provided around the process areas, utilities, storage areas and admin/office buildings. Fire hydrants should be located along access ways and roadways within 3-6 m (10-20 ft) of the roadway for pumper truck access, at least 15 m (50 ft) away from the equipment to be protected. Guardrails or concrete bollards shall be provided as required to protect hydrants from mechanical damage.

Hydrant spacing shall be 60 m (200 ft) in higher hazardous areas and 90 m (300 ft) in utilities, laydown areas, buildings, etc.

Hydrant locations shall be arranged to permit equipment to be reached from at least two opposite directions so that manual hose line approaches can be made from the upwind side.

All required equipment, such as lined hoses, combination spray, solid stream and shutoff nozzles, hydrant wrench, spanners, spare hose washers and adapter fittings, shall be provided in vicinity of hydrants in hose boxes, or this required equipment could also be supplied by fire brigade in a timely manner. Minimum requirements should be met as per NFPA standards below:

- Fire hydrants shall be UL or FM approved
- Fire Hydrants should have a minimum capacity of 2 x 250 gpm at 100 psig
- Fire hydrants should be 6-inch with 8-inch connection to the main
- Fire hydrants shall have two 2-1/2-inch (65 mm) hose outlets and one 5-inch (125 mm) Storz fitting pumper connection.

Fire hydrants shall be installed in accordance with the minimum requirements of NFPA 24 and follow NFPA 25 for testing and inspection.

5.2.6 Fire Water Monitors

The requirement of fire monitors (either mounted on hydrants or standalone fixed fire monitors) shall be evaluated for the areas where access to fire truck is limited. Fire water monitors can be used to provide water spray for firefighting or cooling for areas with more fire hazard potential. Monitors are effective for cooling fire-exposed equipment, for fire intensity control and to flush burning flammable/ combustible liquids away from equipment. Monitors should be located at least 15 m (50 ft) away from the equipment protected and at a maximum distance of 30 m (100 feet) should be equipped with a combination fog and straight stream nozzle. Monitors should be lever-operated type having full 360° rotation and with an elevation angle between 80° upwards and 45° downwards. Each monitor should have means for locking the monitor for both horizontal and vertical adjustments.

A fire water coverage plan shall be developed, and fire water monitors location, type and capacity should be adjusted to provide fire water coverage at the facility.

Fire water and foam-water monitors mounted on mobile apparatus may be used to supplement fixed monitors and to provide water spray or foam water solutions for firefighting or cooling in areas of the plant where fixed monitors are not provided.

5.2.7 Fixed Water Spray/Deluge System

The terms “deluge system” and “water spray system” are used equivalently in this document.

Fixed water spray systems are designed to provide fire (ignition) prevention, exposure protection, control of burning or extinguishment. They are usually utilized when other forms of fire protection are not accessible or are extremely difficult or dangerous, the level of expected hazards is considered high (high fire potential equipment), and the fire outcome cannot be controlled by manual means of suppression. They can be independent of other forms of protection or may supplement them.

A deluge system consists of number of spray nozzles, always open, fitted onto a length of pipe (generally a ring) kept dry, and in which the water flow is controlled by a (or a set of) deluge valve(s). Provisions should be made to design the deluge system for foam and water application so they can be used for fire extinguishment as well.

The deluge valves should be in a safe location near the equipment they protect, to the greatest extent possible, to reduce the time delay in applying water to the exposed equipment. Deluge valves shall be protected against, freezing, blast overpressures or fire to ensure their operability in case of a fire. The piping downstream of the deluge valve should be kept dry and be self-draining in case of a leakage.

Deluge system shall be designed in accordance with the requirements of NFPA 15, NFPA 16 and API 2030.

5.2.7.1 Deluge System Activation

The activation of deluge system upon confirmed fire detection should be either manually within 30 seconds of fire detection, or automatically by automatic detection system using heat, smoke, or flame detectors. A combination of both manual and automatic activation is recommended.

The automatic detection and activation of deluge system should initiate an alarm in control room.

5.2.7.2 Deluge System Requirements

The final selection of protected equipment by deluge systems should be made based on the project specifics, such as location of fire zones, availability of fire brigade and other manual fire protection means and should be included in the fire protection design basis. The following equipment usually requires protection by a deluge system:

5.2.7.2.1 **Pumps**

Large pumps handling flammable liquids or combustible liquids at temperatures above their flash points, and which are located within process structures—or in large pump rows where access for conventional fire suppression using fixed monitor nozzles or hose streams would be difficult. Based on the above, a fixed water spray system should be considered when all three of the following conditions exist:

- The fluid being handled is at a temperature that is significantly (e.g., 22°C or more) above its flash point
- The considered pump is in close proximity to other equipment (including adjacent pumps) or structures that could be quickly damaged by the pump fire
- The pump is located where protection by monitor nozzles or hose streams would be difficult or impractical.

The water spray system should be designed to envelope, as a minimum, the entire pump including the shaft, seals, and other critical parts. Optionally, the spray envelope may be extended 0.6 m (2 ft) beyond the pump periphery and include suction and discharge parting flanges, check valves, gauge connections, block valves, balance lines, and lubrication connections within the spray envelope. The application rate should be not less than 20.4 lpm/m^2 (0.50 gpm/ft^2) of the projected envelope area at grade level.

5.2.7.2.2 **Compressors**

Small motor driven compressors [typically less than 200 to 300 horsepower] handling flammable gases present the same fire concerns as pumps handling flammable liquids. Large engine or turbine driven compressors provide an added fire concern because of the large volumes of hot lubricating oils being handled under pressure in the driver, transmission, and lubrication systems and water spray (deluge) is desirable to protect them. Where water spray is provided, it should be designed to directly spray all exposed equipment surfaces, including auxiliary equipment such as lube oil consoles and lube oil pumps, at an application rate of 10.2 lpm/m^2 (0.25 gpm/ft^2) of projected equipment surface. Where large compressors are located within buildings or under weather canopies additional concerns arise. A fire associated with the compressor or driver could cause structural failure of the building or canopy or expose other adjacent equipment. Instead of providing direct water spray on each equipment or structural item, the general area within the building or canopy can be provided with overall water spray protection to reduce the potential for high temperature combustion gases to accumulate under the roof.

The system should have 180-degree spray nozzles or open sprinklers located just below the roof or canopy and be designed to provide 12.2 lpm/m^2 (0.30 gpm/ft^2) of floor area.

5.2.8 Sprinkler Systems

Sprinkler protection may be provided for buildings such as Control room, Electrolyzer Buildings, Admin Building, Workshop/Warehouse as per the requirements of Californica Building Code, NFC and NFPA 13.

A code compliance review shall be performed in next engineering phase of the project to determine sprinkler system requirement based on each building hazard level, construction material and floor areas.

5.3 Gaseous Agent System

Fire protection systems utilizing gaseous extinguishing agents are available for use where other agents such as water, dry chemical or foam may not be desirable. Clean agents such as FM-200 and inert gases (e.g., CO_2) are normally used to protect enclosed spaces. The decision to use a clean agent should be based on an understanding of the fire hazards in the enclosure and the ability of the enclosure to contain the clean agent during a fire. It is also important to recognize that an enclosure may require a clean agent concentration that creates a safety hazard to personnel and this consideration should be included in choice of a clean extinguishing agent.

The requirement of gaseous system for substation/ instrument room will be evaluated in the next engineering phase.

5.4 Fire Extinguishers

In addition to fixed and mobile fire protection systems, portable and/or wheeled fire extinguishers should also be placed and used throughout Darden Hydrogen Project to enable trained operators to fight small fires and control fire prior to fire response team arrival.

The fire extinguishers shall be UL or FM approved and selected based on type of potential hazard and located within a suitable travel distance from the hazard. Fire extinguishers located in open areas should be protected from heat, sun, and freezing climate.

Dry chemical fire extinguishers should be used for hydrocarbon and hydrogen fires. Carbon dioxide extinguisher system should be used for electric fires, e.g., Substation building.

A visual color and signage should be used to allow personnel to easily identify fire extinguisher locations (red colored).

The number and distribution of fire extinguishers shall comply with the requirements of NFPA 10.

6. Fire and Gas Detection and Alarm Systems

6.1 General

A Fire and Gas (F&G) Detection and Alarm System should be developed for Darden Hydrogen Project to detect hazardous conditions at an early stage and serve to mitigate against the effects of any fire and/or gas releases in order to protect personnel, environment, and equipment by initiating audible and visual alarms or automatic actions, as required. The Fire and Gas Detection and Alarm System shall meet the requirements of NFPA 72, National Fire Alarm and Signaling Code, National Electric Code, California Building Codes, National Fire Code and Regulations.

The F&G systems shall be designed to:

- Alert Personnel, ERT and Control Room Operators to the presence, location, and nature of F&G emergency.

- Activate fire protection systems such as fire water pumps, deluge systems, sprinkler system, gaseous clean agent system, etc., either automatically or by providing audible and visible alarm signals to be manually activated in appropriate locations.
- Initiate isolation functions in process areas either automatically or by providing audible and visible alarm signals to be manually isolated in appropriate locations.
- Initiate HVAC shutdowns and make-up air dampers controls to mitigate hazards.
- Initiate shutdown of electrical equipment.

Detailed fire and gas logic shall be provided to define the requirements of F&G system and its subsequent actions.

Since hydrogen is one of the main processing materials in the Darden Hydrogen Project, early detection of this gas is crucial in preventing subsequent fire and explosion hazards. See Appendix A for the hydrogen characteristics.

6.2 Fire Detection

Fire detection suitable for the identified fire hazards should be provided in areas where a credible fire may occur. Hydrogen burns with a nearly invisible flame (especially during daylight hours), and gives off relatively little radiant heat and hence, a hydrogen fire is often difficult to detect. Thermal imaging cameras and flame detectors should be used to verify that a hydrogen flame is present.

The fire detection system of Darden Hydrogen Project should consist of:

- Smoke
- Heat
- Flame

Upon confirmed fire detection, appropriate action and/or alarm should be initiated. A fire hazard assessment should be performed for the determination of fire detection type such as flame, heat, and smoke detection or a combination of two or more types to be used. Fire detectors shall have voting logic to initiate trip and to minimize spurious alarms or executive actions.

In addition to fire detectors, IR thermal cameras should be utilized for fire detection.

6.2.1 Smoke Detection

A commonly used fire detector is the optical smoke detector (spot-type) which is triggered by an increase of particles in the air. Smoke detectors shall be used in buildings where a flaming fire (e.g., office areas, HVAC systems, cabinets, storage buildings, warehouses, etc.) or a smoldering fire (e.g., control rooms, operation centres, electrical rooms, etc.) might occur. Addressable smoke detectors should be utilized where possible. Smoke detectors shall be selected and designed for the application and conditions in that environment.

6.2.2 Heat Detection

Heat detection could be used in small enclosures and spaces with low ceiling. Heat detection is generally considered to be slower than other detection technologies, but there are also new detection systems which are more advanced and more sensitive to heat, e.g., systems based on fiber optics. Heat detector types, such as fixed-temperature, rate-of-rise, or combination fixed and maximum rate-of-rise, shall be selected for the application. Addressable heat detectors should be utilized where possible.

Dual purpose smoke/heat detectors should be installed in electrical substations, Instrument rooms, and control rooms.

6.2.3 Flame Detection

Flame detectors are fast-acting devices and thus, are typically installed in high-risk areas where flash fires, pool and jet fires are likely to occur, e.g., flammable liquid handling, compressor buildings or areas, loading platforms, etc.

Flame detector-type such as ultraviolet (UV), infrared, combination UV/IR, multi-spectrum IR, heat-activated fusible, or bimetal links shall be selected based on hazard type and flame characteristics. Flame detectors are usually not suitable for detection of smoldering type fires.

Hydrogen burns with a nearly invisible flame (especially during daylight hours), and gives off relatively little radiant heat and hence, a hydrogen fire is often difficult to detect. Thermal imaging cameras and flame detectors should be used to verify that a hydrogen flame is present. Flame detectors in IR region are preferred for Hydrogen flames, as almost no soot is produced in a hydrogen fire. MULT-IR flame detectors are recommended for process units handling Hydrogen.

The MULT-IR detectors utilize three (IR3) or four (IR4) particular IR spectrum frequencies found in the corresponding fire to authenticate an alarm condition and are not affected by sunlight, radiation from welding and/or blackbody radiation from hot sources. Therefore, these types of detectors have high immunity to false alarm and for that reason it is the preferred technology for flame detection.

IR3 flame detectors shall be protected from environmental conditions (rain, snow humidity, solar radiation) by the following means:

- Protection of the detectors by rain/snow covers/hoods or weather protection
- Heating of the sensor’s optic to facilitate the evaporation of condensation.

IR3 flame detectors shall have a cone of vision of at least 90° in horizontal and 90° in vertical.

Flame detectors should be located at 2-3 m above grade or deck. However, their quantity, and location should be determined using a 3D model. If the line-of-sight arrangement of a flame detector is not guaranteed due to obstructions in the area, backup heat detection is recommended.

6.3 Flammable Gas Detection

Accidental release of hydrogen gas from equipment in open areas or inside buildings may result in gas cloud formation, which could be ignited and cause fire and explosion. Flammable gas detectors shall be located taking into account the following criteria:

- The most likely sources of leakage
- The proximity to possible sources of ignition
- The poisoning materials which can affect the detector technology
- The high points such as building rooflines, high-point piping and dead legs due to low density of hydrogen
- The prevailing wind direction and wind speed.

For Hydrogen gas detection, catalytic bead sensors or electro chemical devices are suitable. Where catalytic bead detectors are selected, they shall be poison resistant. The following should be considered when selecting the design of the gas detection system:

- Detectors should be located near leak sources in order to provide an early indication of the hazard before the gas migrates to a location were ignition of combustible gas or toxic exposure could occur. In some situations, leak/release sources and directions cannot be predicted with certainty as gas can be dispersed in any direction by a prevailing wind or mechanical ventilation; therefore, the strategy of placing detectors only in proximity to likely release sources may have limited effectiveness.
- Flammable gas detection should be supplemented by providing detectors in areas where gas can accumulate, such as confined and congested process areas.
- Gas dispersion analysis results, if available, should be consulted for optimum location of gas detectors.
- If multiple leak sources are within the detection range (as per manufacturer's published guidelines), a single detector shall be considered to optimize the number of detectors used.
- For hydrogen gas, detection shall be used any poorly ventilated areas, manholes, roof peaks (below the ceiling) and near ignition sources. Areas with poor ventilation and/or movement shall also be considered as potential areas where gases can accumulate posing a hazard.
- For lighter-than-air-gas (i.e., Hydrogen), the detector shall be installed close to the ceiling and preferably a collecting cone should be used.
- Open path infrared (IR) gas sensors should be used where gas leaks can potentially occur over a widely dispersed area without obstruction. A combination of point and open path gas detectors can be used for voting configuration.

The following are recommended locations for flammable gas detectors:

- At HVAC air intakes to enclosed areas such as Substation and Instrument Equipment Room, Electrolyzer Building, Compressor Building and Administration Buildings. These buildings mostly include ignitions sources and could ignite flammable cloud and start fire or explosion inside the building. The results of gas dispersion analysis (if available) should be consulted to determine which building is within flammability range.
- Close to any equipment considered to be an ignition source or near any other potential ignition sources such as pumps, trucks, etc., located in a potential flammable area.
- Inside enclosed areas, near exhaust openings, if the enclosure contains a fuel source, such as inside Electrolyzer Building.

- Close to any equipment located in a sheltered area and presenting risks of gas leakage.
- Inside Hydrogen compressor building.
- Close to leak sources of equipment such as Hydrogen storage vessels, valves, flanges, connecting pipes, etc.

Voting between gas detectors in adjacent monitored areas is not recommended; instead, detector layout should provide sufficient detectors such that hazards can be sensed by multiple detectors assigned to monitor a single monitored area and successfully detect the gas release before it migrates to adjacent monitored areas. Where there is a potential for cross-monitoring of gas hazards by detectors in adjacent monitored areas, then voting of detectors in adjacent areas may be considered.

6.4 Audible and Visual Alarms

An audible and visual alarm system is crucial for notification of operators, emergency response team and visitors if there is an emergency. The alarm system should be simple and easy to interpret. False alarms should be prevented as much as possible, and number of alarms should be kept to minimum to ensure proper actions are taken when there is an emergency.

Fire and Gas or Emergency horn location and spacing must produce a sound level that is at least 10 dBA above the average ambient sound level with a minimum value of not less than 65 dBA when measured at 3 m from the device. The maximum sound level must not exceed 110 dBA when measured 3 m from the device. The sound level shall comply with PSHA requirements.

The audible alarm notification should be by horns and/or sirens and visual notification should be by strobes/beacons with specific color lenses for fire and flammable gases or toxic gases.

Table 6-1: Alarm Color Code

Colour	Platform Flashing Lights
Red flashing strobe lights	Confirmed heat /smoke detection (on confirmed fire detection)/ Confirmed flammable gas detection
Blue flashing strobe lights	Confirmed toxic gas detection (if applicable)

Hydrogen flammable gas detectors should have 2 alarm settings as below:

- Point gas hydrogen detector (IR): 10% LEL (0.4% volume hydrogen) High Level, 30% LEL (1.2% volume hydrogen) High-High

6.5 Manual Alarm Call Points (MAC)

The requirement of Manual alarm call point (MAC) in the Darden Hydrogen Project in order to alert the operators at the control room of an emergency event should be evaluated in next phase. Where applicable, manual pushbuttons could be used for activating fire protection systems or emergency shutdown (ESD).

Activation of manual alarm call points should provide visual and audible alarm at the central control room and initiate other actions such as fire suppression system, if required and based on the emergency response plan.

7. Personnel Protection and Emergency Response

One of the main objectives of having fire protection and fire and gas detection systems in a facility is ensuring safety to life and health of operators, employees, contractors, and the public. Life-saving equipment shall be accessible throughout the facility, considering the potential hazards that could endanger the life and health of operators at the site, prior to the arrival of the emergency response team and additional medical support. It is crucial that the Emergency Response Plan is developed based on potential hazards at site, location of fire hall and the emergency response team number, apparatus, and travel distance.

All personnel shall be provided with the necessary level of personal protective equipment for protection in anticipated work environments and to assist with escaping to a safe location, should the need arise.

The requirements for personnel protection means include the provision of safety showers, eyewash stations, stretchers and first aid kits. Careful consideration should be given to the environmental conditions that will be encountered with respect to the use of such protective equipment and the types of chemicals likely to be stored at this facility.

In areas where personnel may come into contact with hot surfaces, suitable barriers, signs, guarding or insulation shall be provided.

Guards designed and constructed to recognized standards shall be fitted to each machinery part and other apparatus that may be dangerous to personnel or potentially harmful to other equipment.

All hazardous materials and equipment necessary for safe handling shall be identified.

7.1 First Aid Equipment

First Aid Equipment shall be provided as per minimum requirements of Local Occupational Health and Safety Regulation which are covered by US OSHA.

7.2 Personal Protective Equipment (PPE)

Personal Protective Equipment (PPE) is a worker's last defense against injury and death, despite every hazard protection and prevention in place. PPE should be provided or accessible within Darden Hydrogen Project to protect all personnel against hazards, including, but not limited to:

- Gas detection:
  - Portable gas detectors (flammable/toxic), as required.

- Slips, trips, and falls:
  - Helmets, head protection, non-slip puncture protection sole steel toe footwear with electric shock resistance footwear (including ice cleats during wintertime), non-slip flooring, fall protection equipment, snow/ice removal.
  - Pipefitters and other personnel with the risk of objects and debris falling on feet are recommended to have metatarsal guard safety footwear along with puncture protection sole steel toe footwear with electric shock resistance.
- Hot surfaces:
  - Insulated gloves, heat shielding clothing, and fire-retardant outerwear.
- Noise:
  - Multiple types of hearing protection.
- Cold surfaces:
  - Thermally insulated clothing.
- Eye and face protection:
  - Safety eyewear, safety goggles, safety face shields shall be provided and worn when entering a risk area or performing work that may damage eyes.

7.3 Safety Shower and Eye Wash

Safety showers and eyewash stations shall be permanently installed wherever there is a risk of exposure of personnel to irritants that are toxic by absorption, material being handled at elevated temperatures or chemicals that can cause immediate or irreversible damage on contact with the skin or eyes. If the potential hazard is only to the eyes, then an eyewash only unit needs to be provided; however, a shower unit shall always include an eyewash unit.

Safety Showers and eyewash stations shall be located in accessible, unobstructed locations, within a travel distance no greater than 16.8 m (55 ft) for an average person walking at a normal pace and shall require no more than ten seconds to reach. The location of the showers and eyewash stations shall be selected to meet these requirements and should be marked with clear Safety Green signage. Safety showers and eye wash stations shall be operational at all times and be designed for winter conditions. Safety showers and eye wash stations should be monitored, equipped with an audible and visible local alarm, and an alarm should also be sent to the control room when in use.

The water supply shall be potable water or water certified as suitable for the purpose. The supply shall be capable of providing flow for at least 15 minutes at the design rates to the shower and the eye units.

The delivered water temperature shall not be less than 16°C (60°F) except during initial activation of the eyewash or eyewash/shower unit, when a lower temperature is permitted during the period necessary to flush the aboveground piping immediately in the vicinity of the eyewash or eyewash/shower unit.

Eyewash units shall be provided with pressure controllers or self-regulating orifices to ensure that eyes shall not be injured due to excess water velocity if the water pressure exceeds 207 kPag (30 psig).

All permanently installed eyewashes and showers shall be provided with drainage for periodic testing, such as surface drainage to a catch basin, to a gravel filled pit or to a suitable area no less than 7.5 m (25 ft) away.

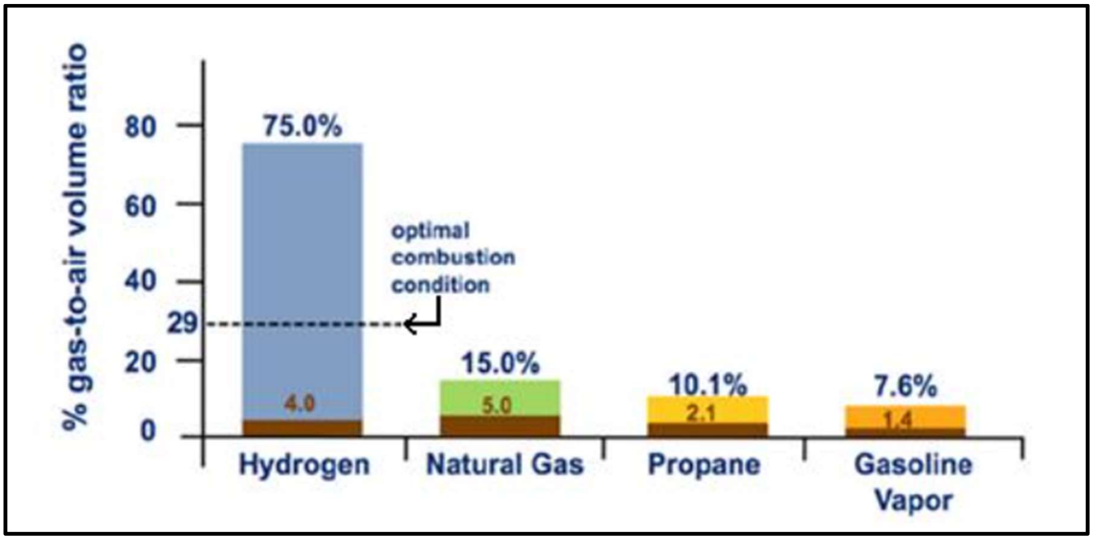
The floor drains shall be installed under eyewash or combination eyewash and safety showers located within buildings with a non-skid floor surface.

A location plan should be developed for safety showers and eyewash stations. Safety showers and eyewash stations shall meet the requirements of ANSI ISEA Z358.1 for the performance, use, installation, testing, and maintenance of the equipment.

Appendix A. Characteristics of Hydrogen

Hydrogen characteristics make this gas different than liquid and vapour hydrocarbons.

Hydrogen is a colorless, odorless, tasteless, and non-poisonous (classified as an asphyxiant) gas under normal conditions on Earth. Hydrogen is highly flammable; it only takes a small amount of energy to ignite it and make it burn. Hydrogen is flammable at concentrations between 4% and 75% in air, which is a wide flammability range compared to other common fuels. See below figure for hydrogen and other common fuels flammability range.



Since hydrogen has a very wide flammability range and low ignition energy, it should be assumed that any hydrogen leak or release is likely to result in hydrogen fire. Hydrogen burns with a pale blue, almost-invisible flame (especially during daylight hours), and gives off relatively little radiant heat and hence, a hydrogen fire is often difficult to detect. The flame may appear yellow if there are impurities in the air like dust or sodium. A pure hydrogen flame will not produce smoke. Hydrogen flames have low radiant heat, so unlike a hydrocarbon fire, you may not feel any heat until you are very close to the flame. Thermal imaging cameras and flame detectors should be used to verify that a hydrogen flame is present. If these tools are not available, personnel should cautiously approach a suspected leak and watch for thermal waves that signal the presence of a flame and put combustible objects or dust particles into the suspected flame to detect its presence.

Normally hydrogen fires are not extinguished until the supply of hydrogen has been shut off or exhausted since there is a danger of re-ignition and explosion. Personnel who work around hydrogen should be trained in the characteristics of hydrogen fires and proper procedures for dealing with them. In general, personnel should be trained to evacuate and assist other persons and call first responders but not to actually attempt to fight a fire.

Although hydrogen fires do not produce smoke themselves, Hydrogen fires can damage or ignite objects in the vicinity through heat transmitted by radiation and convection and so burning of nearby combustible materials can result in smoke. Thus, personnel should be aware that smoke inhalation can be a danger in a hydrogen fire.

Appendix B. Characteristics of Oxygen

Oxygen is a colourless, odourless, and tasteless gas and condensates in a light blue liquid. There is 21 percent oxygen in atmosphere and if a confined space has less than 19.5 percent oxygen it is considered to be oxygen deficient which causes asphyxiation.

Oxygen is highly reactive and forms oxides with almost all elements except noble gases. Oxygen is a strong oxidizer, and when oxygen concentrations and pressures are increased, materials generally become more flammable and require less energy to ignite. In fact, many materials that are not flammable in air (comprised of only 21% oxygen), become flammable in pure oxygen, especially when used under pressure. Many people are surprised to learn that even common engineering metals such as carbon steel and stainless steel are flammable if ignited in high-pressure oxygen.

It is highly recommended to perform a risk assessment to reduce the risk of oxygen enrichment in the facility, to mitigate or reduce the probability and/or consequences of ignition, and to include measures and safeguards such as appropriate materials, spacing, required design changes, operating and maintenance procedures and additional barriers such as fire walls to protect personnel. Normal Oxygen levels range is between 19.5% and 23% as per below table:

State	Oxygen Percentage
Oxygen Deficiency	19.5 % (volume)
Oxygen Enrichment	23 % (volume)