# Safety Plan

## 1 Scope of Work

### 1.1 Background

This document describes the safety plan for the ITM Power hydrogen refuelling station (HRS) located at the following address:

| Site # | Location |
|---|---|
| 1 | 11807 E Carson St., Hawaiian Gardens, CA 90716 |

Each station has the capability to dispense a minimum of 180kg of high quality hydrogen at 700 bar to fuel cell electric vehicles (FCEVs) each day. This hydrogen can be generated on-site via the electrolysis of water by renewable electricity, or the importing of hydrogen via a tube trailer.

ITM Power Inc. (ITM) are the station owner and provider of the electrolysis equipment and thus have a duty to ensure the safety of its staff, customers and others affected by the operation of this equipment. This document, based on Safety Planning for Hydrogen and Fuel Cell Projects[1], summarises the key evidence that ITM use to justify that the hazards on site are controlled and minimised to As Low As Reasonably Practicable (ALARP).

### 1.2 General Site Layout

Each site will comprise of the following components:

- A parking / refuelling area for vehicles
- A hydrogen dispenser
- A secure compound which will contain:
    - A hydrogen generator (electrolyser) in a shipping container
    - A low pressure (50 bar) buffer tank
    - A compressor in a shipping container
    - High pressure (up to 1000 bar) storage
    - A parking area for a hydrogen tube trailer
    - A connection panel for the tube trailer
    - E-stop and safety system including UV/IR detectors and hydrogen leak detection devices

### 1.3 Site Specific Layout

The specific layouts of each site are described in section 5 together with a description of any site specific safety related factors

### 1.4 Project Phases

This will be a commercial HRS with the work divided into distinct phases of:

- Design

[1] By the Hydrogen Safety Panel

- Assembly
- Factory commissioning
- Site installation
- Site commissioning
- Commercial operation
- Eventual site decommissioning

Of these phases, only site commissioning and commercial operation will generate significant quantities of hazardous material (hydrogen). The amount of hydrogen generated, stored and used for each of these phases is summarised below:

| **Phase** | **$H_2$ Generated** | **$H_2$ Stored** | **$H_2$ Used** |
|---|---|---|---|
| Site commissioning | ~50kg | 95kg | None |
| Commercial operation | Max 180kg per day | 95kg | max 180kg per day |

For all other phases of the project, safety will be ensured through compliance with ITMs ISO9001 quality management system and OHSAS 18001 Occupational Health and Safety Management System, and by following regulatory codes, such as NFPA2. As this safety plan is focussed on hydrogen specific safety, the remainder of this document will focus on the commissioning and operation phases of the project – this approach was discussed and agreed with the hydrogen safety panel (Nick Barilo).

Several types of personnel will be on-site:

- Public users of the refuelling station. They will receive both written and verbal training in the use of the equipment before they are allowed to use the station. They will also be required to attend a periodic refresher course.
- Site staff: The HRS will utilise local staff to respond to shutdowns and perform regular basic checks of the system (primarily checking for loss of containment of water or hydrogen). They will be trained by ITM (including verbal training and being supplied with documentation) but will be subcontracted to a company offering this service to a range of HRS. Thus they will be familiar with the general hazards of hydrogen and have some specific knowledge of the site. They will be required to attend an annual refresher training course.
- Commissioning / servicing staff. These are ITM engineers who have a detailed understanding of the equipment and are very familiar with the hazards associated with hydrogen and its associated technology. They have had extensive training and will continue to have a rolling program of updates (see Section 4.1)
- Builders. These will be on-site for several months preparing the location. They will be selected, and their OH&S training confirmed before they enter site, in line with ITM's written procedures. However, no hydrogen will be present.

Additional details of training are provided in Section 4.1.

Until commercial operation, the phases will be managed by ITM's Operation Director, Helio Bustamante. Once in the commercial phase, the site will be managed as a business by Steve Jones, ITM's Managing Director.

## 1.5 Permitting

The following permits will be required before operations on site can commence, this varies from city to city but each of the components listed below are incorporated into the permitting process, this section is described in more detail in the project narrative section of the GFO proposal. Each location will be assigned an Authority Having Jurisdiction (AHJ) and ITM has made initial contact will all relevant AHJ's in our station locations:

- Planning Permit
- Building Permit
- Electrical Permit
- Fire & Safety Permit

# 2 Organisational Policies and Procedures

ITM have an extensive Health and Safety Policy, which governs all of its operations. It includes a policy statement, the company objectives, the organisational structure and arrangements in place to ensure the prevention of harm. The full document is too long to include here, but is available on request. However, a copy of the Statement of Intent signed by ITM Power's CEO is presented below:

## STATEMENT OF INTENT

### HEALTH & SAFETY POLICY STATEMENT

ITM Power Plc is involved in the research and development and supply of clean fuel technology. Our aim is to provide the technology necessary to make the hydrogen economy a commercial reality and replace hydrocarbon fuels and hence society's total reliance on their constant supply.
We recognise that our employees are our most valuable assets and we are therefore committed to ensuring that the highest possible standards of Health, Safety and Welfare are maintained.

ITM is committed to-

- Ensuring so far as is reasonably practicable, the health, safety and welfare of all employees at work and of all persons not directly employed by the company, but who may be directly affected by its activities
- Identifying and managing hazards and associated risks for all activities carried out at ITM or by ITM employees
- Complying with all applicable OH & S legislation, codes of practice and any other requirements to which ITM subscribes
- Continual improvement to deliver improved OH & S Standards and performance

ITM will achieve these commitments by-

- Adhering to the OH&S Management System specifications outlined in the international standard ISO 18001
- Setting and reviewing OH&S objectives, targets and management programmes;
- Implementing an internal audit programme to measure compliance with our planned OH&S arrangements and the requirements of ISO 18001
- Providing training for all personnel working for and on behalf of ITM, including contractors to ensure they are aware of the requirements of this OH&S policy statement, how their activities can impact on the Safety of themselves and others, and their OH&S responsibilities
- Regularly reviewing both the Policy and the OH&S management system to ensure continued relevance to the organisation

This policy is publicly available on demand.

Signed........................................................

Dr. Graham Cooley
CEO ITM Power (PLC)

06/11/15

In addition, it is felt useful to include the contents pages to provide an indication of the topics covered:

# CONTENTS

In addition to the overall policy, each process through the design, manufacturing, factory commissioning and site commissioning are governed by over 200 procedures that cover quality, H&S and environmental management. .

## 2.1 Hydrogen and Fuel Cell Experience

ITM have been operating for 15 years, initially as a research company (studying fuel cells and electrolysers) and then as a manufacturers of electrolysers and as system integrators. This has allowed ITM to gain knowledge of range of hydrogen technologies including (but not limited to):

### 2.1.1 Electrolysers:

- PEM electrolysers
- Liquid alkaline electrolysers
- APEM electrolysers
- Connection of electrolysers to PV, wind turbines and tidal turbines

### 2.1.2 Fuel Cells:

- Static Hydrogen fuel cells
- Mobile hydrogen fuel cells (cars, vans, fork lifts, pallet trucks)
- Marine based fuel cells
- Methanol fuel cells
- Sodium borohydride fuel cells

### 2.1.3 Compressors:

- Mechanical compressors

- Ionic compressors

### 2.1.4 Storage:

- Stainless steel hydrogen storage (Type I)
- Composite hydrogen storage (Type II to IV)
- Metal hydride storage
- Hydrogen tube trailers

### 2.1.5 Hydrogen Transportation:

- Transporting of hydrogen by road (ADR)
- Transporting of hydrogen by sea (IMDG)

### 2.1.6 End Uses of Hydrogen:

- Hydrogen combustion in vehicles
- Hydrogen combustion in static boilers
- Hydrogen dispensing (including protocols, and design and operation of hydrogen refuelling stations)
- Injection of hydrogen into the gas grid

### 2.1.7 Conversion of hydrogen to other fuels

- Reacting of hydrogen to form methane (via both chemical and biological methanation)
- Reacting of hydrogen to form ammonia and urea
- Reacting of hydrogen to form diesel

With specific reference to this application, ITM has 15 current hydrogen station projects either built or in the process of being built. While some of these have been sold to and are operated by third parties, most are owned and operated by ITM. As such, ITM are very familiar with the processes and technology required to make a safe and reliable HRS.

Engineers will be on site for commissioning, which is identified as an activity with increased risk. As such, work will always be conducted with pairs of engineers, able to discuss potential problems. One engineer will always have at least 1 year of experience.

In addition to practical experience of designing, building and operating refuelling stations, ITM are heavily involved in the writing of national, regional and international standards for HRS:

- ITM staff also lead the UK delegation to ISO TC 197 and are secretary of ISO TC 197 WG24, covering hydrogen vehicle fueling station safety standards (ISO 19880-1).
- ITM contributes to ISO TC 197 WG26, covering electrolyser safety standards (ISO 22734); WG27 & WG28, covering hydrogen quality standards for fuel cell use (ISO 14687 & ISO 19880-8); and WG19, covering the safety standard for hydrogen dispensers (ISO 19880-2).
- An ITM staff member currently serves as chair of British Standards Institute (BSI) committee PVE/3/8 and the UK lead expert to the Comité Européen de Normalization (CEN) TC 268, WG5 preparing hydrogen refueling station standards to be harmonized to the European Directive 2014/94/EU on the deployment of alternative fuels infrastructure.
- ITM staff also serve as secretary of the British Compressed Gases Association (BCGA) Technical Sub-Committee (TSC) 9, and led the development of the industry code of practice (CP) BCGA CP41 - The design, construction, maintenance and operation of filling stations dispensing gaseous fuels. Additionally, through the BCGA, ITM are involved with the Energy Institute (EI) and Association for Petroleum and Explosives Administration (APEA) in the development of an Addendum to the Blue Book to facilitate hydrogen fueling co-located with petrol dispensing forecourts in the UK.

# 3 Identification of Safety Vulnerabilities

ITM rely on several techniques to identify safety vulnerabilities within its hydrogen refuelling stations, these are executed at different stages of the project to ensure constant analysis of risk and to allow any new risks to be highlighted and considered as the project develops.

## 3.1 Hazard and Operability (HazOp) Studies

ITM conduct two HazOps – one at the design stage and one at the as-built stage (which takes into account any code or assembly modifications introduced during the build and factory commissioning process). Each study is conducted by a team of several engineers, with representatives, from the Process, Electrical and Safety Engineering teams to ensure a wide spread of skills. While novice engineers are encouraged to participate, there will always at least three team members who have conducted at least 10 previous studies, to ensure the correct depth of knowledge. Teams are led by a chairperson who has considerable HazOp experience and has attended a HazOp Leaders course.

The studies require the process and instrumentation diagrams (P&IDs) of the site to be divided into nodes (often based around the fluid media or pressure). Keywords are then considered for each node, such flow, temperature and pressure. Then for each keyword, deviations are studied, such as No Flow, More Flow, Flow Elsewhere etc., where the possible causes, consequences and prevention systems for each are detailed. Each of these deviations are conducted as semi-quantitative risk assessments, with numbers assigned for likelihood, consequence and final risk for both the safety and operability of the plant. Rules are then applied to determine whether the system is adequate, or whether an action is required to lower the risk. Any deviation that could result in a fatality (no matter how small the likelihood) is referred for further consideration in a Layer of Protection Analysis (LOPA).

Several HazOps have been conducted that cover the HRS. These are available on request.

## 3.2 Layer of Protection Analysis (LOPA)

LOPA is a standard tool within the process engineering industry, but as yet, is not widely used within the hydrogen industry. The technique takes specific scenarios (such as overpressure) and initiators that could cause the scenario (such as sensor failure) from the HazOp study and attempts to determine the likely frequency of a fatality based on such things as the frequency of an initiator occurring, the independent layers of protection in place to prevent that deviation resulting in the scenario (hydrogen detectors, pressure relief valves, HazLoc equipment etc) and the likelihood of someone being on site.

The risks are then totalled and compared to government standards, which have thresholds for:

- Risk is unacceptable
- Risk is tolerable if As Low As Reasonably Practicable (ALARP)
- Risk is broadly acceptable

A site will usually be found to be within the 'tolerable if ALARP' region. Therefore a Cost / Benefit Analysis (CBA) will be conducted. Again, this follows an approved methodology to determine whether the cost of introducing a risk reduction measure is worth the incremental benefit it will bring. If all of the high risk initiators are shown to be ALARP, then the risk that the site presents is considered tolerable.

The LOPA and CBA studies are normally written by an engineer experienced in the technique, but are then reviewed as a team exercise, usually with process engineers. This may go through several iterations until all team members are happy with the study.

The LOPA and CBA studies are site specific and therefore will be conducted for the each HRS after a contract is awarded. Examples of previous LOPA and CBAs for similar HRS can be provided on request.

## 3.3 Hazard Identification (HazID)

While HazOps and LOPAs are good at identifying weaknesses in the sites process engineering, they do not consider non-process dangers, such as slips, trips and falls, adverse weather, vandalism etc.

The purpose of a Hazard Identification (HazID) study is to take a high level examination of the risks (particularly non-process risks) that the system presents to ensure that they will be considered in detail during subsequent studies, in many ways it is similar to both fault and event tree analysis. This ensures that the hazards considered in the Risk Assessment are based on an objective assessment, and not the subjective views of the author.

ITM use a standardised list of hazards (published by Burk, 1992, as referenced in DOE Handbook, 2004). While it is acknowledged that pre-prescribed lists can limit thinking about hazards, this is out-weighted by the benefits of having an objective list and not overlooking a risk.

The HazID study is site specific and will therefore be completed for each HRS once a contract is awarded. Examples of previous HazIDs for similar HRS can be provided on request.

## 3.4 Risk Assessment (RA)

The ITM risk assessments are designed to be compliant with ISO 14121-1 Safety of Machinery, as required in Section 5.1 of ISO 22734-1 Hydrogen Generators using Water Electrolysis Process.

The ITM RA is semi-quantitative and considers the hazards for the site (both process and non-process), their likelihood of occurring the consequences of an occurrence, and then calculates the risk. Based, on this risk, it considers if additional risk control measures are required.

The RA study is site specific and will therefore be completed for each HRS once a contract is awarded. Examples of previous RAs for similar HRS can be provided on request.

## 3.5 Safety Critical Equipment

Control for the plant is overseen by a Site PLC, which communicates with individual equipment PLCs, particularly the electrolyser, dispenser and the compressor. Equipment PLCs will automatically shut themselves down for process errors that could result in safety problems (e.g. flow of water to stacks too low) are communicated to the site PLC, which in turn triggers a site-wide shutdown.

In addition, there are specific safety PLCs/circuits which are independent of the process PLCs. These monitor key safety equipment which if triggered indicate that an emergency situation is already present such as smoke alarms, hydrogen alarms, fire detectors and E-Stops (full list is below) and can initiate a site-wide shutdown. Non-instrumented safety systems include earth bonding and pressure relief valves.

All safety critical equipment is guaranteed to be functional in a hydrogen environment, ITM never use generic safety equipment. If there is any doubt to a products applicability to a hydrogen environment the product will not be used.

All safety systems are functionally tested during regular servicing and are highlighted within the maintenance manuals to ensure ongoing safety is maintained. Replacement and/or recalibration of all safety critical equipment is conducted in line with or sooner that the manufacturers guidelines.

The full list of equipment on monitors on safety circuits (not the process PLCs) is provided below:

**Electrolyser**:

- 4x PRV
- Smoke detector
- 2x $H_2$ detector

**Buffer tank**:

- 2x PRV
- Fire detector

**Compressor/dispenser**

- 4x PRV
- 3x Fire detector
- 4x Pressure transducers
- 3x Temperature transducers

## 3.6 Hazardous Materials

The key hazardous material considered here is hydrogen. Other hazardous materials are present on the plant (ambient pressure oxygen, hydraulic oil and glycol), but are considered low risk.

### 3.6.1 Source:

- Hydrogen generation via electrolysis at a maximum rate of 85kg per day
- Hydrogen supply via a tube trailer.

### 3.6.2 Storage:

Materials will be stored on site in certified vessels at the following approximate volumes and pressures:

| **Description** | **Pressure (bar)** | **Mass $H_2$ stored (kg)** |
|---|---|---|
| Buffer tank | 50 | 2 |
| Intermediate pressure storage | 200 | 4 |
| High Pressure storage | 85 | 1000 |
| Tube trailer | 350max | 250 |

In addition, small volumes of hydrogen will be located in the electrolyser, compressor and interconnecting pipework.

### 3.6.3 Ignition Sources:

The site is compliant with NFPA2, and therefore there should be no ignition sources. A full HazLoc safety study will be conducted for each site, but in summary:

- For high pressure fittings, there are no ignition sources within the hazardous area zone extents defined in NFPA2
- For the high-level hydrogen vents, there are no ignition sources within the hazardous area zone extents defined in NFPA2
- Where electrical equipment is used within a hazardous area, it is appropriately HazLoc rated for the class and division required.
- The dispenser is vented after use, in line with refuelling station guidance

- Fire walls are provided to reduce zone extents and prevent hazardous areas extending into uncontrolled areas
- Commissioning / maintenance engineers are trained to operate around high pressure flammable gases and have appropriate personal protective equipment.

### 3.6.4 Explosion Hazards:

There are several potential explosion hazards identified in the HazOp and LOPA:

- Catastrophic leak, followed by ignition in the electrolyser or compressor containers
- Catastrophic leak from an external fitting, followed by ignition
- The heater in the gas dryer remains engaged, softening the pressure vessel, leading to catastrophic failure
- External fire, softens pressure vessels on site, leading to catastrophic failure
- Jet fire from a fitting leak impinges on pressure vessels, locally softening them and leading to catastrophic failure
- Failure of logic/equipment controlling the ramp rate of hydrogen into the vehicle, leading to overheating of the vehicle tank, softening and catastrophic failure.
- Failure of logic/equipment controlling the pre-chilling of the hydrogen entering the vehicle, leading to overheating of the vehicle tank, softening and catastrophic failure.
- Failure of the logic to stop hydrogen generation / compression at the required pressures, leading to over pressurisation and catastrophic failure of equipment

All of these have been assessed in detail as part of the LOPA and the risks are within tolerable levels.

### 3.6.5 Material Interactions

All materials used have been selected to be compatible with each other and the media they will be exposed to. The obvious potential material interaction is the embrittlement of materials with hydrogen. An example of where this went wrong is the Emeryville refuelling station fire in 2012. ITM process engineers go to great lengths to ensure that all of the parts that will be exposed to hydrogen will not embrittle; this is backed up by manufacture declarations and, where appropriate, material compatibility reports which are stored in the project technical file.

### 3.6.6 Possible Leakage

There are numerous possible sources of hydrogen leaks in the site. This includes:

- From all mechanical fittings (this is minimised where possible by using welded fittings)
- From valve seats (both between different parts of the hydrogen system, and between the hydrogen system and vents)
- From the compressor seals
- Through non-return valves failing to check

The likelihood (based on industry data) and consequence of leaks from all sources have been considered at two levels:

- Non-catastrophic. This is required for HazLoc calculations (which specifically excludes catastrophic failure). ITM use a hole size of $0.25mm^2$
- Catastrophic (100% of area)

The risks of these have been semi-quantitatively assessed by ITM, and determined to be tolerable.

### 3.6.7 Accumulation

The HRS is designed to prevent the gas becoming trapped and is equipped with effective high and low level ventilation openings. Any points of possible leakage are either covered by appropriate gas detection, in an area where a leak cannot accumulate or is freely ventilated.

### 3.6.8 Detection:

The detection of a hydrogen leak is achieved in many ways, including:

- Direct detection with hydrogen detectors in indoor locations, where the detector is located at the highest point.
- Indirect detection by:
    - Unexpected pressure drop during operation
    - Pressure hold test (where electrolyser generation or flow to the vehicle is paused and the system monitors the pressure for evidence of leaks)
    - Failure to pressurize the system within certain durations

Should the leak become ignited, this can be detected in other ways including:

- Smoke sensors
- Heat sensors
- UV/IR flame sensors

## 3.7 Site Specific Hazards

While each HRS is built to a common standard with similar hazards, each will present individual hazards associated with factors such as other fuels on site, the proximity of hazardous materials on adjacent sites or the proximity of the public to the site. The hazards for each site are described in Section 5.

## 3.8 What hazard associated with this system design, installation and operation is most likely to occur?

Based on ITM experience and numerous safety studies the hazards most likely to occur are:

- Minor hydrogen leak which pose minimal risk to the system
- Slips, trips and falls (although they will not be considered further here as this report is focussing on the specifics of hydrogen hazards)

Leak risks are mitigated by diligent maintenance procedures and leak detection strategies such as routine leak tests by staff. Slips trips and falls are mitigated by maintaining a clean and clear site and posting appropriate signage and hazard markings on the site.

## 3.9 What hazard associated with this system design, installation and operation has the potential to result in the worst consequence?

Based on the numerous safety studies the hazard with the highest consequence is:

Catastrophic failure, followed by ignition of a pressurised hydrogen store, brought about by external fire, vehicle collision or impingement by ignited hydrogen jets.
These risks are mitigated by the use of bollards and curb stones for crash protection, posting of appropriate signage on the site, the installation of shields to prevent jet impingement, UVIR sensors and by maintaining a high level of record keeping and test records for pressurised components.

## 3.10 Updates

In line with industry practice, the HazOp and LOPA will be re-assessed every 5 years, or when something on the site materially changes (see Section 4.2.13 for details)

The risk assessment will the reviewed every year, or when something on the site materially changes.

## 3.11 Risk Reduction Plan

The methods used to identify safety vulnerabilities considered hundreds of potential hazards. As requested in Safety Planning for Hydrogen and Fuel Cell Projects, only the significant safety vulnerabilities related to hydrogen will be described here in a risk binning format. As such, insignificant safety vulnerabilities or those not directly related to hydrogen will not be discussed.

**Risk Matrix** [2]

| Consequence Category | | Likelihood | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **1** Extremely Unlikely | **2** Very Unlikely | **3** Unlikely | **4** Quite Unlikely | **5** Somewhat Likely | **6** Fairly Probable | **7** Probable |
| **Very Major Catastrophic** >100 fatalities | **A** | **R8** | **R7** | **R6** | **R5** | **R4** | **R3** | **R2** |
| **Catastrophic** Overall 11 to 100 fatalities, fatalities to workers and/or public, international media exposure | **B** | **R9** | **R8** | **R7** | **R6** | **R5** | **R4** | **R3** |
| **Extremely Serious** Overall 1-10 fatalities, worker fatality, major injury to member of public. National news, prosecution and fine. | **C** | **R10** | **R9** | **R8** | **R7** | **R6** | **R5** | **R4** |
| **Major** Serious injury to worker (permanent disability). Injury to member of public. | **D** | **R11** | **R10** | **R9** | **R8** | **R7** | **R6** | **R5** |
| **Serious** Significant injury to worker. Minor injury to member of public. Adverse local publicity. | **E** | **R12** | **R11** | **R10** | **R9** | **R8** | **R7** | **R6** |
| **Minor** Minor injury to worker. Few complaints. | **F** | **R12** | **R11** | **R10** | **R9** | **R8** | **R7** | **R6** |

*Table 1 The Risk Matrix based on the likelihood and consequence of a hazard*

[2] As used in HSL report PS/08/01 "Assessing the safety of delivery and storage of hydrogen", also "Moonis, Wilday, Wardman - Process Safety and Environmental Protection, 88, 2010, 2, 97-108 - Semi-quantitative risk assessment of commercial scale supply chain of hydrogen fuel and implications for industry and society".

**RISK RATING = CONSEQUENCE CATEGORY x LIKELIHOOD**

Score 'Likelihood' from 1 to 7 where 1 is "Extremely Unlikely" and 7 is "Probable".

Score 'Consequence Category' from A to F where A is "Very Major Catastrophic" and F is "Minor".

Consider harm to people, the environment, damage to buildings, etc. and other potential losses to ITM such as share price.

| RISK RATING | PRIORITY | REQUIRED ACTION [3] |
|---|---|---|
| **High (R1-R5)** | **1** | High risk, not acceptable. Further analysis should be performed to give a better estimate of the risk. If this analysis still shows unacceptable or medium risk redesign or other changes should be introduced to reduce the criticality. |
| **Medium (R6-R7)** | **2** | The risk may be acceptable but redesign or other changes should be considered if reasonably practical. Further analysis should be performed to give a better estimate of the risk. When assessing the need of remedial actions, the number of events falling into this risk level should be taken into consideration to assure that the risk is as low as reasonable practical (ALARP). |
| **Low (R8-R12)** | **3** | The risk is low and further risk reducing measures are not necessary. |

*Table 2. The risk rating and required actions*

[3] Taken from Table 2 of DNV report "Hydrogen Applications – Risk Acceptance Criteria and Risk Assessment Methodology": http://www.eihp.org/public/Reports/Final_Report/Sub-Task_Reports/ST5.2/EHEC%20paper_final.pdf

**Definitions:**

| | |
|---|---|
| **Hazard:** | A potential source of harm. Must be a reasonably foreseeable hazard, defined as use of a machine in a way not intended by the designer, but which may result from readily predictable human behaviour. A hazard is either permanently present during the intended use of the machine (e.g. motion of hazardous moving elements, electric arc during a welding phase, unhealthy posture, noise emission, high temperature), or can appear unexpectedly (e.g. explosion, crushing hazard as a consequence of an unintended / unexpected startup, ejection as a consequence of a breakage, or fall as a consequence of acceleration / deceleration) |
| **Consequence**: | What will happen if the hazard is realised? |
| **To Whom**: | Consider all of the people who could be injured: The operator, those in the vicinity, visitors, cleaners, contractors etc. |
| **Likelihood:** | This is the likelihood of the harm being realised in the time before the RA is next reviewed (generally a year), with all of the present control measures in place. The definition of the grades of likelihood is provided in Table 1. |
| **Severity:** | This is the severity of the accident, with all of the present control measures in place. The definition of the grades of severity is provided in the Table 1. |
| **Risk Factor:** | The product of the likelihood and severity. The definition of the grades of risk is provided in the Risk Table and the required action is summarised in Table 2. |
| **Existing Controls**: | Detail of all present control measures to prevent the harm being realised |
| **Action needed**: | Should the risk factor be too high, further control measures should be detailed. The effect of these actions on the risk factor should be considered. |

## Loss of Hydrogen Containment

| # | Hazard | Consequence | To Whom | Likelihood | Severity | Risk Factor | Existing Controls | Action Needed |
|---|---|---|---|---|---|---|---|---|
| | Loss of containment of hydrogen from **external** fittings. | Minor leaks may result in a small jet fire.<br><br>This may affect personnel and equipment that is in direct contact with it (such as the hydrogen dryer vessels – potentially leading to an escalation to a significant release).<br><br>Significant releases followed by ignition could result in deflagration and subsequent jet fire<br><br>The deflagration would be expected to cause minimal damage and only result in significant injuries to personnel in close proximity to it. | ITM operator | 2-3 | E-F | R9-R11<br><br>**Low Risk** | **Control of releases:**<br><br>• Installation of manifold connections carried out according to manufacturer's instructions.<br>• FAT includes pressure test of all parts in $H_2$ system to at least 1.43x maximum allowable pressure (unless pressure tested previously).<br>• Vessels are pre-tested for leaks as part of suppliers ASME conformance testing.<br>• Pre-commissioning prior to hydrogen production and following any invasive maintenance, includes helium pressure test of system to maximum working pressure.<br>• Regular inspection and leak testing of pressure systems according to maintenance schedule and written scheme of examination.<br>• Major leaks would result in a pressure drop, resulting in a shutdown.<br>• Assuming no additional upstream failures of check valves, the release would be limited to downstream vessel size<br>• Open air - natural ventilation to dissipate minor leakage.<br><br>**Control of ignition sources:**<br><br>• Area around potential hydrogen leak points defined as Zone 2 and all electrical components within this area are appropriately HazLoc rated to reduce likelihood of ignition sources being present.<br>• Signage warning of the presence of a hazardous area.<br>• No ignition sources or flammable materials within hazardous area.<br>• No air intakes within hazardous area. | Confirm no site pipe work runs have leak points around ignition sources or air intakes |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | **Personnel Controls:**<br><br>• A significant release would be audible to personnel in vicinity. They can instigate a shutdown from an E-Stop.<br>• Pressing E-Stop push buttons, located around HRS, immediately shots down the system, closing all valves<br>• Visual alarm located on container roof alerts staff in the case of a Shutdown<br>• Escalation of a jet fire into a fire of the adjacent properties considered unlikely. | |
| | Hydrogen leak **inside** the electrolyser stack compartment | Ignition of explosive atmosphere.<br><br>Pressure wave from resulting explosion may blow out doors / roof fans, which could become a projectile risk if detached.<br><br>Likely damage to internal equipment. | ITM operator | 2-3 | D-E | R8 -R10<br><br>**Low Risk** | **Control of Releases:**<br><br>• Installation of manifold connections carried out according to manufacturer's instructions.<br>• Pressure testing of hydrogen system to 1.43x maximum allowable pressure (PS) during FAT and SAT (1.3x for stacks differential pressure).<br>• Regular helium leak testing of pressure systems according to maintenance schedule.<br>• Pressure sensors continuously monitor hydrogen system pressure through PLC. An unexpected drop in pressure (resulting from a 'major' leak in the HGas) instigates a fast shutdown (Shutdown 2), causing de-energisation of the PSU and fast venting of the HGas hydrogen.<br>• Regular automated pressure decay test undertaken to identify presence of 'minor' HGas pipework leaks.<br>• Forced air flow rate through the stack compartment sufficient to justify a Zone 2 NE for any 'negligible' release not detected by the pressure decay test.<br>• Power to the electrolyser stacks is isolated in the case of any alarm instigating a shutdown, preventing further $H_2$ generation<br>• Non-return valves in gas handling room to minimise backflow into stack compartment in the case of a leak (limiting stored volume to less than 100 normal litres). | Ensure that labelling is in place to warn personnel to not enter the generation compartment when the system is pressurised.<br><br>Installation of signage according to D934-0041. |

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| | | | | | | | • Limited stored hydrogen in the HGas, below a quantity of ~2750 normal litres (backflow $H_2$ from HRS prevented by NRV006).<br>• Functionality of check valves will be regularly tested in accordance with Maintenance Plan.<br><br>**Control of ignition sources**<br><br>• Forced ventilation from roof fans to dissipate “negligible” leakage (i.e. not identified by pressure decay test) provide sufficient air flow for generation room to be classified a Zone 2 NE. Fans monitored by pressure switches which will shut down the HGas if the fans fail.<br>• Hydrogen sensor mounted on roof of stack compartment alarms above 25% LFL and instigates emergency shutdown through PLC. This will rapidly depressurise the electrolyser stacks and hydrogen system through the hydrogen vent to a safe location, whilst removing electrical power to the plant.<br>• Forced ventilation is sufficient that if the entire output of all three stacks were to enter the stack compartment, the release would be diluted to below the LFL. Note – ventilation fans are HazLoc and don’t present an ignition source.<br>• Audible / visual alarm located on container roof warns staff in the case of a Shutdown 1 / 2, for instance a pressure drop alarm.<br><br>**Control of ignited hydrogen:**<br><br>• Temperature sensors mounted to stack compartment ceiling alarm above 40 ºC and instigate shutdown.<br><br>**Control of projectiles:** | |

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| | | | | | | | • Container walls provide enclosure to contain projectiles.<br>• Container louvres provide some pressure relief to an internal pressure wave.<br>• Personnel not permitted inside gas generation room whilst hydrogen system is pressurised. | |
| | Hydrogen leakage from process equipment / storage inside compressor / storage compartment of the container during operation (not including dispensing system) | Ignition causing jet fire or explosion<br><br>Asphyxiation | Maintenance engineer / fuelling operative / passers-by<br><br>Maintenance engineer | 1-2<br><br>1 | B-E<br><br>C-D | R7-R11<br>**Med risk**<br><br>R9-R10<br>**Low risk** | **Prevention of leaks:**<br><br>• Factory testing includes pressure test of all parts in the fuelling station to at least 1.43 × maximum allowable pressure (PS) where appropriate, and where not already tested by the individual equipment / component manufacturer.<br>• Nitrogen & hydrogen leak test of manifold to 0.9 * maximum allowable pressure (PS) once on site.<br><br>**Detection of leaks:**<br><br>• Hydrogen sensor located inside compressor / storage compartment.<br>• Routine checks conducted by trained personnel.<br>• Regular inspection and leak testing of pressure systems according to Written Scheme of Examination / maintenance schedule.<br>• Large leak may be audible to passers-by, with emergency contact details on the fences around the station and break-glass alarm points.<br><br>**Prevention of ignition:**<br><br>• Compressor / storage compartment of the container defined as Zone 2 and all electrical components are appropriately HazLoc rated to | Prepare site specific emergency plan<br><br>Put label on compressor / storage compartment door to highlight entry limitations<br><br>Ensure a personnel emergency exit is included for each compound |

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| | | | | | | | reduce likelihood of ignition sources being present in the case of a leak.<br>• Intermittent forced ventilation to dissipate minor leakage.<br>• Hydrogen sensor, to increase forced ventilation at 20% LFL, and to shut down plant at 40% LFL- instigates de-energisation of compressor, closes valves that isolate high pressure storage vessels from the majority of potential leak points, closes the inlet valve from electrolyser buffer store (though this is located inside the container, the electrolyser shutdown will close the externally located buffer store isolation valve), and displays a red light above the door to the compressor compartment. Alarm also instigates emergency shut down of HGas.<br>• HazLoc-rated glands to prevent hydrogen entering adjacent control compartment from compressor / storage compartment.<br>• Compressor / storage compartment doors locked by key outside of operational checks / maintenance, also in fenced compound with locked gate.<br>• Container walls / doors contain releases inside compressor / storage compartment to prevent hydrogen released inside the container impinging on / being drawn into the air intake louvres into the control room.<br>• Compound wall between container and dispensing area minimises likelihood of ignition sources (e.g. vehicle) being in a hazardous area created by a release from within the container. Non-HazLoc rated equipment excluded from the manufacturer defined hazardous areas.<br>• Compound fence / wall preventing unauthorised access to vicinity of hydrogen | |

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| | | | | | | | equipment (other than dispenser and tube trailer connection point), and no hazardous areas that extend outside the compound boundary fence / wall.<br>• No fixed ignition sources in the hazardous areas associated with the container that extend outside the compound fence / wall (from the venting systems, above head height).<br>• No portable non-HazLoc electrical items permitted in hazardous areas when hydrogen equipment and manifold pressurised.<br>• ITM maintenance staff trained of requirement to ensure ignition sources are kept out of HazLoc hazardous areas.<br>• Hazardous area drawing indicates locations of Zones.<br>• Signage on door to compressor compartment.<br><br>**Detection of ignited jet**<br><br>• Flame detector inside compound instigates fire alarm sounder for the fuelling station, and notifies the monitoring company, who in turn can notify the fire brigade and security.<br><br>**Mitigation of ignited releases:**<br><br>• Storage cylinders protected from impingement of ignited jets from process equipment.<br>• Explosion relief designed into the roof of the container.<br>• Site separation distances conform to NFPA2<br><br>**Protection of personnel** | |

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| | | | | | | | • No personnel in compartment whilst compressor in operation or during refuelling.<br>• Only trained personnel permitted to enter container and recommended to be wearing anti-static boots in the compressor compartment.<br>• Visual alarm located on compartment door to indicate whether “safe” to enter, that turns red if 20 or 40% LFL is reached.<br>• Clearly defined emergency procedure.<br>• Emergency stop push buttons inside both compressor / storage compartment and control compartment, and on dispenser and tube trailer connection point.<br>• Site “global e-stop” push button positioned close to entrance/exit for easy fire service access.<br>• If activated, any e-stop isolates the storage vessels (see hydrogen sensor alarm above for details) and de-energises the compressor.<br>• Additional plant electrical isolation available, as explained in the emergency procedure.<br>• “Break-glass” fire alarm activator located by the exit point(s) from the compound, which notify the monitoring company, who in turn can notify the fire brigade and security.<br>• Doors to be left open during maintenance to prevent asphyxiation. Relatively small compartment and easy to exit. Whilst ladders may be required, a step is built into the design to provide an alternative.<br>• Lights (HazLoc rated in compressor / storage compartment, in the hydrogen compound and the dispensing area) remain on at all times, even when there is a hydrogen leak detected or emergency stop button pressed. Street lighting (outside of zones) will also be unaffected. | |

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| | | | | | | | • Restricted maintenance allowed when only one member of maintenance staff present. | |
| | Hydrogen leakage in manifold between buffer store, tube trailer incoming connection, and pipework leading to container hydrogen inlet, or<br><br>hydrogen leakage from pipework between container and dispenser, between container and tube trailer outgoing connection, or from the heat exchanger<br><br>(not including the pipework / manifold on the refuelling area side of the boundary wall) | Ignition causing fire or explosion | Maintenance engineer / fuelling operative / passers-by | 1-2 | C-E | R8-R11<br><br>Low risk | **Prevention of leaks:**<br><br>• Factory testing includes pressure test of all parts in the fuelling station to at least 1.43 × maximum allowable pressure (PS) where appropriate, and where not already tested by the individual equipment / component manufacturer.<br>• Nitrogen & hydrogen leak test of manifold to 0.9 * maximum allowable pressure (PS) once on site.<br>• Equipment and piping in fenced compound with locked gate.<br><br>**Detection of leaks:**<br><br>• Routine checks conducted by trained personnel.<br>• Regular inspection and leak testing of pressure systems according to Written Scheme of Examination / maintenance schedule.<br>• Large leak may be audible to passers-by, with emergency contact details on the fences around the station and break-glass alarm points.<br><br>**Dilution of leaks:**<br><br>• Natural ventilation – located outdoors<br><br>**Prevention of ignition:**<br><br>• Area surrounding potential leak points defined as Zone 2 and all electrical components are appropriately HAZLOC rated to reduce likelihood | None |

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| | | | | | | | of ignition sources being present in the case of a leak.<br>• Compound wall between container and dispensing area minimises likelihood of ignition sources (e.g. vehicle) being in a hazardous area created by a release from equipment / joints within the compound. Non-HAZLOC rated equipment excluded from the hazardous areas defined around potential release points.<br>• Compound fence / wall preventing unauthorised access to vicinity of hydrogen equipment (other than dispenser and tube trailer connection point), and no hazardous areas that extend outside the boundary fence / wall.<br>• No fixed ignition sources in the hazardous areas associated with the container that extend outside the compound fence / wall (from the venting systems, above head height).<br>• No portable non-HAZLOC electrical items permitted in hazardous areas when hydrogen equipment and manifold pressurised.<br>• ITM maintenance staff trained of requirement to ensure ignition sources are kept out of HAZLOC hazardous areas.<br>• Hazardous area drawing indicates locations of Zones.<br>• Ex signage warning of the presence of a hazardous area at entry points to compound.<br><br>**Detection of ignited jet**<br><br>• Flame detector inside compound instigates fire alarm sounder for the fuelling station, and notifies the monitoring company, who in turn can notify the fire brigade and security. | |

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| | | | | | | | **Protection of personnel**<br><br>• Clearly defined emergency procedure.<br>• Emergency stop push buttons for the electrolyser easily accessible inside the compound, which instigate a refueller shutdown.<br>• Site “global e-stop” push button positioned close to entrance/exit for easy fire service access.<br>• If activated, any e-stop isolates the storage vessels (see hydrogen sensor alarm in 4.2.1 above for details) and de-energises the compressor.<br>• Additional plant electrical isolation available, as explained in the emergency procedure.<br>• “Break-glass” fire alarm activator located by the exit point(s) from the compound, which notify the monitoring company, who in turn can notify the fire brigade and security.<br>• Lights (HAZLOC rated in the hydrogen compound and the dispensing area) remain on at all times, even when there is a hydrogen leak detected or emergency stop button pressed. Street lighting (outside of zones) will also be unaffected.<br>• Restricted maintenance allowed when only one member of maintenance staff present. | |
| | Leakage from dispenser / pipework leading to the dispenser outside of fuelling | Ignition causing jet fire or explosion | Maintenance engineer / fuelling operative / passers-by | 2-3 | C-D | R7-R10<br><br>Med risk | **Prevention of leaks:**<br><br>• Factory testing includes pressure test of all parts in the fuelling station to at least 1.43 × maximum allowable pressure (PS) where appropriate, and where not already tested by the individual equipment / component manufacturer.<br>• Nitrogen & hydrogen leak test of manifold to 0.9 * maximum allowable pressure (PS) once on site. | None |

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| | | Asphyxiation | Maintenance engineer | 1 | C-D | R9-R10 **Low risk** | • Dispenser protected against vehicular impact by bollards and kerb of raised plinth on which dispenser is located.<br>• Majority of pipework / components inside dispenser cabinet protected from tampering by locked enclosure panels.<br><br>**Detection of leaks:**<br><br>• Routine checks conducted by trained personnel.<br>• Regular inspection and leak testing of pressure systems according to Written Scheme of Examination / maintenance schedule.<br>• Large leak may be audible to passers-by, with emergency contact details on the fences around the station and break-glass alarm points.<br><br>**Dilution of leaks:**<br><br>• Natural ventilation to dissipate minor leakage, although this is restricted within the dispenser enclosure.<br><br>**Prevention of ignition:**<br><br>• Quantity of hydrogen that can be released into the fuelling area minimised by isolation valves between the storage and the pipework leading to the dispenser that are closed outside of fuelling.<br>• Dispenser enclosure process compartment defined as Zone 2 and all electrical components are appropriately HAZLOC rated to reduce likelihood of ignition sources being present in the case of a leak. | |

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| | | | | | | | • Non-HAZLOC electrical equipment in the dispenser is located inside a sealed compartment.<br>• Electrical equipment mounted onto the dispenser enclosure is HAZLOC rated.<br>• No smoking, etc. signage on dispenser<br>• Site boundary fence / wall minimises unauthorised access to vicinity of hydrogen dispenser, and no hazardous areas that extend outside the boundary fence / wall.<br>• No portable non-HAZLOC electrical items permitted in hazardous areas when hydrogen equipment and manifold pressurised.<br>• ITM maintenance staff trained of requirement to ensure ignition sources are kept out of HAZLOC hazardous areas.<br>• Hazardous area drawing indicates locations of Zones.<br>• Ex-signage on door to dispenser compartment.<br><br>**Detection of ignited jet**<br><br>• Flame detector trained on dispenser area instigates fire alarm sounder for the fuelling station, and notifies the monitoring company, who in turn can notify the fire brigade and security.<br><br>**Protection of personnel**<br><br>• Clearly defined emergency procedure.<br>• Emergency stop push buttons easily accessible in the refuelling area.<br>• Site "global e-stop" push button positioned close to entrance/exit for easy fire service access. | |

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| | | | | | | | • If activated, any e-stop isolates the storage vessels (see hydrogen sensor alarm in 4.2.1 above for details) and de-energises the compressor.<br>• Additional plant electrical isolation available, as explained in the emergency procedure.<br>• "Break-glass" fire alarm activator located by the exit point(s) from the compound, which notify the monitoring company, who in turn can notify the fire brigade and security.<br>• Dispenser process compartment is too small to enter (from asphyxiation perspective).<br>• Lights (HAZLOC rated in the hydrogen compound and the dispensing area) remain on at all times, even when there is a hydrogen leak detected or emergency stop button pressed. Street lighting (outside of zones) will also be unaffected.<br>• Restricted maintenance allowed when only one member of maintenance staff present. | |
| | Leakage from tube trailer connection equipment (inlet / outlet) outside of use | Ignition causing jet fire or explosion<br><br>Asphyxiation | Maintenance engineer / fuelling operative / passers-by<br><br>Maintenance engineer | 2-3<br><br>1 | C-D<br><br>C-D | R7-R10<br>**Med risk**<br><br>R9-R10<br>**Low risk** | **Prevention of leaks:**<br>• Factory testing includes pressure test of all parts in the fuelling station to at least 1.43 × maximum allowable pressure (PS) where appropriate, and where not already tested by the individual equipment / component manufacturer.<br>• Nitrogen & hydrogen leak test of manifold to 0.9 * maximum allowable pressure, PS, once on site.<br>• Tube trailer connection point enclosure protected against vehicular impact by bollards and kerb. | None |

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| | | | | | | | • Pipework / components inside tube trailer connection point cabinet protected from tampering by locked enclosure panels.<br><br>**Detection of leaks:**<br><br>• Routine checks conducted by trained personnel.<br>• Regular inspection and leak testing of pressure systems according to Written Scheme of Examination / maintenance schedule.<br>• Large leak may be audible to passers-by, with emergency contact details on the fences around the station and break-glass alarm points.<br><br>**Dilution of leaks:**<br><br>• Limited natural ventilation only.<br><br>**Prevention of ignition:**<br><br>• Enclosure compartment defined as Zone 2 and all electrical components are appropriately HAZLOC rated to reduce likelihood of ignition sources being present in the case of a leak.<br>• Site boundary fence / wall minimises unauthorised access to vicinity of hydrogen dispenser, and no hazardous areas that extend outside the boundary fence / wall.<br>• Ex-signage on door to tube trailer connection point compartment.<br>• ITM maintenance staff trained of requirement to ensure ignition sources are kept out of HAZLOC hazardous areas.<br>• No smoking etc signage on tube trailer connection point. | |

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| | | | | | | | **Detection of ignited jet**<br><br>• Flame detector trained on tube trailer connection area instigates fire alarm sounder for the fuelling station, and notifies the monitoring company, who in turn can notify the fire brigade and security.<br><br>**Protection of personnel**<br><br>• Clearly defined emergency procedure.<br>• Emergency stop push buttons easily accessible in the refuelling area.<br>• Site “global e-stop” push button positioned close to entrance/exit for easy fire service access.<br>• If activated, any e-stop isolates the storage vessels (see hydrogen sensor alarm in 4.2.1 above for details) and de-energises the compressor.<br>• Additional plant electrical isolation available, as explained in the emergency procedure.<br>• “Break-glass” fire alarm activator located by the exit point(s) from the compound, which notify the monitoring company, who in turn can notify the fire brigade and security.<br>• Tube trailer connection enclosure is too small to enter (from asphyxiation perspective).<br>• Lights (HAZLOC rated in the hydrogen compound and the dispensing area) remain on at all times, even when there is a hydrogen leak detected or emergency stop button pressed. Street lighting (outside of zones) will also be unaffected.<br>• Restricted maintenance allowed when only one member of maintenance staff present. | |

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| | On-site collision of passing vehicle with refuelling station, (or vehicle being refuelled) causing pressurised pipework / vessel rupture and hydrogen leakage | Ignition causing fire or explosion | Maintenance engineer / fuelling operative / passers-by | 1-2 | C-E | R8-R11 **Low risk** | • 20 mph speed limit on site to reduce likelihood of crash into dispenser, or into a vehicle being fuelled, leading to damage to the dispenser.<br>• Storage vessels located inside the container, with the container in a separate fenced off compound with locked gates, and protected by firewall.<br>• Raised kerb and bollards located between fuelling area and the dispenser.<br>• When dispensing not in progress, process isolation valves reduce the volume of gas that would escape in the case of a collision with external components of the dispensing system.<br>• Container offers degree of protection to internal manifold and compressor, and is located behind firewall.<br>• Hydrogen sensor instigates safety system in case of leakage inside compressor compartment of container (see hydrogen sensor alarm in 4.2.1 above for details).<br>• Signage around refueller.<br>• Restricted access to refuelling station with automated gates at the entrance operated by entry card. | None |
| | Vandalism leading to release of hydrogen | Ignition of flammable gas mixture / electrocution of personnel | Maintenance engineer / fuelling operative / passers-by | 2 | C-E | R8-R10 **Low risk** | • Hydrogen equipment and dispenser in separate fenced off compounds with locked gates. Fence located at least 1 m from any hydrogen equipment.<br>• Public access to dispensing area limited by entry key-fob to those with hydrogen vehicles. The staff working in the area are likely to approach anyone obviously out of place.<br>• Doors to compartments of refuelling station compressor / storage container, tube trailer | None |

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| | | | | | | | connection point and dispenser locked by key outside of operational checks / maintenance.<br>• When not refuelling, process isolation valves reduce the volume of gas that would escape in the case of vandalism of components of the dispensing system external to the hydrogen compound.<br>• Site security cameras are active and monitored.<br>• Refueller is on patrol route of site security.<br>• Security signage on each side of refuelling station.<br>• Dispensing system (accessible to public) leak checked in control logic prior to refuelling. | |
| | Hydrogen leak from worn / damaged filling nozzle and hose or from incorrectly attached filling nozzle to form potentially explosive atmosphere | Ignition causing fire or explosion | Fuelling operative / passers-by | 1-2 | C-E | R8 -R11<br><br>**Low risk** | **Prevention of damage / wear:**<br><br>• Nozzle stored on side of dispenser in dedicated location when not in use.<br>• "Customer refuelling manual" includes visual inspection of refuelling nozzle and hose prior to refuelling, checking for damaged components / debris.<br><br>**Prevention / minimisation of leak**<br><br>• Refuelling nozzle and receptacle certified to SAE J2600 that only allows connection with 700 bar rated vehicle system.<br>• Positive engagement required for gas flow. Red indicator ring when correctly fitted.<br>• Refuelling control logic includes initial leak test on dispensing manifold, hose and components, and vehicle in accordance with ISO / DIS 20100:2011. Refuelling line is open to storage tank for maximum of 3 seconds during leak test. | Test of earthing connection through fuelling pad<br><br>Test of earth connection through nozzle to ground |

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| | | | | | | | • Average pressure ramp rate expected that would indicate the presence of a major leak, as the ramp rate would not be achieved.<br>• Fill carried out by operator trained according to "Customer refuelling manual" (D925-00xx).<br>• Anything above a minor leak will be audible and fuelling can be halted using the emergency stop push button at the dispenser (see hydrogen sensor alarm in 4.2.1 above for details).<br>**Prevention of ignition**<br>• Conductive fuelling pad bonds vehicle to refueller earth to avoid static discharge.<br>• Outdoor refuelling only to ensure adequate ventilation.<br>• Area around dispenser is zone 2, with appropriate electrical equipment used.<br>• Vehicle engine and power electronics turned off during refuelling. (Other than when fuelling data is recorded, when fuelling is monitored by a member of ITM staff)<br>**Protection of personnel**<br>• All non-approved personnel outside 5m separation distance during refuelling - station not on a publically accessible site.<br>• Site "global e-stop" push button positioned close to entrance/exit for easy fire service access. | |
| | Hydrogen leak from vehicle during filling | Ignition causing fire or explosion | Fuelling operative / passers-by | 2-3 | C-E | R7-R10<br>**Med risk** | **Prevention / minimisation of leak:**<br>• Control of vehicles being filled by issue of access cards by ITM to enable access, with vehicle | Seek additional maintenance information from |

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| | | | | | | | manufacturers having pre-approved the vehicles to be filled to ensure vehicles are suitable.<br>• Hyundai and Toyota vehicle hydrogen system components rated for temperatures as low as -40 °C.<br>• Identified Revolve vehicles suitable for filling, and registration numbers known and agreed with the operator Commercial Group.<br>• Vehicles under manufacturer's maintenance schedules.<br>• Short initial refuel (several seconds) followed by pause in refuelling protocol will identify leaks.<br>• Anything above a minor leak will be audible.<br>• "Customer refuelling manual" includes direction to carry out visual inspection of vehicle receptacle prior to refuelling, checking for debris, and training given to users.<br>• Additional controls to prevent overheating and over-pressurisation<br><br>**See Prevention of ignition and Protection of Personnel**<br><br>Note: Additional risk assessment to be prepared for prior to filling any new vehicles to help identify any potential issues with vehicles. | FCEV manufacturers |
| | Driving away / vehicle moving when refuelling nozzle attached - leading to breakage of | Ignition causing fire or explosion | Fuelling operative / passers-by | 1-2 | C-E | R8 -R11<br>**Low risk** | • Break-away coupling between nozzle and refuelling station minimises hydrogen leakage should the vehicle move whilst connected to the dispensing equipment, by sealing both the line from the dispenser and the line from the vehicle. | None |

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| | filling line and hydrogen leak | Whipping of unattached hose leading to personnel injuries. | Fuelling operative | 1 | C-D | R9 -R10<br>Low risk | • A check valve in the vehicle fill line further protects from hydrogen loss from the vehicle tank.<br>• Fill carried out by operator trained according to “Customer refuelling manual”, which includes measures to minimise risk of vehicle movement, including ensuring handbrake is engaged.<br>• Filling carried out on flat road surface.<br>• Vehicle access to site controlled by automated gate, with entry to authorised users only.<br>• 20 mph speed limit on site to reduce likelihood of crash leading to movement of the vehicle being refuelled.<br>• Manually operated emergency stop isolates flow to refuelling dispenser.<br>• Remote emergency stop push-button at other points on site, including by the entrance / exit.<br>• In case of break-away coupling failure to seal, the PLC logic has a high flow alarm on the dispensing line mass flow meter that would halt refuelling, also failure to achieve the minimum Average Pressure Ramp Rate would cause an alarm and shut the isolation valves.<br>• Some vehicles (Hyundai & Toyota) prevent driving when the fuel cap is open. | |
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| **Over-Pressurisation Hazards** | | | | | | | | |
| | Hydrogen generation leads to over-pressurisation of stack / hydrogen manifold in generation room / | Failure of components leads to projectile risk and un-ignited low pressure wave or, in the case of ignition, fire or explosion. | ITM operator | 1-2 | C-E | R8-R11 | Only the controls to protect against the over pressure and resulting pressure wave / projectiles are listed here. For the controls to protect against external releases. See above risks for controls to protect against external and internal hydrogen leaks. | None |

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| | hydrogen system in gas handling room | Pressure wave from resulting explosion may blow out doors / roof fans, which could become a projectile risk if detached.<br><br>Personnel external to the plant most at risk from projectiles.<br><br>Personnel in container have a high risk of harm to due to pressure wave from explosion and projectiles.<br><br>Likely damage to equipment. | | | | **Low Risk** | **Pressure Control:**<br><br>• The control system stops generation, setting the stack PSUs at 0 % output, when the combined manifold pressure transducer PT005 reaches 20 bar<br>• If this fails to prevent further hydrogen generation, alarm on pressure transducers PT001-5 reaching 22 bar, instigates a controlled shutdown.<br>• Adequately sized pressure relief valves fitted to each stack vent over pressure to a safe location. These protect the stacks in case of pressure transmitter or control system failure.<br>• Further adequately sized pressure relief valves fitted on the hydrogen process vessel S002 and gas dryer vent over-pressure to a safe location. These protect the vessels in case of pressure transmitter or control system failure.<br>• Pressure testing of systems to at least 1.43 x maximum allowable pressure (PS) carried out (1.3 times for stacks).<br>• On site commissioning includes helium leak test of systems to working pressure.<br><br>**Personnel Controls:**<br><br>• Commissioning personnel are not allowed in generation compartment when the hydrogen system is pressurised.<br>• Doors to gas generation room are locked, or access by tool, to minimise unauthorised access.<br>• Audible / visual alarm located on container roof warns staff in the case of a Shutdown 1 / 2, for instance an over-pressure alarm.<br><br>**Control of ignited hydrogen:** | |

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| | | | | | | | • Temperature sensors mounted to stack compartment ceiling alarm above 40 ºC and instigate shutdown.<br><br>**Control of projectiles:**<br><br>• Container walls provide enclosure to contain projectiles.<br>• Container louvres provide some pressure relief to an internal pressure wave.<br>• Personnel not permitted inside gas generation room whilst hydrogen system is pressurised. | |
| | Hydrogen PRV vent blockage during operation. | Inability of PRVs to relieve over pressure leading to a catastrophic loss of containment and subsequent injury to personnel. | ITM operator | 2-3 | D-F | R8-R11<br><br>Low Risk | See above risk analysis for measures for preventing over-pressurisation. In addition:<br><br>• Vent lines are protected to prevent rain ingress. | None |
| | Reverse flow of high pressure hydrogen from the Buffer Tank assembly to the gas handling room | Over pressurisation of equipment leading to loss of containment and deflagration. | ITM operators | 1 | C-D | R9-R10<br><br>Low Risk | • Non-return valve NRV006 on hydrogen process line to Buffer Tank assembly minimises backflow to ITM system. This will be regularly tested for functionality in accordance with the Maintenance Schedule.<br>• HRS has a non-return valve to prevent back flow of gas from high pressure systems.<br>• PRV008 set at 24 bar located in the hydrogen system to protect the HGas180 components from over pressure.<br>• Buffer tank assembly PRV009/10 set at 24 bar | None |
| | Reverse flow of high pressure hydrogen from the refuelling station high | Over pressurisation of equipment leading to loss of containment and deflagration. | ITM operator, public refuellers, nearby public | 1 | C-D | R9-R10 | • HRS non-return valves prevent hydrogen backflow to Buffer Tank assembly.<br>• PRV009/10 set at 24 bar located in the buffer tank panel to protect components from over pressure. | None |

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| | pressure vessels to the Buffer Tank assembly | | | | | Low Risk | • A high pressure alarm will be communicated to the HRS and shut an isolation valve between systems | |
| | Over-pressurisation during refilling of high pressure hydrogen storage tanks, leading to rupture | Un-ignited pressure wave or ignition causing fire or explosion. | Maintenance engineer / fuelling operative / passers-by | 1 | B-D | R8-R10 Low risk | • PLC stalls compression at 945 bar through pressure transmitters 40A20PT708, with redundancy through 50A20PT026, 50B20PT026, 50C20PT026 and 50D20PT026.<br>• Alarm through safety PLC monitoring 40A20PT708, at 950 bar leading to de-energisation of compressor.<br>• Adequately sized PED Cat IV pressure relief valves fitted after the compressor, set at 1000 bar, protect the high pressure storage and are regularly tested in accordance with Written Scheme of Examination.<br>• All vessels compliant with PED and pressure tested to 1.43 × maximum working pressure.<br>• Each pressure system assembly pressure tested to 1.43 × maximum allowable pressure.<br>• Relief gas vented to safe place (no ignition sources), vent exit is >5 m above container.<br>• Site separation distances conform to NFPA2 (though not appropriate for catastrophic failure of a vessel). | None |
| | Backflow from tube trailer inlet / high pressure storage vessels leading to over-pressurisation and rupture of electrolyser buffer storage / manifold from storage. | Un-ignited pressure wave or ignition causing fire or explosion | Maintenance engineer / fuelling operative / passers-by | 1 | C-D | R9–R10 Low risk | • Manifold from buffer storage cylinder protected from over-pressurisation by check valve 00B20CV008 between tube trailer inlet line (which could be up to 250 bar under normal operation if hydrogen is supplied from cylinders / a tube trailer) and the manifold.<br>• Backflow from the high pressure storage through the compressor prevented by numerous compressor check valves and 10A20CV032. | None |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | • Buffer storage has additional protection, with an alarm on PT03, and PSV01 set at 24 bar.<br>• Electrolyser protected by additional check valve and other measures, see separate ITM risk assessment | |
| | Over-pressurisation of vehicle hydrogen storage system during fuelling causing tank / component failure and hydrogen leakage | Tank rupture, ignition causing fire or explosion<br><br>Component failure, ignition causing fire or explosion | Fuelling operative / passers-by<br><br>Fuelling operative / passers-by | 1<br><br>1 | B-D<br><br>C-E | R8-R10<br>**Low risk**<br><br>R9-R11<br>**Low risk** | • Maximum fill pressure limited by PLC logic to 720 bar. This is significantly less than the maximum operating pressure permitted for the vehicle high pressure hydrogen systems of 875 bar (at up to 85 deg C). An emergency stop is carried out if the pressure in the dispenser reaches 720 bar.<br>• Pressure transducer PT10 halts refuelling at the desired "target" pressure through the PLC by closing process solenoid valves<br>• Refuelling carried out to SAE TIR J2601: 2010 fuelling protocol that takes into account the ambient temperature and starting pressure of the vehicle, to avoid over-filling of the vehicle under conditions that could lead to the vehicle equilibrating to ambient temperature and exceeding the rated pressure of the vehicle compressed hydrogen storage system (CHSS).<br>• PSV 08 in dispensing line set at 875 bar.<br><br>**See Prevention of ignition and Protection of Personnel in previous examples** | |
| **Heat Leading to Catastrophic Failure of Vessels** | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Heater in gas purification module fails to turn off | Softening of pressure vessel walls leading to catastrophic failure | ITM operator, public refuellers, nearby public | 1 | E-C | R10-R12<br>Low risk | **Preventing overheating**<br>• Heater is controlled and monitored by PLC<br>• Independent process control thermostat within the heater controls the temperature<br>• Second independent thermostat acts as a high level switch<br>• Downstream process temperature sensor will shutdown above 40C<br><br>**Controlling failure**<br>• Volume of vessel is small and pressure only 20 bar<br>• Mesh screen over gas handling area will help to reduce projectiles<br>• Limited number of people within range of projectiles<br>• Projectiles not expected to extend beyond site boundary | |
| | External fire in refuelling station spreading to HGas or buffer tank assembly | Significant damage to plant leading to a loss of containment of hydrogen and subsequent deflagration | ITM operator, public refuellers, nearby public | 1-2 | C-E | R8-R11<br>Low Risk | • A fire detected at the refuelling station will result in the HGas receiving a signal to shut down and vent its inventory.<br>• HGas will shut down and vent its inventory if a fire is detected via smoke detectors or high temperature in the stack compartment.<br>• If there were a significant fire in the refuelling station, it is unlikely that personnel would be in HGas or around the Buffer Tank assembly | None |
| | Arson | Ignition of flammable gas mixture | Passers-by | 2 | C-E | R8-R10<br>Low risk | • Hydrogen equipment and dispenser in separate fenced off compounds with locked gates. Fence located at least 1 m from any hydrogen equipment.<br>• Public access to dispensing area limited by entry key-fob to those with hydrogen vehicles. The staff working in the area are likely to approach anyone obviously out of place.<br>• Doors to compartments of refuelling station compressor / storage container, tube trailer connection point and dispenser locked by key outside of operational checks / maintenance. | None |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | • When not refuelling, process isolation valves reduce the volume of gas that would escape in the case of vandalism of components of the dispensing system external to the hydrogen compound.<br>• Flame detectors in hydrogen compound, also on the dispenser and tube trailer areas instigate emergency shutdown, halt hydrogen generation and vents hydrogen from electrolyser.<br>• Site security cameras are active and monitored.<br>• Refueller is on patrol route of site security.<br>• Security signage on each side of refuelling station. | |
| | Overheating of the vehicle storage vessel(s) due to compressive heating during fuelling exceeding natural heat loss.<br><br>Potential reduction in pressure safety factor of components leading to leak / burst, or activation of TPRD at 104-109°C and | Unignited pressure shock wave or ignition causing fire or explosion | Fuelling operative / passers-by | 1-2 | B-C | R8-R10<br>**Low risk** | • Fuelling carried out to SAE TIR J2601: 2010 fuelling protocol that takes into account the ambient temperature and starting pressure of the vehicle, to avoid over-heating of the vehicle compressed hydrogen storage system (CHSS) above 85 °C during filling.<br>• For 70 MPa fuelling, the CHSS temperature is monitored by the dispenser using SAE J2799 communications, with an abort signal sent to the dispenser to halt fuelling at 85 °C.<br>• Hydrogen supplied to vehicle is pre-cooled before entering the vehicle.<br>• Control of vehicles being filled by issue of entry cards by ITM to enable access, with vehicle manufacturers having pre-approved the vehicles to be filled to ensure vehicles are suitable. | None |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | complete venting of vehicle storage vessel(s). | | | | | | • Vehicle TPRD activates at 104-109°C to protect storage vessels – however to be avoided to prevent venting of all stored hydrogen on vehicle.<br><br>**See Prevention of ignition and Protection of Personnel in 4.2.22** | |
| **Miscellaneous** | | | | | | | | |
| | Domino effect of refueller cylinder explosion / leakage & jet-fire on near-by hazards | Setting fire to adjacent buildings / harm to passers-by | Maintenance engineer / fuelling operative / passers-by | 1 | B-E | R8-R11 **Low risk** | Safety systems as described in 4.2.1 – 4.2.4 above to reduce likelihood of ignition and minimise gas volume leaked.<br><br>• High pressure hydrogen storage cylinders protected from impingement of ignited jets from process equipment.<br>• Minimal manifold joints in the vicinity of the storage cylinders to protect from impingement of ignited jets.<br>• Site separation distances conform to NFPA2.<br>• Emergency stop push buttons located at different locations around refuelling station, these isolate storage vessels (see hydrogen sensor alarm in 4.2.1 above for details) and de-energise the compressor.<br>• Separate site specific fire risk assessment carried out.<br>• Clearly defined emergency procedure.<br>• Fire detection in appropriate places around the site, and "break-glass" fire alarm activators accessible close to refuelling area entrance, which notify the monitoring company, who in turn can notify the fire brigade and security. | Ensure location of and signage for evacuation point is clear |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | • Low pressure buffer storage area open air, with easy access for fire brigade to spray water onto the storage vessel to cool it in case of a fire.<br>• Explosion relief designed into the roof of the container.<br>• Fire extinguisher provided in case of electrical fire whilst personnel present. | |

## 3.12 Operating Procedures

In addition to policies, ITM operations are governed by over 200 procedures. A summary of the procedures and how they are implemented for an HRS build through each part of the life cycle is provided below. The procedures form part the training that all staff undertake, copies of the procedures are available on the site and the procedures are periodically reviewed and modified as required to ensure a high level of safety, applicability and user accessibility:

| Life cycle phase | Sample of key procedures | Enforced by |
|---|---|---|
| Design | QMS OP03 Product Design<br>QMS OP04 Purchasing<br>QMS OP22 Technical file process | Operations director enforcing design stage gates<br>All documentation stored in technical file<br>Audits |
| Build | QMS OP7 Manufacturing<br>SP3-03 Orbital welding<br>SP3-27 Working at heights<br>SP3-36 Assembly of high pressure LEP stack<br>SP3-39 Inspection and Handling components | Supervisor overseeing operations.<br>H&S Manager conducting workplace inspections<br>Quality manager inspecting finished components |
| Factory commissioning | SP3-30 Hydrostatic pressure testing<br>SP6-04 PRV Setting procedure<br>SP6-05 Stack pressure testing<br>SP6-47 Isolation and Lockoff of electricity to containerised electrolyser | Commissioning team leader<br>Commissioning check lists<br>H&S Manager conducting workplace inspections<br>Quality manager signing off completed systems |
| Site groundworks and installation | QMS OP10 Control of Outsourced Services and Processes<br>HSMS OP05 Managing Contractors<br>SP5.2 Visitors and Contractors | Risk assessment and method statements from subcontractor.<br>Regular site visits. |
| Site commissioning | SP6-50 ITM Activities on a Customer Site<br>SP3-30 Hydrostatic Pressure Testing<br>SP6-04 PRV Setting Procedure<br>SP6-05 Stack Pressure Testing<br>SP6-47 Isolation and Lockoff of electricity to containerised electrolyser | Commissioning team leader<br>Commissioning check lists |
| Commercial operation and maintenance | HRS User Manual<br>Refuelling User Guide<br>Maintenance manual | Regular site inspections.<br>Maintenance team<br>Monitoring of site data. |
| Decommissioning | EMS OP02 Waste disposal and recycling<br>HSMS OP07 COSHH | Environmental Manager.<br>Waste disposal notes. |

## 3.13 Equipment Mechanical Integrity

This section describes how the mechanical integrity pressure systems (vessels, tubes etc) is ensured.

### 3.13.1 Written Procedures

For every plant, ITM prepare a 'Pressure Safety Case' which details the pressure system, the calculations used to prove its safety and compiles all of the relevant supplier certificates and

declarations of conformity into a single location. This is in a set format to ensure that the documentation for each site is to the same standard. Rather than include a full safety case, the table of contents is provided below to provide an indication of the information contained.

## Table of Contents



*Figure 1. A table of contents from a typical pressure safety case*

### 3.13.2 Proper Design, Testing and Commissioning

ITM do not manufacture pressure vessels and therefore rely on suppliers to provide declarations of conformity, as opposed to conducting the full design calculations ourselves. These declarations are compiled and supplied as the appendices in the pressure safety case.

Once pressure systems (vessels, piping, sensors etc) are assembled by ITM staff, they undergo a proof pressure test and then leak tests using helium as part of commissioning. Test certificates (detailing the procedure and results) are then issued for each test. These are then stored in the technical file.

### 3.13.3 Validation of Materials Compatibility

On all purchase orders, ITM specify if a material needs to operate in contact with hydrogen (or any other fluid) in addition to standard information such as pressure range, temperature range, hazardous location classification etc. In addition, ITM request materials certificates for all pressure vessels to confirm both the material and its quality. These are retained in the technical file.

### 3.13.4 Preventative Maintenance Plan

ITM compile the maintenance plans for all components on the HRS into a single site maintenance plan. This is them implemented during regular service intervals.

### 3.13.5 Calibration of Safety Related Devices

The key safety devices in the pressure system are the Pressure Relief Devices. These are calibrated annually in line with manufacturers' recommendations. The calibration is logged in a Test Record detailing the procedure followed and the results. These are then stored in the technical file.

### 3.13.6 Testing and Inspection

Pressure systems are inspected for corrosion or damage, and leak tested annually. These are logged in Test Records, detailing the procedure followed and the results. These are then stored in the technical file.

### 3.13.7 Training for Maintenance, Calibration, Testing and Inspection Personnel

As detailed in the H&S Policy, ITM have detailed processes to ensure staff competence. In addition to HR holding all training records, each manager has a matrix of skills that staff require to complete their job. New staff are trained in the essential and then receive on-going training to complete the matrix. With time and training (and if appropriate to their role) staff can move from testing existing systems, to performing like-for-like swaps of components on a system, to building systems and then designing systems. Additional details are provided in Section 4.1.

### 3.13.8 Documentation

As described above, all calibrations, tests and inspections are recorded on forms which detail the methodology required, have sections for the date, equipment, location, results of test and then the operators signature. These are then stored in the product's technical file. Any failures are highlighted to their manager and the Quality Manager.

### 3.13.9 Correcting Deficiencies that are Outside Acceptable Limits

If a system had failed a test that is easy to rectify (eg a pressure test or calibration test) staff are trained in how to resolve (ie check the system for leaks or recalibrate a PRV). If a failed test requires more significant intervention (eg the replacement of a part), then this requires a Change Note, as described in the following section.

## 3.14 Management of Change (MOC) Procedures

Management of change at ITM is governed by procedure QMS OP23 Management of Change (changes to documentation are managed under a separate process). The key processes are described in Figure 2.

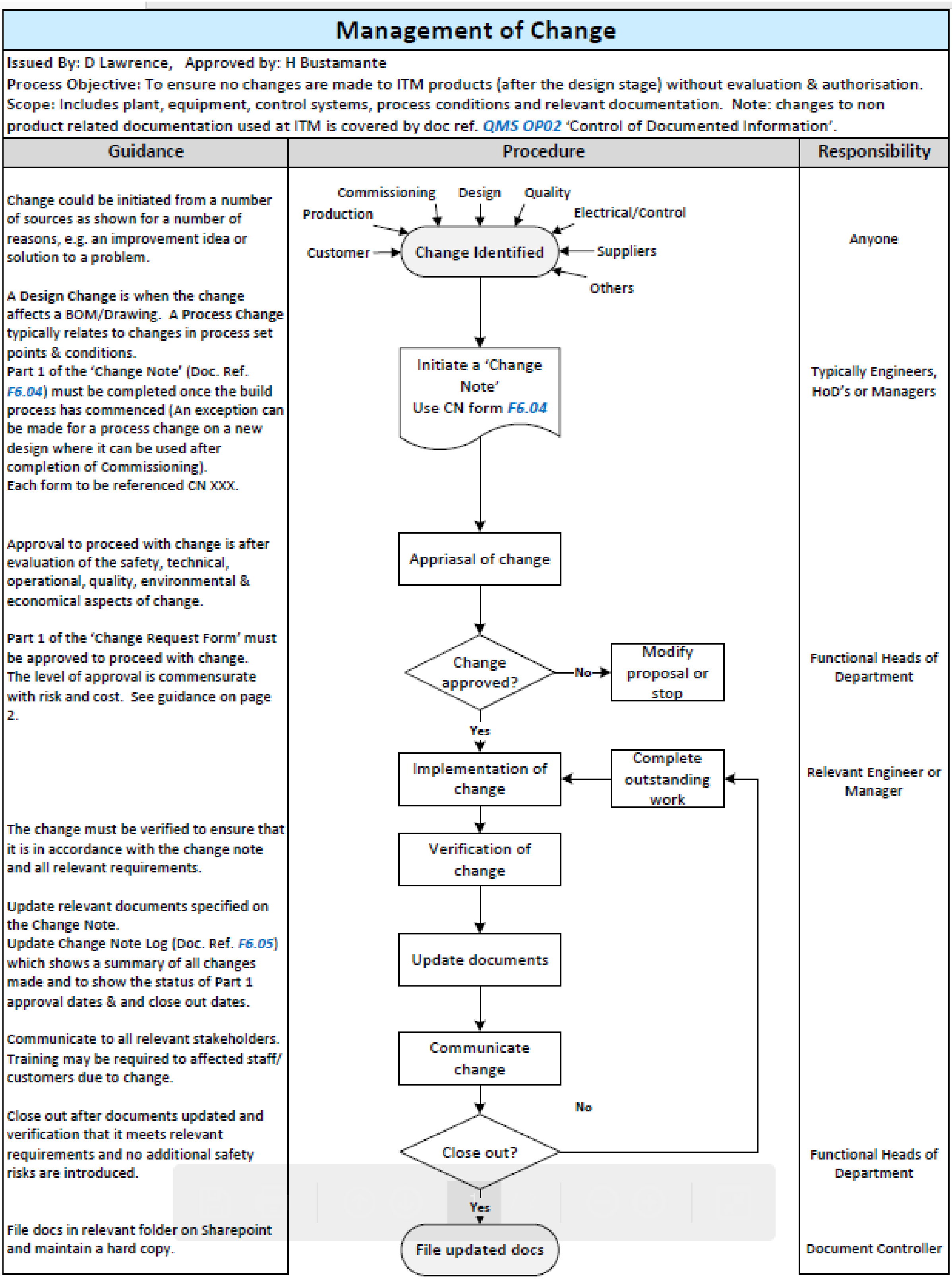



*Figure 2. The flow diagram for the management of change*

The procedure also specifies who must give approval for changes to different aspects of the system, with final approval being that of the Quality Manager, as shown in Figure 3 below.

APPROVAL GUIDANCE

The table below provides guidance on the required approvals on the Change Note.

In addition, it may be required to obtain specialists to review the Change Note proposal e.g. those of a safety critical nature.

| Change Type | Approval 1 | Approval 2 | Approval 3 |
|---|---|---|---|
| Drawing change (mechanical) | Design Engineer | | Quality Manager |
| Drawing change (stack related) | Design Engineer | Chief Engineer | Quality Manager |
| Drawing change (electrical) | Design Engineer | Control Systems Eng. | Quality Manager |
| Process change | Process Engineer | Lead Process Eng ( if complexity requires) | Quality Manager |
| | | | |

*Figure 3. Approval guidance for ITM's Management of Change procedure*

The form to apply for a change is presented in Figure 4.

| Quality Management System - Form | ITM POWER Energy Storage \| Clean Fuel |
|---|---|
| | Document Ref: F6.04 Issue E |
| Title: Equipment Change Note | |

This form is to be used for changes to ITM plant to ensure changes are evaluated & authorised.
See Doc. Ref. QMS OP17 'Management of Change' procedure for further guidance on the process.

## PART 1 – TO BE COMPLETED BY ORIGINATOR

| CHANGE No. | ORIGINATOR | POSITION | DATE |
|---|---|---|---|
| CNXXX | | | |

**APPLICABILITY** *(State Y below where applicable)*

| DESIGN<br>*Change to an ITM part on a BOM/Drawing once the build process has commenced* | PROCESS<br>*Change to a process condition or set point* | OTHER<br>*Please specify* |
|---|---|---|
| | | |

**PLANT/PART AFFECTED**

| PLANT SERIAL No(s) | DESCRIPTION | TOP LEVEL ASSEMBLY No. | DRAWING / PART No. / DOCUMENT REF. No. |
|---|---|---|---|
| | | | |
| **DOCUMENT No's.** (*list below if additional space is required*): | | | |
| **DOES CHANGE AFFECT OTHER PLANT?** (*Please specify*): | | | |

| DESCRIPTION OF CHANGE |
|---|
| |

| REASON / JUSTIFICATION FOR CHANGE |
|---|
| |

**WHO IS AFFECTED** *(State Y below for all applicable)*

| DESIGN ENGINEERING | PROCESS ENGINEERING | E & I | STACK | PRODUCTION | COMMISSIONING |
|---|---|---|---|---|---|
| | | | | | |
| **EXTERNAL / OTHER** (*Please specify*): | | | | | |

| APPROVAL TO PROCEED WITH CHANGE | | | |
|---|---|---|---|
| NAME | POSITION | SIGNATURE | DATE |
| | | | |
| | | | |
| | | | |

*See Doc. Ref. QMS OP17 'Management of Change' procedure for guidance on appropriate approval level*

| PART 2 – VERIFICATION OF CHANGE |
|---|

| **WHAT WAS ACTUALLY IMPLEMENTED** *(State any variations to original change proposal)* |
|---|
| |

| **VERIFICATION OF CHANGE** *(Did it work/is it safe?)* |
|---|
| |

| **WHAT DOCUMENTATION HAS BEEN UPDATED** (*Also state by who, when & new revision status*) |
|---|
| |

| CHANGE NOTICE CLOSEOUT | | | |
|---|---|---|---|
| NAME | POSITION | SIGNATURE | DATE |
| | | | |
| | | | |
| | | | |

The Originator to complete the 'Change Log' (Form F6.05) and pass signed form to Document Controller for uploading to Sharepoint.

*Figure 4. The form to request a change*

## 3.15 Project Safety Documentation

All project documentation (safety and non-safety) are stored in the project's technical file. This is an electronic folder held on ITMs servers that contain all of the information about the project, including hard copies of documents that are scanned in).

Document numbering is used to track individual documents, with version control employed to ensure that the most recent version is used.

Each product has a document register where all of the documents are recorded. A blank register is presented in Figure 5 below; the titles of the documents provide an indication of the documents that will populate the technical file.

| New Doc. Number | Latest Revision | Revision Date | Author | Document title |
|---|---|---|---|---|
| D9xx - 0001 | 02 | 01/06/16 | DL | Document numbering register (This one) |
| D9xx - 0002 | 05 | 01/01/16 | DL | Project file structure |
| D9xx - 0003 | | | | Project initiation form (F6.09) |
| D9xx - 0004 | | | | Project plan |
| D9xx - 0005 | | | | Reserved for home docs. |
| D9xx - 0006 | | | | Reserved for home docs. |
| D9xx - 0007 | | | | Reserved for home docs. |
| D9xx - 0008 | | | | Reserved for home docs. |
| D9xx - 0009 | | | | Reserved for home docs. |
| **PRODUCT DESIGN DOCUMENTS** | | | | |
| D9xx - 0010 | | | | Block diagram (Process Flow Diagram) |
| D9xx - 0011 | | | | Piping and Instrument Diagram |
| D9xx - 0012 | | | | Water regulation drawing |
| D9xx - 0013 | | | | Trace heating & thermal insulation drawing |
| D9xx - 0014 | | | | Equipment List |
| D9xx - 0015 | | | | Instrument and calibration List |
| D9xx - 0016 | | | | Valve list |
| D9xx - 0017 | | | | Pressure system test requirements **(NEW DOC)** |
| D9xx - 0018 | | | | Reserved for product design docs. |
| D9xx - 0019 | | | | Reserved for product design docs. |
| D9xx - 0020 | | | | Reserved for product design docs. |
| D9xx - 0021 | | | | Reserved for product design docs. |
| D9xx - 0022 | | | | PED safety case |
| D9xx - 0023 | | | | PED safety case - Full (If Required) |
| D9xx - 0024 | | | | Pressure relief valve sizing calculations: EN ISO 4126-1 |
| D9xx - 0025 | | | | PED category of main elements |
| D9xx - 0026 | | | | Hazardous area drawing 1 (state if internal or external) |
| D9xx - 0027 | | | | Hazardous area drawing 2 (state if internal or external) |
| D9xx - 0028 | | | | Hazardous area drawing 3 (state if internal or external) |
| D9xx - 0029 | | | | Hazardous area drawing 4 (state if internal or external) |
| D9xx - 0030 | | | | ATEX safety case |
| D9xx - 0031 | | | | HAZ I report |
| D9xx - 0032 | | | | HAZ 2 matrix |

| | | | | |
|---|---|---|---|---|
| D9xx - 0033 | | | | HAZ 3 matrix |
| D9xx - 0034 | | | | HazOp III report |
| D9xx - 0035 | | | | LOPA worksheet/analysis |
| D9xx - 0036 | | | | LOPA report |
| D9xx - 0037 | | | | DSEAR risk assessment |
| D9xx - 0038 | | | | Sign layout - container |
| D9xx - 0039 | | | | Reserved |
| D9xx - 0040 | | | | Reserved |
| D9xx - 0041 | | | | Reserved |
| D9xx - 0042 | | | | Reserved |
| D9xx - 0043 | | | | Reserved |
| D9xx - 0044 | | | | Reserved |
| D9xx - 0045 | | | | Reserved |
| D9xx - 0046 | | | | Reserved |
| D9xx - 0047 | | | | Reserved |
| D9xx - 0048 | | | | Reserved |
| D9xx - 0049 | | | | Reserved |
| D9xx-0050>59 | | | | Reserved |
| **MECHANICAL ASSEMBLY DRAWINGS** | | | | |
| **Use Part No** | - | - | - | - |
| | | | | |
| | | | | |
| **ELECTRICAL DESIGN** | | | | |
| D9xx - 0060 | | | | User requirement specification |
| D9xx - 0061 | | | | Emergency shutdown response matrix |
| D9xx - 0062 | | | | PLC hardware list |
| D9xx - 0063 | | | | IO Schedule |
| D9xx - 0064 | | | | Electrical connections |
| D9xx - 0065 | | | | Electrical equipment list |
| D9xx - 0066 | | | | PSU requirements |
| D9xx - 0067 | | | | Main control panel drawing (supplied by sub contractor) |
| D9xx - 0068 | | | | Emergency stop layout |
| D9xx - 0069 | | | | Motor ratings |
| D9xx - 0070 | | | | Cable block diagram |
| D9xx - 0071 | | | | Alarms and warnings list |
| D9xx - 0072 | | | | Logic flow diagram |
| D9xx - 0073 | | | | Setpoints and timers list |
| D9xx - 0074 | | | | Data transfer |

| | | | | |
|---|---|---|---|---|
| D9xx - 0075 | | | | Shutdown modes |
| D9xx - 0076 | | | | Electrical drawing review |
| D9xx - 0077 | - | | | Reserved for process control docs. |
| D9xx - 0078 | - | | | Reserved for process control docs. |
| D9xx - 0079 | - | | | Reserved for process control docs. |
| D9xx-0080>89 | - | | | Reserved for process control docs. |
| **ELECTRICAL/CONTROL SUB CONTRACTOR SUPPLIED INFORMATION** | | | | |
| - | | | | Schematics drawing |
| - | | | | FDS functional design specification |
| - | | | | Electrical data dossier (BOM) |
| - | | | | Cable testing certificates |
| - | | | | |
| - | | | | |
| - | | | | |
| **PRODUCTION DOCUMENTS** | | | | |
| D9xx - 0090 | | | | Stack test report |
| D9xx - 0091 | | | | Component traceability details |
| D9xx - 0092 | | | | CE data plate |
| D9xx - 0093 | | | | Certificate of Conformity by NoBo- Pressure Equipment Regs. |
| D9xx - 0094 | | | | Declaration of Conformity by ITM |
| D9xx - 0095 | | | | Reserved for production docs. |
| D9xx - 0096 | | | | Reserved for production docs. |
| D9xx - 0097 | | | | Reserved for production docs. |
| D9xx - 0098 | | | | Reserved for production docs. |
| D9xx - 0099 | | | | Reserved for production docs. |
| | | | | |
| **COMMISSIONING DOCUMENTS** | | | | |
| D9xx - 0100 | | | | Installation, commissioning and operation risk assessment |
| D9xx - 0101 | | | | General risk assessment (FAT, On-site Commissioning & Operation) |
| D9xx - 0102 | | | | Lifting plan at ITM |
| D9xx - 0103 | | | | RA for lifting plan at ITM - **To be a generic Doc filed in Sharepont RA** |
| D9xx - 0104 | | | | Method statement for installation and commissioning of HGas180 |
| D9xx - 0105 | | | | Reserved for Commissioning - RA's & method statements |
| D9xx - 0106 | | | | Reserved for Commissioning - RA's & method statements |
| D9xx - 0107 | | | | SOP – Alarms and warnings testing procedure |
| D9xx - 0108 | | | | Reserved for Commissioning - procedures |
| D9xx - 0109 | | | | Reserved for Commissioning - procedures |
| D9xx - 0110 | | | | Equipment list - Commissioning checklist |
| D9xx - 0111 | | | | Instrument list - Commissioning checklist |
| D9xx - 0112 | | | | Valve list - Commissioning checklist |
| D9xx - 0113 | | | | Alarms and warnings checklist |

| | | | | |
|---|---|---|---|---|
| D9xx - 0114 | | | | FAT checklist - Part 1 - Pre-commissioning |
| D9xx - 0115 | | | | FAT checklist - Part 2 - Commissioning |
| D9xx - 0116 | | | | SAT checklist - Part 1 - Pre-commissioning |
| D9xx - 0117 | | | | SAT checklist - Part 2 - Commissioning |
| D9xx - 0118 | | | | Reserved for Commissioning - checklists |
| D9xx - 0119 | | | | Reserved for Commissioning - checklists |
| D9xx - 0120 | | | | PED Hydraulic proof pressure test - Hydrogen assembly |
| D9xx - 0121 | | | | Helium leak test - Hydrogen assembly |
| D9xx - 0122 | | | | Ventilation fans - Air flow measurement |
| D9xx - 0123 | | | | Hydraulic, pneumatic and PRV setpoints report |
| D9xx - 0124 | | | | Pneumatic pressure test of MT001 assembly test report |
| D9xx - 0125 | | | | On-site leak test - Hydrogen assembly |
| D9xx - 0126 | | | | Reserved for Commissioning - test reports |
| D9xx - 0127 | | | | Reserved for Commissioning - test reports |
| D9xx - 0128 | | | | Reserved for Commissioning - test reports |
| D9xx - 0129 | | | | Reserved for Commissioning - test reports |
| D9xx -0130>159 | | | | Reserved for Commissioning |
| **OPERATION & MAINTENANCE DOCUMENTS** | | | | |
| | | | | |
| | | | | |
| | | | | |
| D9xx-0160 | | | | Maintenance Plan |
| | | | | SOP - Maintenance activities procedure |
| | | | | |
| | | | | |
| | | | | De-commissioning procedure |
| | | | | De-commissioning checklist |
| | | | | De-commissioning risk assessment |
| | | | | Reserved |
| D9xx-0170-199 | | | | Reserved |
| | | | | |
| **CUSTOMER & SITE DOCUMENTS** | | | | |
| D9xx -0201 | | | | User documentation manual contents pages |
| D9xx -0202 | | | | ITM - User manual |
| D9xx -0203 | | | | Customer refuelling manual |
| D9xx -0204 | | | | Customer maintenance manual |
| D9xx -0205 | | | | Reserved |
| D9xx -0206 | | | | Reserved |
| D9xx -0207 | | | | Reserved |
| D9xx -0208 | | | | Reserved |
| D9xx -0209 | | | | Reserved |
| D9xx -0210 | | | | Reserved |

| STAGE GATE & TECHNICAL REVIEW DOCUMENTS | | | | |
|---|---|---|---|---|
| - | | | | TECHNICAL REVIEW 1: Ensure key docs are created to allow progress to product design (Form F6.14) |
| - | | | | GATE 2: Product design review (Form F6.12) |
| - | | | | GATE 3: Production review (Form F6.33) |
| - | | | | TECHNICAL REVIEW 2: Ensure factory commissioning checks, tests & reports completed (Form F6.34) |
| - | | | | GATE 4: OK to ship (Form F6.35) |
| - | | | | TECHNICAL REVIEW 3: Ensure commissioning site acceptance test reports completed (Form F6.36) |
| - | | | | GATE 5: Customer product acceptance form (Form F6.37) |
| - | | | | 12 month review after introduction of new product platform (Form F6.38) |

*Figure 5. Documents in a typical technical file*

The editing of documents is covered by procedure QMS OP21 Document Control. This is enforced through a dedicated Document Controller and a version control system.

Files are backed up in the following manner:

- Within the server via a RAID array
- Within the site to another server in real time (so a server failure will result in only a few minutes of disruption)
- Nightly, to a second ITM site
- Four removable discs in quarterly rotation to ensure up to a year of data is available

# 4 Communication Plan

## 4.1 Training

The people exposed to hazardous substances (ie hydrogen) will be:

- ITM Engineers, who will be exposed to the largest hazards
- Commissioning engineers from partners supplying the compressor/dispenser and maintenance engineers
- The public refuelling operatives

The competency of these groups will be determined in the following ways.

### 4.1.1 ITM Engineers

As detailed in Section 3.13.7, ITM have detailed processes to ensure staff competence. During recruitment, staff are chosen for their skills, often having been an engineer in the military.

All new starters are provided with basic H&S information common to all ITM employees. They are required to sign procedures and then complete a questionnaire based on what they have learnt, on which they must score 100%.

Once in the job, each manager has a matrix of skills that their staff require to complete their job. New staff are trained in the essential requirements and then receive on-going training to complete the matrix. With time and training (and if appropriate to their role) staff can move from testing existing systems, to performing like-for-like swaps of components on a system, to building systems and then designing systems.

Competency at a task is assured in various other ways, depending on the level of risk. For low risk activities, reading and signing a procedure is acceptable. For high risk activities, ITM have Competency Assessments, where staff are shown an activity by a trainer and are then required to demonstrate it back to them to a required standard. Ongoing training is provided by Toolbox talks (short training sessions on the shop floor provided by a supervisor) on particular subjects. These are backed up by a questionnaire to ensure they understood their training. Scores are logged to note trends in data.

Alternatively, employees may be sent on training courses, either internal or run by external companies. Feedback is sought from attendees after the course and those judged to be inadequate are not used again.

Despite these procedures, it is acknowledged that staff competency will grow with time, thus a novice commissioning engineer will not be allowed on site without being accompanied by someone with over a year of experience.

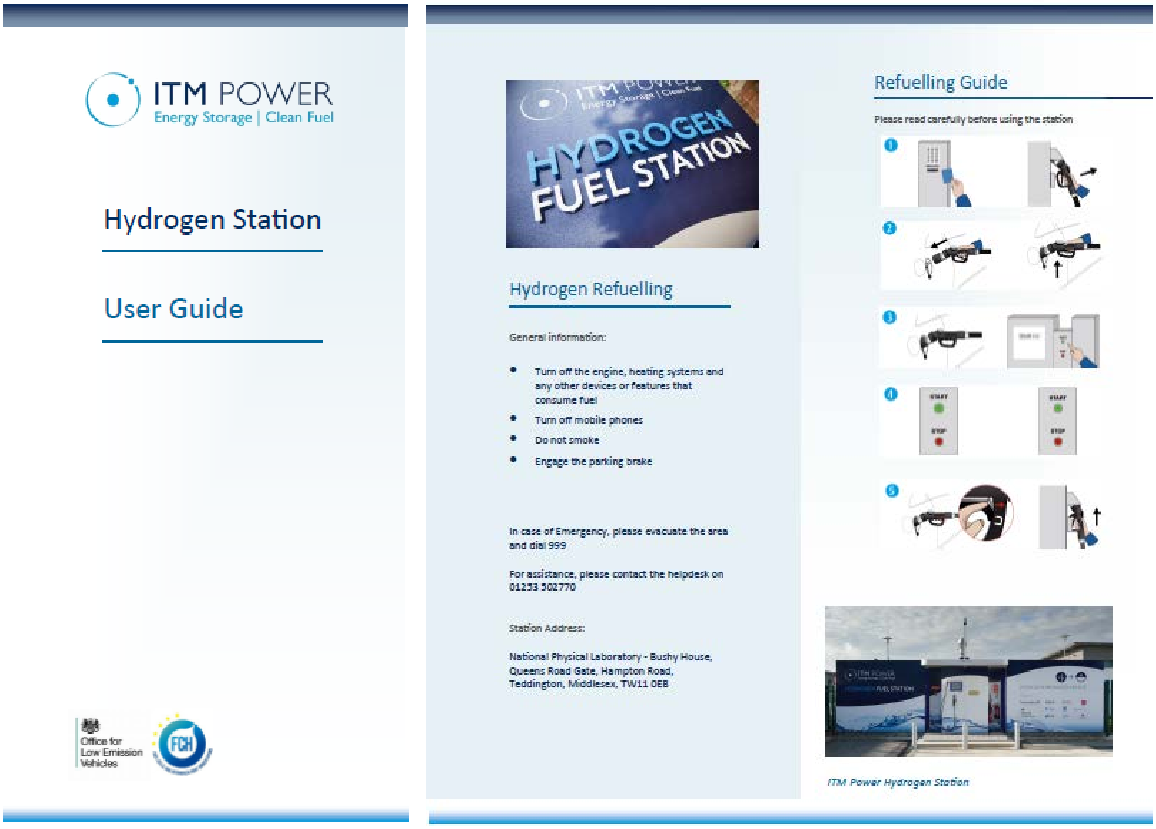
### 4.1.2 Commissioning Engineers from Partner Companies

The suppliers of the compressor/disperser will be required to come on site for several days to commission their equipment. ITM will treat them as any other contractor and follow the requirements of procedure HSMS OP05 Managing Contractors. This requires them to provide method statements, risk assessments and evidence of competency ahead of their arrival at site.

Key H&S information is shared between partners on a shared Cloud drive, with regular meetings to discuss progress.

### 4.1.3 Public Refuelling Operatives

They will be provided with training and handed documentation, a copy of which (for another refuelling station) is provided below:


ITM POWER
Energy Storage | Clean Fuel

Hydrogen Station

User Guide

Office for Low Emission Vehicles

HYDROGEN FUEL STATION

Hydrogen Refuelling

General information:

- Turn off the engine, heating systems and any other devices or features that consume fuel
- Turn off mobile phones
- Do not smoke
- Engage the parking brake

In case of Emergency, please evacuate the area and dial 999

For assistance, please contact the helpdesk on 01253 502770

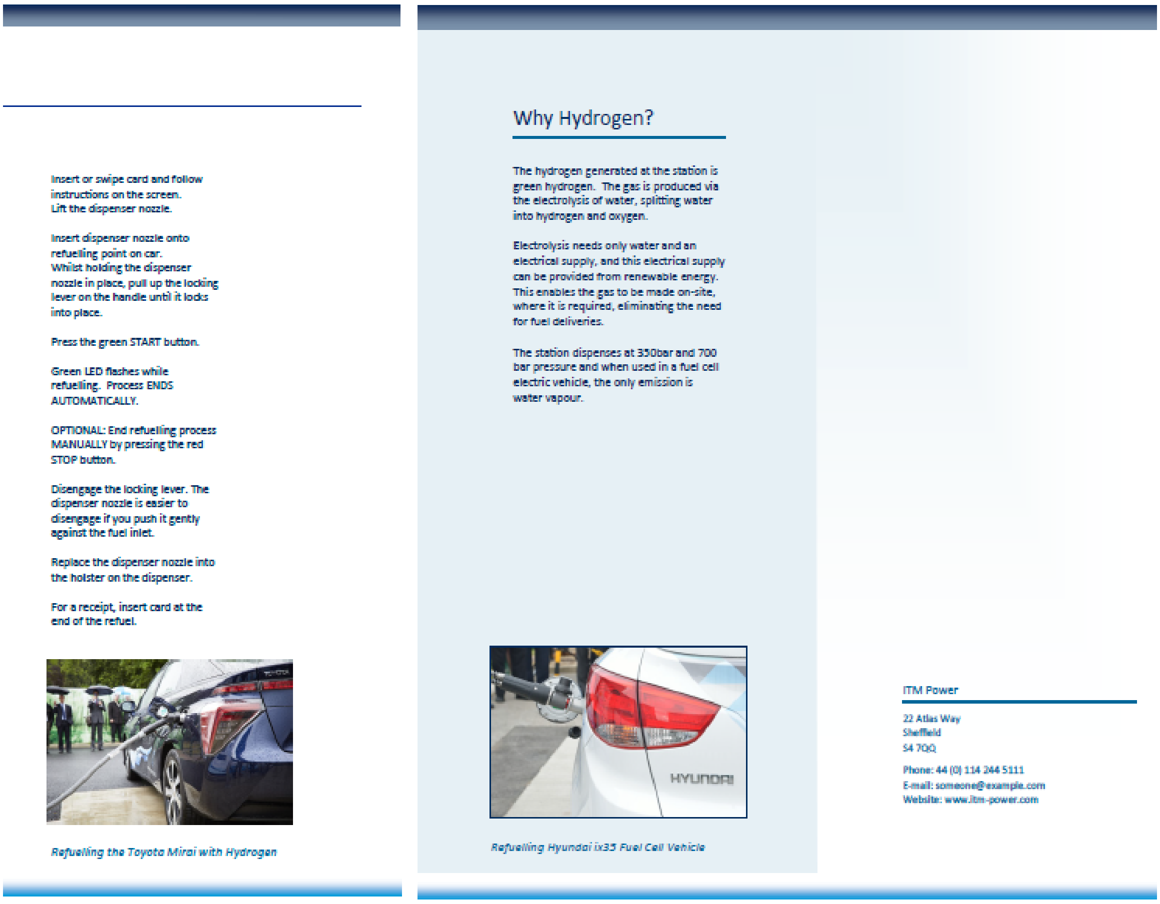
Station Address:

National Physical Laboratory - Bushy House, Queens Road Gate, Hampton Road, Teddington, Middlesex, TW11 0EB

Refuelling Guide

Please read carefully before using the station

*ITM Power Hydrogen Station*



Insert or swipe card and follow instructions on the screen.
Lift the dispenser nozzle.

Insert dispenser nozzle onto refuelling point on car.
Whilst holding the dispenser nozzle in place, pull up the locking lever on the handle until it locks into place.

Press the green START button.

Green LED flashes while refuelling. Process ENDS AUTOMATICALLY.

OPTIONAL: End refuelling process MANUALLY by pressing the red STOP button.

Disengage the locking lever. The dispenser nozzle is easier to disengage if you push it gently against the fuel inlet.

Replace the dispenser nozzle into the holster on the dispenser.

For a receipt, insert card at the end of the refuel.

*Refuelling the Toyota Mirai with Hydrogen*

Why Hydrogen?

The hydrogen generated at the station is green hydrogen. The gas is produced via the electrolysis of water, splitting water into hydrogen and oxygen.

Electrolysis needs only water and an electrical supply, and this electrical supply can be provided from renewable energy. This enables the gas to be made on-site, where it is required, eliminating the need for fuel deliveries.

The station dispenses at 350bar and 700 bar pressure and when used in a fuel cell electric vehicle, the only emission is water vapour.

*Refuelling Hyundai ix35 Fuel Cell Vehicle*

ITM Power

22 Atlas Way
Sheffield
S4 7QQ

Phone: 44 (0) 114 244 5111
E-mail: someone@example.com
Website: www.itm-power.com

*Figure 6. User guide supplied to the public*

Refresher courses will be provided.

## 4.2 Safety Reviews

There are several stages in the project where the safety of the system will be reviewed. These include:

### 4.2.1 Design review

Usually an informal process early in the design where a team of engineers from different disciples discuss the design and highlight any obvious problems. This enables the formal hazard studies to work from a better design and not end up redesigning during the studies.

### 4.2.2 HazID:

A high level examination of the equipment and site looking for a wide range of hazards. This has been described in detail in Section 3.3

### 4.2.3 HazOp:

A methodical risk-based review of the process system looking for every possible way it could fail. This has been described in detail in Section 3.1

### 4.2.4 LOPA:

A method to quantify the risk that a plant presents, to be compared to government acceptable levels. This has been described in detail in Section 3.2

### 4.2.5 Risk Assessment:

A semi-quantitative method of risk binning for both process and non-process risks. This has been described in detail in Section 3.4

### 4.2.6 Pressure Safety Case

A document in a set format that describes the pressure systems, calculations for things such as pressure relief valve sizing, and all certificates and declarations of compliance from suppliers. This is described further in Section. 3.13

### 4.2.7 HazLoc Safety Case

This is a document in a set format that describes the system and possible ignition sources and how they are controlled. It includes assumptions of hole sizes and calculations of jet lengths and the requirements of NFPA2. The document concludes with the hazardous area drawings and the declarations of conformance from the suppliers of all HazLoc equipment.

### 4.2.8 Project Stage Gates:

A total of 7 reviews and stage gates are built into the project to ensure that all of the requirements are met before the project can move on. This will prevent the design/build moving forward without the correct studies having taken place. The stage gates include:

- Technical Review 1: Ensure key docs are created to allow progress to product design. Recorded on form F6.14. Signed by the CTO and Operations Director
- Gate 2: Production design review. Recorded on form F6.12. Signed by the CTO and Operations Director
- Gate 3: Production review. Recorded on form F6.33. Signed by the Production Manager, CTO and Operations Director
- Technical Review 2: Ensure factory commissioning checks, tests and reports completed. Recorded on form F6.34. Signed by the Head of Commissioning and Operations Director
- Gate 4: Product readiness for Shipping. Recorded on form F6.35. Signed by the CTO and Operations Director
- Technical Review 3: Ensure site commissioning checks, tests and reports completed. Recorded on form F6.36. Signed by the Head of Commissioning and Operations Director
- Gate 5: Customer product acceptance form. Recorded on form F6.37. Signed by the customer and a representative of ITM.

### 4.2.9 Workplace Inspections:

These are regularly undertaken by the site H&S Manager and a second senior manager to ensure that H&S procedures are being adhered to.

### 4.2.10 Site Inspections during Ground Works:

During the building phase the site manager will make regular visits to the site to ensure that the build is on target and that contractors are adhering to ITM H&S procedures, specifically HSMS OP05 Managing Contractors.

### 4.2.11 Site Inspections During Operation:

Once operational, ITM require the site to be visited once per week to make a series of basic checks, such as water / hydrogen leaks, check pressures in bottles air and whether the site is secure. This will be conducted by a subcontractor who is familiar with hydrogen technology and is trained by ITM.

### 4.2.12 Maintenance Visits

ITM require a major and minor services each year, each offset by 6 months. These will be conducted by trained ITM engineers and will involve the review of a range of equipment including:

- Inspection of the system, looking for corrosion or damage
- Leak testing of pressure systems
- Calibration of sensors
- Functional testing of all safety systems

### 4.2.13 Document Reviews

Safety documents will be reviewed under the following circumstances:

- After a set period: HazOps and LOPAs are reviewed every 5 years and risk assessments are reviewed annually.
- If the system changes: As described in Section 3.14, documents are updated as part of the change management procedure
- In response to an accident, incident, reactive audit, proactive audit or changes in:
    - Legislation
    - Industry practice / guidance
    - Hazards associated with adjacent properties

## 4.3 Safety Events and Lessons Learned:

While Section 3.3 of ITMs H&S Policy describes the generality of dealing with and investigating incidents, specific guidance is provided in SP7.8 Standard Procedure for Reporting Investigating and Analysing Incidents. The forms for investigating the incident depend on the type of incident:

- Form 8.22 Accident Reporting Form should be used if there was an injury
- Form 8.23 Near Miss and Incident Reporting Form should be used if there was not an injury

The summary of the procedure is:

### 4.3.1 The reporting procedure within the organization

**For minor injuries:**

- Obtain first aid treatment/assistance for any injuries
- Investigate the accident using the form F8.23 as soon as possible after the occurrence and within 12 hours by the Health and Safety Manager, with any relevant staff.

**For Reportable Injuries** (as defined by OSHA)**:**

- Take patient to hospital
- Preserve the accident scene, take witness statements
- Complete Form 300, and summary Form 300A

**For severe Injuries** (as defined by OSHA):

- Take patient to hospital
- Preserve the accident scene, take witness statements
- For fatalities, report to OSHA within 8hrs, otherwise within 24hrs.

In all but the most minor or cases (cuts and abrasions) an investigation should be conducted to establish the causes and root causes.

### 4.3.2 The Method and Procedure used to Investigate Events

If there was an injury, use Form 8.22 Accident Reporting Form, otherwise use Form 8.23 Near Miss and Incident Reporting Form, however, both forms follow a similar format. Key sections from the accident form is provided below:

- Address of company
- Location of accident
- Details of injured person
    - Name
    - Works number
    - Position
    - Address
    - Normal hours of work
- Details of the accident
    - Place
    - Time of accident
    - Time reported
    - Sketch or photograph of the scene
    - Was the person authorised to conduct the task?
    - Was the person trained to conduct the task?
    - A description of the accident
    - Do risk assessments, toolbox talks or standard procedures exist that cover the incident?
    - Was the injured person aware of the assessments, toolbox talks and standard procedures?
    - Was the injured person adhering to the risk assessment and / or tool box talk and / or safe system of work?
- Witnesses
    - Name
    - Position
- Was the injured person able to continue normal duties
- Could protective clothing / equipment have prevented the injury?
- Treatment details
    - Type of injury
    - Treatment given by
    - Treatment
- Statement of the injured person
- Statements of witnesses
- Interim conclusion:
    - Immediate cause of accident
    - Underlying cause of accident
    - Root cause of accident
- Actions
- Review of recommended action (completed by appropriate manager / director)

### 4.3.3 How Corrective Measures will be Implemented

As can be seen from the detail for the accident / near miss investigation detailed above, it requires actions to be written down and then confirmed by a manager / director that they have been completed.

In addition, all accidents are discussed at the company's monthly H&S Committee meeting and accident statistics are compiled annually, looking for trends which could indicate an underlying problem.

### 4.3.4 How lessons learned from incidents and near-misses are documented and disseminated

As previously described, the actions to prevent a reoccurrence are written down on the accident investigation form and are disseminated to ITM's H&S Committee. This includes senior managers, directors, and representatives of employee safety, all of whom disseminate relevant information to staff.

Incidents involving hydrogen are reported to the h2tools/lessons website for international dissemination.

## 4.4 Emergency Response

The response to an emergency is determined by the HRS's Emergency Plan. This is a document (based on a set format) that ITM put together for each HRS and comprises two parts:

- The main document which is shared between ITM, contractors, first responders, the landlord and other stakeholders. This provides details of:
    - Background information of the site
        - Equipment
        - Volumes and pressures of hydrogen on site
    - Roles and responsibilities at the HRS
    - Fire plan
        - Fire plan principles
        - Fire prevention procedures
        - Means of escape
        - Process for raising an alarm (including interaction between the sites automated system for dialling the fire service, site security, the fire service and ITM)
        - Testing of the fire alarm
    - How to turn off power to the site (E-Stops and at the local substation)
    - Evacuation of adjacent buildings
- A simpler appendix to be shared with members of the public using the refuelling station as well as being displayed at the HRS. This includes:
    - Simple instructions for what to do in the event of an emergency
    - Location of evacuation point
    - Location of Fire glass break points, Equipment E-Stops and Global E-Stops.

ITM recognise the critical role that first responders have in an Emergency Response. As well as having a familiarisation visit to the station before it is operational, they will be provided with key pieces of information including the Emergency Plan, Maintenance Plan and the guide for users of the station.

## 4.5 Self Audits

In line with ITM's Health and Safety and Quality management systems, ITM proactively look for potential problems with paperwork and physical systems through the use of internal audits, based on procedure QMS OP26 Internal Audit. In addition, ITM may conduct a reactive audit in response to an event, (eg a supplier has alerted ITM to a problem with a part).

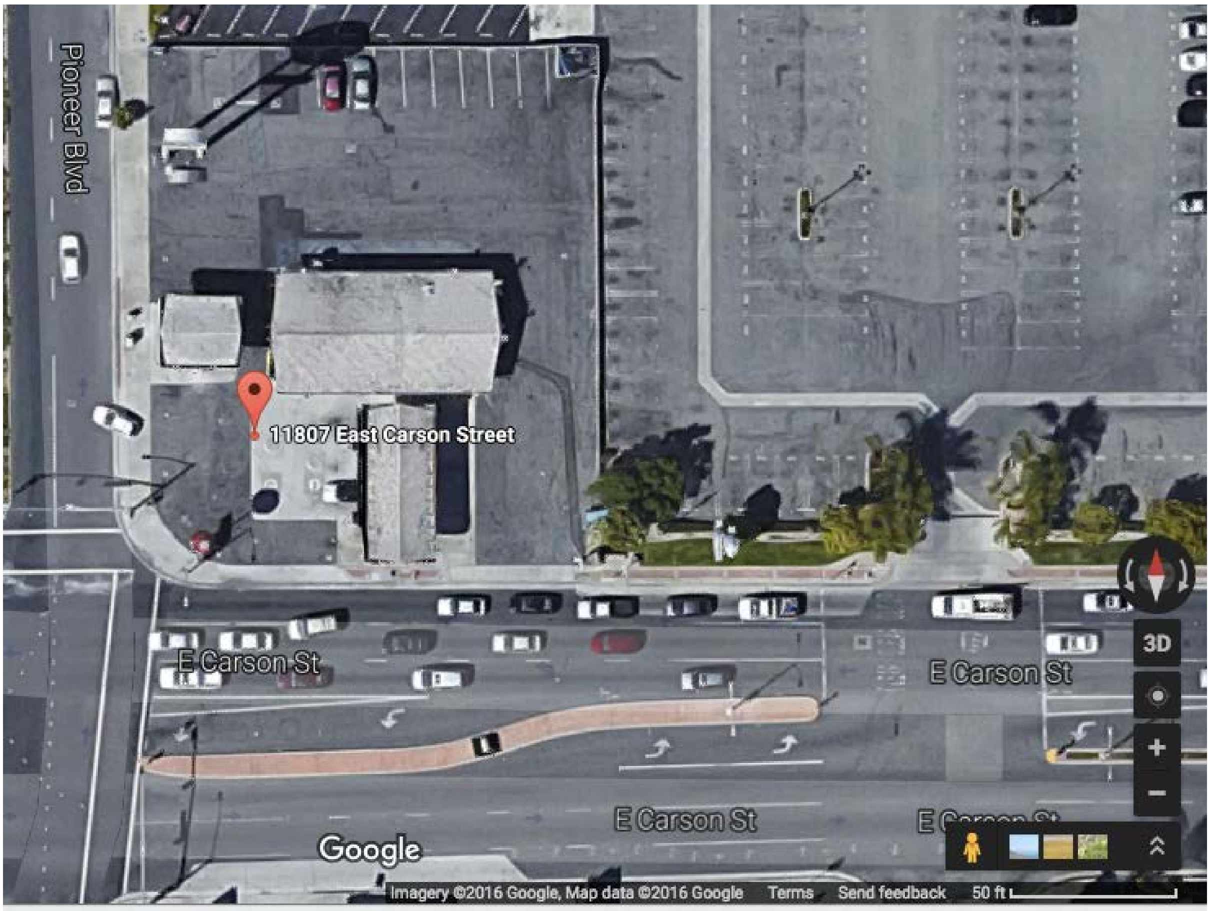
ITM have several members of staff who are trained to conduct internal audits and have forms to complete to record results (Form F2.02).

## 4.6 Process Flow Diagram

The PFD for the stations will be provided as a separate document.

# 5 Appendix A – site specific factors

## 5.1 Site 1 – Hawaiian Gardens




This site is located on an existing fuel station and is next door to commercial space. The station will be constructed in the North-East corner of the lot and fire walls will be used to limit the extent of setbacks on the site.

The site has good access for engineering staff and the public and is not backed onto by any local residences or occupied space and has a retaining wall at the rear perimeter.

The area that will house the hydrogen equipment on this site is set back from the main building and the electricity service panel and so electrical zoning is not considered to be a problem.

It is not anticipated that this site will cause any additional/specific safety concerns.

# Safety Plan

# 6 Scope of Work

## 6.1 Background

This document describes the safety plan for the ITM Power hydrogen refuelling station (HRS) located at the following address:

| Site # | Location |
|---|---|
| 2 | 1165 43rd Ave, Sacramento, CA 95822 |

Each station has the capability to dispense a minimum of 180kg of high quality hydrogen at 700 bar to fuel cell electric vehicles (FCEVs) each day. This hydrogen can be generated on-site via the electrolysis of water by renewable electricity, or the importing of hydrogen via a tube trailer.

ITM Power Inc. (ITM) are the station owner and provider of the electrolysis equipment and thus have a duty to ensure the safety of its staff, customers and others affected by the operation of this equipment. This document, based on Safety Planning for Hydrogen and Fuel Cell Projects[4], summarises the key evidence that ITM use to justify that the hazards on site are controlled and minimised to As Low As Reasonably Practicable (ALARP).

## 6.2 General Site Layout

Each site will comprise of the following components:

- A parking / refuelling area for vehicles
- A hydrogen dispenser
- A secure compound which will contain:
  - A hydrogen generator (electrolyser) in a shipping container
  - A low pressure (50 bar) buffer tank
  - A compressor in a shipping container
  - High pressure (up to 1000 bar) storage
  - A parking area for a hydrogen tube trailer
  - A connection panel for the tube trailer
  - E-stop and safety system including UV/IR detectors and hydrogen leak detection devices

## 6.3 Site Specific Layout

The specific layouts of each site are described in section 5 together with a description of any site specific safety related factors

[4] By the Hydrogen Safety Panel

## 6.4 Project Phases

This will be a commercial HRS with the work divided into distinct phases of:

- Design
- Assembly
- Factory commissioning
- Site installation
- Site commissioning
- Commercial operation
- Eventual site decommissioning

Of these phases, only site commissioning and commercial operation will generate significant quantities of hazardous material (hydrogen). The amount of hydrogen generated, stored and used for each of these phases is summarised below:

| Phase | $H_2$ Generated | $H_2$ Stored | $H_2$ Used |
|---|---|---|---|
| Site commissioning | ~50kg | 95kg | None |
| Commercial operation | Max 180kg per day | 95kg | max 180kg per day |

For all other phases of the project, safety will be ensured through compliance with ITMs ISO9001 quality management system and OHSAS 18001 Occupational Health and Safety Management System, and by following regulatory codes, such as NFPA2. As this safety plan is focussed on hydrogen specific safety, the remainder of this document will focus on the commissioning and operation phases of the project – this approach was discussed and agreed with the hydrogen safety panel (Nick Barilo).

Several types of personnel will be on-site:

- Public users of the refuelling station. They will receive both written and verbal training in the use of the equipment before they are allowed to use the station. They will also be required to attend a periodic refresher course.
- Site staff: The HRS will utilise local staff to respond to shutdowns and perform regular basic checks of the system (primarily checking for loss of containment of water or hydrogen). They will be trained by ITM (including verbal training and being supplied with documentation) but will be subcontracted to a company offering this service to a range of HRS. Thus they will be familiar with the general hazards of hydrogen and have some specific knowledge of the site. They will be required to attend an annual refresher training course.
- Commissioning / servicing staff. These are ITM engineers who have a detailed understanding of the equipment and are very familiar with the hazards associated with hydrogen and its associated technology. They have had extensive training and will continue to have a rolling program of updates (see Section 4.1)
- Builders. These will be on-site for several months preparing the location. They will be selected, and their OH&S training confirmed before they enter site, in line with ITM's written procedures. However, no hydrogen will be present.

Additional details of training are provided in Section 4.1.

Until commercial operation, the phases will be managed by ITM's Operation Director, Helio Bustamante. Once in the commercial phase, the site will be managed as a business by Steve Jones, ITM's Managing Director.

## 6.5 Permitting

The following permits will be required before operations on site can commence, this varies from city to city but each of the components listed below are incorporated into the permitting process, this section is described in more detail in the project narrative section of the GFO proposal. Each location will be assigned an Authority Having Jurisdiction (AHJ) and ITM has made initial contact will all relevant AHJ's in our station locations:

- Planning Permit
- Building Permit
- Electrical Permit
- Fire & Safety Permit

# 7 Organisational Policies and Procedures

ITM have an extensive Health and Safety Policy, which governs all of its operations. It includes a policy statement, the company objectives, the organisational structure and arrangements in place to ensure the prevention of harm. The full document is too long to include here, but is available on request. However, a copy of the Statement of Intent signed by ITM Power's CEO is presented below:

## STATEMENT OF INTENT

### HEALTH & SAFETY POLICY STATEMENT

ITM Power Plc is involved in the research and development and supply of clean fuel technology. Our aim is to provide the technology necessary to make the hydrogen economy a commercial reality and replace hydrocarbon fuels and hence society's total reliance on their constant supply.
We recognise that our employees are our most valuable assets and we are therefore committed to ensuring that the highest possible standards of Health, Safety and Welfare are maintained.

ITM is committed to-

- Ensuring so far as is reasonably practicable, the health, safety and welfare of all employees at work and of all persons not directly employed by the company, but who may be directly affected by its activities
- Identifying and managing hazards and associated risks for all activities carried out at ITM or by ITM employees
- Complying with all applicable OH & S legislation, codes of practice and any other requirements to which ITM subscribes
- Continual improvement to deliver improved OH & S Standards and performance

ITM will achieve these commitments by-

- Adhering to the OH&S Management System specifications outlined in the international standard ISO 18001
- Setting and reviewing OH&S objectives, targets and management programmes;
- Implementing an internal audit programme to measure compliance with our planned OH&S arrangements and the requirements of ISO 18001
- Providing training for all personnel working for and on behalf of ITM, including contractors to ensure they are aware of the requirements of this OH&S policy statement, how their activities can impact on the Safety of themselves and others, and their OH&S responsibilities
- Regularly reviewing both the Policy and the OH&S management system to ensure continued relevance to the organisation

This policy is publicly available on demand.

Signed......G Cooley......

Dr. Graham Cooley
CEO ITM Power (PLC)

06/11/15

In addition, it is felt useful to include the contents pages to provide an indication of the topics covered:

# CONTENTS

In addition to the overall policy, each process through the design, manufacturing, factory commissioning and site commissioning are governed by over 200 procedures that cover quality, H&S and environmental management. .

## 7.1 Hydrogen and Fuel Cell Experience

ITM have been operating for 15 years, initially as a research company (studying fuel cells and electrolysers) and then as a manufacturers of electrolysers and as system integrators. This has allowed ITM to gain knowledge of range of hydrogen technologies including (but not limited to):

### 7.1.1 Electrolysers:

- PEM electrolysers
- Liquid alkaline electrolysers
- APEM electrolysers
- Connection of electrolysers to PV, wind turbines and tidal turbines

### 7.1.2 Fuel Cells:

- Static Hydrogen fuel cells
- Mobile hydrogen fuel cells (cars, vans, fork lifts, pallet trucks)
- Marine based fuel cells
- Methanol fuel cells
- Sodium borohydride fuel cells

### 7.1.3 Compressors:

- Mechanical compressors

- Ionic compressors

### 7.1.4 Storage:

- Stainless steel hydrogen storage (Type I)
- Composite hydrogen storage (Type II to IV)
- Metal hydride storage
- Hydrogen tube trailers

### 7.1.5 Hydrogen Transportation:

- Transporting of hydrogen by road (ADR)
- Transporting of hydrogen by sea (IMDG)

### 7.1.6 End Uses of Hydrogen:

- Hydrogen combustion in vehicles
- Hydrogen combustion in static boilers
- Hydrogen dispensing (including protocols, and design and operation of hydrogen refuelling stations)
- Injection of hydrogen into the gas grid

### 7.1.7 Conversion of hydrogen to other fuels

- Reacting of hydrogen to form methane (via both chemical and biological methanation)
- Reacting of hydrogen to form ammonia and urea
- Reacting of hydrogen to form diesel

With specific reference to this application, ITM has 15 current hydrogen station projects either built or in the process of being built. While some of these have been sold to and are operated by third parties, most are owned and operated by ITM. As such, ITM are very familiar with the processes and technology required to make a safe and reliable HRS.

Engineers will be on site for commissioning, which is identified as an activity with increased risk. As such, work will always be conducted with pairs of engineers, able to discuss potential problems. One engineer will always have at least 1 year of experience.

In addition to practical experience of designing, building and operating refuelling stations, ITM are heavily involved in the writing of national, regional and international standards for HRS:

- ITM staff also lead the UK delegation to ISO TC 197 and are secretary of ISO TC 197 WG24, covering hydrogen vehicle fueling station safety standards (ISO 19880-1).
- ITM contributes to ISO TC 197 WG26, covering electrolyser safety standards (ISO 22734); WG27 & WG28, covering hydrogen quality standards for fuel cell use (ISO 14687 & ISO 19880-8); and WG19, covering the safety standard for hydrogen dispensers (ISO 19880-2).
- An ITM staff member currently serves as chair of British Standards Institute (BSI) committee PVE/3/8 and the UK lead expert to the Comité Européen de Normalization (CEN) TC 268, WG5 preparing hydrogen refueling station standards to be harmonized to the European Directive 2014/94/EU on the deployment of alternative fuels infrastructure.
- ITM staff also serve as secretary of the British Compressed Gases Association (BCGA) Technical Sub-Committee (TSC) 9, and led the development of the industry code of practice (CP) BCGA CP41 - The design, construction, maintenance and operation of filling stations dispensing gaseous fuels. Additionally, through the BCGA, ITM are involved with the Energy Institute (EI) and Association for Petroleum and Explosives Administration (APEA) in the development of an Addendum to the Blue Book to facilitate hydrogen fueling co-located with petrol dispensing forecourts in the UK.

# 8 Identification of Safety Vulnerabilities

ITM rely on several techniques to identify safety vulnerabilities within its hydrogen refuelling stations, these are executed at different stages of the project to ensure constant analysis of risk and to allow any new risks to be highlighted and considered as the project develops.

## 8.1 Hazard and Operability (HazOp) Studies

ITM conduct two HazOps – one at the design stage and one at the as-built stage (which takes into account any code or assembly modifications introduced during the build and factory commissioning process). Each study is conducted by a team of several engineers, with representatives, from the Process, Electrical and Safety Engineering teams to ensure a wide spread of skills. While novice engineers are encouraged to participate, there will always at least three team members who have conducted at least 10 previous studies, to ensure the correct depth of knowledge. Teams are led by a chairperson who has considerable HazOp experience and has attended a HazOp Leaders course.

The studies require the process and instrumentation diagrams (P&IDs) of the site to be divided into nodes (often based around the fluid media or pressure). Keywords are then considered for each node, such flow, temperature and pressure. Then for each keyword, deviations are studied, such as No Flow, More Flow, Flow Elsewhere etc., where the possible causes, consequences and prevention systems for each are detailed. Each of these deviations are conducted as semi-quantitative risk assessments, with numbers assigned for likelihood, consequence and final risk for both the safety and operability of the plant. Rules are then applied to determine whether the system is adequate, or whether an action is required to lower the risk. Any deviation that could result in a fatality (no matter how small the likelihood) is referred for further consideration in a Layer of Protection Analysis (LOPA).

Several HazOps have been conducted that cover the HRS. These are available on request.

## 8.2 Layer of Protection Analysis (LOPA)

LOPA is a standard tool within the process engineering industry, but as yet, is not widely used within the hydrogen industry. The technique takes specific scenarios (such as overpressure) and initiators that could cause the scenario (such as sensor failure) from the HazOp study and attempts to determine the likely frequency of a fatality based on such things as the frequency of an initiator occurring, the independent layers of protection in place to prevent that deviation resulting in the scenario (hydrogen detectors, pressure relief valves, HazLoc equipment etc) and the likelihood of someone being on site.

The risks are then totalled and compared to government standards, which have thresholds for:

- Risk is unacceptable
- Risk is tolerable if As Low As Reasonably Practicable (ALARP)
- Risk is broadly acceptable

A site will usually be found to be within the 'tolerable if ALARP' region. Therefore a Cost / Benefit Analysis (CBA) will be conducted. Again, this follows an approved methodology to determine whether the cost of introducing a risk reduction measure is worth the incremental benefit it will bring. If all of the high risk initiators are shown to be ALARP, then the risk that the site presents is considered tolerable.

The LOPA and CBA studies are normally written by an engineer experienced in the technique, but are then reviewed as a team exercise, usually with process engineers. This may go through several iterations until all team members are happy with the study.

The LOPA and CBA studies are site specific and therefore will be conducted for the each HRS after a contract is awarded. Examples of previous LOPA and CBAs for similar HRS can be provided on request.

## 8.3 Hazard Identification (HazID)

While HazOps and LOPAs are good at identifying weaknesses in the sites process engineering, they do not consider non-process dangers, such as slips, trips and falls, adverse weather, vandalism etc.

The purpose of a Hazard Identification (HazID) study is to take a high level examination of the risks (particularly non-process risks) that the system presents to ensure that they will be considered in detail during subsequent studies, in many ways it is similar to both fault and event tree analysis. This ensures that the hazards considered in the Risk Assessment are based on an objective assessment, and not the subjective views of the author.

ITM use a standardised list of hazards (published by Burk, 1992, as referenced in DOE Handbook, 2004). While it is acknowledged that pre-prescribed lists can limit thinking about hazards, this is out-weighted by the benefits of having an objective list and not overlooking a risk.

The HazID study is site specific and will therefore be completed for each HRS once a contract is awarded. Examples of previous HazIDs for similar HRS can be provided on request.

## 8.4 Risk Assessment (RA)

The ITM risk assessments are designed to be compliant with ISO 14121-1 Safety of Machinery, as required in Section 5.1 of ISO 22734-1 Hydrogen Generators using Water Electrolysis Process.

The ITM RA is semi-quantitative and considers the hazards for the site (both process and non-process), their likelihood of occurring the consequences of an occurrence, and then calculates the risk. Based, on this risk, it considers if additional risk control measures are required.

The RA study is site specific and will therefore be completed for each HRS once a contract is awarded. Examples of previous RAs for similar HRS can be provided on request.

## 8.5 Safety Critical Equipment

Control for the plant is overseen by a Site PLC, which communicates with individual equipment PLCs, particularly the electrolyser, dispenser and the compressor. Equipment PLCs will automatically shut themselves down for process errors that could result in safety problems (e.g. flow of water to stacks too low) are communicated to the site PLC, which in turn triggers a site-wide shutdown.

In addition, there are specific safety PLCs/circuits which are independent of the process PLCs. These monitor key safety equipment which if triggered indicate that an emergency situation is already present such as  smoke alarms, hydrogen alarms, fire detectors and E-Stops (full list is below) and can initiate a site-wide shutdown. Non-instrumented safety systems include earth bonding and pressure relief valves.

All safety critical equipment is guaranteed to be functional in a hydrogen environment, ITM never use generic safety equipment. If there is any doubt to a products applicability to a hydrogen environment the product will not be used.

All safety systems are functionally tested during regular servicing and are highlighted within the maintenance manuals to ensure ongoing safety is maintained. Replacement and/or recalibration of all safety critical equipment is conducted in line with or sooner that the manufacturers guidelines.

The full list of equipment on monitors on safety circuits (not the process PLCs) is provided below:

**Electrolyser**:

- 4x PRV
- Smoke detector
- 2x $H_2$ detector

**Buffer tank**:

- 2x PRV
- Fire detector

**Compressor/dispenser**

- 4x PRV
- 3x Fire detector
- 4x Pressure transducers
- 3x Temperature transducers

## 8.6 Hazardous Materials

The key hazardous material considered here is hydrogen. Other hazardous materials are present on the plant (ambient pressure oxygen, hydraulic oil and glycol), but are considered low risk.

### 8.6.1 Source:

- Hydrogen generation via electrolysis at a maximum rate of 85kg per day
- Hydrogen supply via a tube trailer.

### 8.6.2 Storage:

Materials will be stored on site in certified vessels at the following approximate volumes and pressures:

| Description | Pressure (bar) | Mass $H_2$ stored (kg) |
|---|---|---|
| Buffer tank | 50 | 2 |
| Intermediate pressure storage | 200 | 4 |
| High Pressure storage | 85 | 1000 |
| Tube trailer | 350max | 250 |

In addition, small volumes of hydrogen will be located in the electrolyser, compressor and interconnecting pipework.

### 8.6.3 Ignition Sources:

The site is compliant with NFPA2, and therefore there should be no ignition sources. A full HazLoc safety study will be conducted for each site, but in summary:

- For high pressure fittings, there are no ignition sources within the hazardous area zone extents defined in NFPA2
- For the high-level hydrogen vents, there are no ignition sources within the hazardous area zone extents defined in NFPA2
- Where electrical equipment is used within a hazardous area, it is appropriately HazLoc rated for the class and division required.
- The dispenser is vented after use, in line with refuelling station guidance

- Fire walls are provided to reduce zone extents and prevent hazardous areas extending into uncontrolled areas
- Commissioning / maintenance engineers are trained to operate around high pressure flammable gases and have appropriate personal protective equipment.

### 8.6.4 Explosion Hazards:

There are several potential explosion hazards identified in the HazOp and LOPA:

- Catastrophic leak, followed by ignition in the electrolyser or compressor containers
- Catastrophic leak from an external fitting, followed by ignition
- The heater in the gas dryer remains engaged, softening the pressure vessel, leading to catastrophic failure
- External fire, softens pressure vessels on site, leading to catastrophic failure
- Jet fire from a fitting leak impinges on pressure vessels, locally softening them and leading to catastrophic failure
- Failure of logic/equipment controlling the ramp rate of hydrogen into the vehicle, leading to overheating of the vehicle tank, softening and catastrophic failure.
- Failure of logic/equipment controlling the pre-chilling of the hydrogen entering the vehicle, leading to overheating of the vehicle tank, softening and catastrophic failure.
- Failure of the logic to stop hydrogen generation / compression at the required pressures, leading to over pressurisation and catastrophic failure of equipment

All of these have been assessed in detail as part of the LOPA and the risks are within tolerable levels.

### 8.6.5 Material Interactions

All materials used have been selected to be compatible with each other and the media they will be exposed to. The obvious potential material interaction is the embrittlement of materials with hydrogen. An example of where this went wrong is the Emeryville refuelling station fire in 2012. ITM process engineers go to great lengths to ensure that all of the parts that will be exposed to hydrogen will not embrittle; this is backed up by manufacture declarations and, where appropriate, material compatibility reports which are stored in the project technical file.

### 8.6.6 Possible Leakage

There are numerous possible sources of hydrogen leaks in the site. This includes:

- From all mechanical fittings (this is minimised where possible by using welded fittings)
- From valve seats (both between different parts of the hydrogen system, and between the hydrogen system and vents)
- From the compressor seals
- Through non-return valves failing to check

The likelihood (based on industry data) and consequence of leaks from all sources have been considered at two levels:

- Non-catastrophic. This is required for HazLoc calculations (which specifically excludes catastrophic failure). ITM use a hole size of $0.25mm^2$
- Catastrophic (100% of area)

The risks of these have been semi-quantitatively assessed by ITM, and determined to be tolerable.

### 8.6.7 Accumulation

The HRS is designed to prevent the gas becoming trapped and is equipped with effective high and low level ventilation openings. Any points of possible leakage are either covered by appropriate gas detection, in an area where a leak cannot accumulate or is freely ventilated.

### 8.6.8 Detection:

The detection of a hydrogen leak is achieved in many ways, including:

- Direct detection with hydrogen detectors in indoor locations, where the detector is located at the highest point.
- Indirect detection by:
  - Unexpected pressure drop during operation
  - Pressure hold test (where electrolyser generation or flow to the vehicle is paused and the system monitors the pressure for evidence of leaks)
  - Failure to pressurize the system within certain durations

Should the leak become ignited, this can be detected in other ways including:

- Smoke sensors
- Heat sensors
- UV/IR flame sensors

## 8.7 Site Specific Hazards

While each HRS is built to a common standard with similar hazards, each will present individual hazards associated with factors such as other fuels on site, the proximity of hazardous materials on adjacent sites or the proximity of the public to the site. The hazards for each site are described in Section 5.

## 8.8 What hazard associated with this system design, installation and operation is most likely to occur?

Based on ITM experience and numerous safety studies the hazards most likely to occur are:

- Minor hydrogen leak which pose minimal risk to the system
- Slips, trips and falls (although they will not be considered further here as this report is focussing on the specifics of hydrogen hazards)

Leak risks are mitigated by diligent maintenance procedures and leak detection strategies such as routine leak tests by staff. Slips trips and falls are mitigated by maintaining a clean and clear site and posting appropriate signage and hazard markings on the site.

## 8.9 What hazard associated with this system design, installation and operation has the potential to result in the worst consequence?

Based on the numerous safety studies the hazard with the highest consequence is:

Catastrophic failure, followed by ignition of a pressurised hydrogen store, brought about by external fire, vehicle collision or impingement by ignited hydrogen jets.
These risks are mitigated by the use of bollards and curb stones for crash protection, posting of appropriate signage on the site, the installation of shields to prevent jet impingement, UVIR sensors and by maintaining a high level of record keeping and test records for pressurised components.

## 8.10 Updates

In line with industry practice, the HazOp and LOPA will be re-assessed every 5 years, or when something on the site materially changes (see Section 4.2.13 for details)

The risk assessment will the reviewed every year, or when something on the site materially changes.

## 8.11 Risk Reduction Plan

The methods used to identify safety vulnerabilities considered hundreds of potential hazards. As requested in Safety Planning for Hydrogen and Fuel Cell Projects, only the significant safety vulnerabilities related to hydrogen will be described here in a risk binning format. As such, insignificant safety vulnerabilities or those not directly related to hydrogen will not be discussed.

**Risk Matrix** [5]

| Consequence Category | | Likelihood | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **1** Extremely Unlikely | **2** Very Unlikely | **3** Unlikely | **4** Quite Unlikely | **5** Somewhat Likely | **6** Fairly Probable | **7** Probable |
| **Very Major Catastrophic** >100 fatalities | **A** | **R8** | **R7** | **R6** | **R5** | **R4** | **R3** | **R2** |
| **Catastrophic** Overall 11 to 100 fatalities, fatalities to workers and/or public, international media exposure | **B** | **R9** | **R8** | **R7** | **R6** | **R5** | **R4** | **R3** |
| **Extremely Serious** Overall 1-10 fatalities, worker fatality, major injury to member of public. National news, prosecution and fine. | **C** | **R10** | **R9** | **R8** | **R7** | **R6** | **R5** | **R4** |
| **Major** Serious injury to worker (permanent disability). Injury to member of public. | **D** | **R11** | **R10** | **R9** | **R8** | **R7** | **R6** | **R5** |
| **Serious** Significant injury to worker. Minor injury to member of public. Adverse local publicity. | **E** | **R12** | **R11** | **R10** | **R9** | **R8** | **R7** | **R6** |
| **Minor** Minor injury to worker. Few complaints. | **F** | **R12** | **R11** | **R10** | **R9** | **R8** | **R7** | **R6** |

*Table 3 The Risk Matrix based on the likelihood and consequence of a hazard*

[5] As used in HSL report PS/08/01 “Assessing the safety of delivery and storage of hydrogen”, also “Moonis, Wilday, Wardman - Process Safety and Environmental Protection, 88, 2010, 2, 97-108 - Semi-quantitative risk assessment of commercial scale supply chain of hydrogen fuel and implications for industry and society”.

**RISK RATING = CONSEQUENCE CATEGORY x LIKELIHOOD**

Score 'Likelihood' from 1 to 7 where 1 is "Extremely Unlikely" and 7 is "Probable".

Score 'Consequence Category' from A to F where A is "Very Major Catastrophic" and F is "Minor".

Consider harm to people, the environment, damage to buildings, etc. and other potential losses to ITM such as share price.

| RISK RATING | PRIORITY | REQUIRED ACTION [6] |
|---|---|---|
| **High (R1-R5)** | **1** | High risk, not acceptable. Further analysis should be performed to give a better estimate of the risk. If this analysis still shows unacceptable or medium risk redesign or other changes should be introduced to reduce the criticality. |
| **Medium (R6-R7)** | **2** | The risk may be acceptable but redesign or other changes should be considered if reasonably practical. Further analysis should be performed to give a better estimate of the risk. When assessing the need of remedial actions, the number of events falling into this risk level should be taken into consideration to assure that the risk is as low as reasonable practical (ALARP). |
| **Low (R8-R12)** | **3** | The risk is low and further risk reducing measures are not necessary. |

*Table 4. The risk rating and required actions*

[6] Taken from Table 2 of DNV report "Hydrogen Applications – Risk Acceptance Criteria and Risk Assessment Methodology": http://www.eihp.org/public/Reports/Final_Report/Sub-Task_Reports/ST5.2/EHEC%20paper_final.pdf

**Definitions:**

| | |
|---|---|
| **Hazard:** | A potential source of harm. Must be a reasonably foreseeable hazard, defined as use of a machine in a way not intended by the designer, but which may result from readily predictable human behaviour. A hazard is either permanently present during the intended use of the machine (e.g. motion of hazardous moving elements, electric arc during a welding phase, unhealthy posture, noise emission, high temperature), or can appear unexpectedly (e.g. explosion, crushing hazard as a consequence of an unintended / unexpected startup, ejection as a consequence of a breakage, or fall as a consequence of acceleration / deceleration) |
| **Consequence**: | What will happen if the hazard is realised? |
| **To Whom**: | Consider all of the people who could be injured: The operator, those in the vicinity, visitors, cleaners, contractors etc. |
| **Likelihood:** | This is the likelihood of the harm being realised in the time before the RA is next reviewed (generally a year), with all of the present control measures in place. The definition of the grades of likelihood is provided in Table 1. |
| **Severity:** | This is the severity of the accident, with all of the present control measures in place. The definition of the grades of severity is provided in the Table 1. |
| **Risk Factor:** | The product of the likelihood and severity. The definition of the grades of risk is provided in the Risk Table and the required action is summarised in Table 2. |
| **Existing Controls**: | Detail of all present control measures to prevent the harm being realised |
| **Action needed**: | Should the risk factor be too high, further control measures should be detailed. The effect of these actions on the risk factor should be considered. |

## Loss of Hydrogen Containment

| # | Hazard | Consequence | To Whom | Likelihood | Severity | Risk Factor | Existing Controls | Action Needed |
|---|---|---|---|---|---|---|---|---|
| | Loss of containment of hydrogen from **external** fittings. | Minor leaks may result in a small jet fire.<br><br>This may affect personnel and equipment that is in direct contact with it (such as the hydrogen dryer vessels – potentially leading to an escalation to a significant release).<br><br>Significant releases followed by ignition could result in deflagration and subsequent jet fire<br><br>The deflagration would be expected to cause minimal damage and only result in significant injuries to personnel in close proximity to it. | ITM operator | 2-3 | E-F | R9-R11<br><br>**Low Risk** | **Control of releases:**<br><br>• Installation of manifold connections carried out according to manufacturer's instructions.<br>• FAT includes pressure test of all parts in $H_2$ system to at least 1.43x maximum allowable pressure (unless pressure tested previously).<br>• Vessels are pre-tested for leaks as part of suppliers ASME conformance testing.<br>• Pre-commissioning prior to hydrogen production and following any invasive maintenance, includes helium pressure test of system to maximum working pressure.<br>• Regular inspection and leak testing of pressure systems according to maintenance schedule and written scheme of examination.<br>• Major leaks would result in a pressure drop, resulting in a shutdown.<br>• Assuming no additional upstream failures of check valves, the release would be limited to downstream vessel size<br>• Open air - natural ventilation to dissipate minor leakage.<br><br>**Control of ignition sources:**<br><br>• Area around potential hydrogen leak points defined as Zone 2 and all electrical components within this area are appropriately HazLoc rated to reduce likelihood of ignition sources being present.<br>• Signage warning of the presence of a hazardous area.<br>• No ignition sources or flammable materials within hazardous area.<br>• No air intakes within hazardous area. | Confirm no site pipe work runs have leak points around ignition sources or air intakes |

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| | | | | | | | **Personnel Controls:**<br><br>• A significant release would be audible to personnel in vicinity. They can instigate a shutdown from an E-Stop.<br>• Pressing E-Stop push buttons, located around HRS, immediately shots down the system, closing all valves<br>• Visual alarm located on container roof alerts staff in the case of a Shutdown<br>• Escalation of a jet fire into a fire of the adjacent properties considered unlikely. | |
| | Hydrogen leak **inside** the electrolyser stack compartment | Ignition of explosive atmosphere.<br><br>Pressure wave from resulting explosion may blow out doors / roof fans, which could become a projectile risk if detached.<br><br>Likely damage to internal equipment. | ITM operator | 2-3 | D-E | R8 -R10<br><br>**Low Risk** | **Control of Releases:**<br><br>• Installation of manifold connections carried out according to manufacturer's instructions.<br>• Pressure testing of hydrogen system to 1.43x maximum allowable pressure (PS) during FAT and SAT (1.3x for stacks differential pressure).<br>• Regular helium leak testing of pressure systems according to maintenance schedule.<br>• Pressure sensors continuously monitor hydrogen system pressure through PLC. An unexpected drop in pressure (resulting from a 'major' leak in the HGas) instigates a fast shutdown (Shutdown 2), causing de-energisation of the PSU and fast venting of the HGas hydrogen.<br>• Regular automated pressure decay test undertaken to identify presence of 'minor' HGas pipework leaks.<br>• Forced air flow rate through the stack compartment sufficient to justify a Zone 2 NE for any 'negligible' release not detected by the pressure decay test.<br>• Power to the electrolyser stacks is isolated in the case of any alarm instigating a shutdown, preventing further $H_2$ generation<br>• Non-return valves in gas handling room to minimise backflow into stack compartment in the case of a leak (limiting stored volume to less than 100 normal litres). | Ensure that labelling is in place to warn personnel to not enter the generation compartment when the system is pressurised.<br><br>Installation of signage according to D934-0041. |

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| | | | | | | | • Limited stored hydrogen in the HGas, below a quantity of ~2750 normal litres (backflow $H_2$ from HRS prevented by NRV006).<br>• Functionality of check valves will be regularly tested in accordance with Maintenance Plan.<br><br>**Control of ignition sources**<br><br>• Forced ventilation from roof fans to dissipate “negligible” leakage (i.e. not identified by pressure decay test) provide sufficient air flow for generation room to be classified a Zone 2 NE. Fans monitored by pressure switches which will shut down the HGas if the fans fail.<br>• Hydrogen sensor mounted on roof of stack compartment alarms above 25% LFL and instigates emergency shutdown through PLC. This will rapidly depressurise the electrolyser stacks and hydrogen system through the hydrogen vent to a safe location, whilst removing electrical power to the plant.<br>• Forced ventilation is sufficient that if the entire output of all three stacks were to enter the stack compartment, the release would be diluted to below the LFL. Note – ventilation fans are HazLoc and don’t present an ignition source.<br>• Audible / visual alarm located on container roof warns staff in the case of a Shutdown 1 / 2, for instance a pressure drop alarm.<br><br>**Control of ignited hydrogen:**<br><br>• Temperature sensors mounted to stack compartment ceiling alarm above 40 ºC and instigate shutdown.<br><br>**Control of projectiles:** | |

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| | | | | | | | • Container walls provide enclosure to contain projectiles.<br>• Container louvres provide some pressure relief to an internal pressure wave.<br>• Personnel not permitted inside gas generation room whilst hydrogen system is pressurised. | |
| | Hydrogen leakage from process equipment / storage inside compressor / storage compartment of the container during operation (not including dispensing system) | Ignition causing jet fire or explosion<br><br>Asphyxiation | Maintenance engineer / fuelling operative / passers-by<br><br>Maintenance engineer | 1-2<br><br>1 | B-E<br><br>C-D | R7-R11<br>Med risk<br><br>R9-R10<br>Low risk | **Prevention of leaks:**<br>• Factory testing includes pressure test of all parts in the fuelling station to at least 1.43 × maximum allowable pressure (PS) where appropriate, and where not already tested by the individual equipment / component manufacturer.<br>• Nitrogen & hydrogen leak test of manifold to 0.9 * maximum allowable pressure (PS) once on site.<br><br>**Detection of leaks:**<br>• Hydrogen sensor located inside compressor / storage compartment.<br>• Routine checks conducted by trained personnel.<br>• Regular inspection and leak testing of pressure systems according to Written Scheme of Examination / maintenance schedule.<br>• Large leak may be audible to passers-by, with emergency contact details on the fences around the station and break-glass alarm points.<br><br>**Prevention of ignition:**<br>• Compressor / storage compartment of the container defined as Zone 2 and all electrical components are appropriately HazLoc rated to | Prepare site specific emergency plan<br><br>Put label on compressor / storage compartment door to highlight entry limitations<br><br>Ensure a personnel emergency exit is included for each compound |

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| | | | | | | | reduce likelihood of ignition sources being present in the case of a leak.<br>• Intermittent forced ventilation to dissipate minor leakage.<br>• Hydrogen sensor, to increase forced ventilation at 20% LFL, and to shut down plant at 40% LFL- instigates de-energisation of compressor, closes valves that isolate high pressure storage vessels from the majority of potential leak points, closes the inlet valve from electrolyser buffer store (though this is located inside the container, the electrolyser shutdown will close the externally located buffer store isolation valve), and displays a red light above the door to the compressor compartment. Alarm also instigates emergency shut down of HGas.<br>• HazLoc-rated glands to prevent hydrogen entering adjacent control compartment from compressor / storage compartment.<br>• Compressor / storage compartment doors locked by key outside of operational checks / maintenance, also in fenced compound with locked gate.<br>• Container walls / doors contain releases inside compressor / storage compartment to prevent hydrogen released inside the container impinging on / being drawn into the air intake louvres into the control room.<br>• Compound wall between container and dispensing area minimises likelihood of ignition sources (e.g. vehicle) being in a hazardous area created by a release from within the container. Non-HazLoc rated equipment excluded from the manufacturer defined hazardous areas.<br>• Compound fence / wall preventing unauthorised access to vicinity of hydrogen | |

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| | | | | | | | equipment (other than dispenser and tube trailer connection point), and no hazardous areas that extend outside the compound boundary fence / wall.<br>• No fixed ignition sources in the hazardous areas associated with the container that extend outside the compound fence / wall (from the venting systems, above head height).<br>• No portable non-HazLoc electrical items permitted in hazardous areas when hydrogen equipment and manifold pressurised.<br>• ITM maintenance staff trained of requirement to ensure ignition sources are kept out of HazLoc hazardous areas.<br>• Hazardous area drawing indicates locations of Zones.<br>• Signage on door to compressor compartment.<br><br>**Detection of ignited jet**<br><br>• Flame detector inside compound instigates fire alarm sounder for the fuelling station, and notifies the monitoring company, who in turn can notify the fire brigade and security.<br><br>**Mitigation of ignited releases:**<br><br>• Storage cylinders protected from impingement of ignited jets from process equipment.<br>• Explosion relief designed into the roof of the container.<br>• Site separation distances conform to NFPA2<br><br>**Protection of personnel** | |

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| | | | | | | | • No personnel in compartment whilst compressor in operation or during refuelling.<br>• Only trained personnel permitted to enter container and recommended to be wearing anti-static boots in the compressor compartment.<br>• Visual alarm located on compartment door to indicate whether “safe” to enter, that turns red if 20 or 40% LFL is reached.<br>• Clearly defined emergency procedure.<br>• Emergency stop push buttons inside both compressor / storage compartment and control compartment, and on dispenser and tube trailer connection point.<br>• Site “global e-stop” push button positioned close to entrance/exit for easy fire service access.<br>• If activated, any e-stop isolates the storage vessels (see hydrogen sensor alarm above for details) and de-energises the compressor.<br>• Additional plant electrical isolation available, as explained in the emergency procedure.<br>• “Break-glass” fire alarm activator located by the exit point(s) from the compound, which notify the monitoring company, who in turn can notify the fire brigade and security.<br>• Doors to be left open during maintenance to prevent asphyxiation. Relatively small compartment and easy to exit. Whilst ladders may be required, a step is built into the design to provide an alternative.<br>• Lights (HazLoc rated in compressor / storage compartment, in the hydrogen compound and the dispensing area) remain on at all times, even when there is a hydrogen leak detected or emergency stop button pressed. Street lighting (outside of zones) will also be unaffected. | |

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| | | | | | | | • Restricted maintenance allowed when only one member of maintenance staff present. | |
| | Hydrogen leakage in manifold between buffer store, tube trailer incoming connection, and pipework leading to container hydrogen inlet, or<br><br>hydrogen leakage from pipework between container and dispenser, between container and tube trailer outgoing connection, or from the heat exchanger<br><br>(not including the pipework / manifold on the refuelling area side of the boundary wall) | Ignition causing fire or explosion | Maintenance engineer / fuelling operative / passers-by | 1-2 | C-E | R8-R11<br><br>Low risk | **Prevention of leaks:**<br><br>• Factory testing includes pressure test of all parts in the fuelling station to at least 1.43 × maximum allowable pressure (PS) where appropriate, and where not already tested by the individual equipment / component manufacturer.<br>• Nitrogen & hydrogen leak test of manifold to 0.9 * maximum allowable pressure (PS) once on site.<br>• Equipment and piping in fenced compound with locked gate.<br><br>**Detection of leaks:**<br><br>• Routine checks conducted by trained personnel.<br>• Regular inspection and leak testing of pressure systems according to Written Scheme of Examination / maintenance schedule.<br>• Large leak may be audible to passers-by, with emergency contact details on the fences around the station and break-glass alarm points.<br><br>**Dilution of leaks:**<br><br>• Natural ventilation – located outdoors<br><br>**Prevention of ignition:**<br><br>• Area surrounding potential leak points defined as Zone 2 and all electrical components are appropriately HAZLOC rated to reduce likelihood | None |

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| | | | | | | | of ignition sources being present in the case of a leak.<br>• Compound wall between container and dispensing area minimises likelihood of ignition sources (e.g. vehicle) being in a hazardous area created by a release from equipment / joints within the compound. Non-HAZLOC rated equipment excluded from the hazardous areas defined around potential release points.<br>• Compound fence / wall preventing unauthorised access to vicinity of hydrogen equipment (other than dispenser and tube trailer connection point), and no hazardous areas that extend outside the boundary fence / wall.<br>• No fixed ignition sources in the hazardous areas associated with the container that extend outside the compound fence / wall (from the venting systems, above head height).<br>• No portable non-HAZLOC electrical items permitted in hazardous areas when hydrogen equipment and manifold pressurised.<br>• ITM maintenance staff trained of requirement to ensure ignition sources are kept out of HAZLOC hazardous areas.<br>• Hazardous area drawing indicates locations of Zones.<br>• Ex signage warning of the presence of a hazardous area at entry points to compound.<br><br>**Detection of ignited jet**<br><br>• Flame detector inside compound instigates fire alarm sounder for the fuelling station, and notifies the monitoring company, who in turn can notify the fire brigade and security. | |

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| | | | | | | | **Protection of personnel**<br><br>• Clearly defined emergency procedure.<br>• Emergency stop push buttons for the electrolyser easily accessible inside the compound, which instigate a refueller shutdown.<br>• Site "global e-stop" push button positioned close to entrance/exit for easy fire service access.<br>• If activated, any e-stop isolates the storage vessels (see hydrogen sensor alarm in 4.2.1 above for details) and de-energises the compressor.<br>• Additional plant electrical isolation available, as explained in the emergency procedure.<br>• "Break-glass" fire alarm activator located by the exit point(s) from the compound, which notify the monitoring company, who in turn can notify the fire brigade and security.<br>• Lights (HAZLOC rated in the hydrogen compound and the dispensing area) remain on at all times, even when there is a hydrogen leak detected or emergency stop button pressed. Street lighting (outside of zones) will also be unaffected.<br>• Restricted maintenance allowed when only one member of maintenance staff present. | |
| | Leakage from dispenser / pipework leading to the dispenser outside of fuelling | Ignition causing jet fire or explosion | Maintenance engineer / fuelling operative / passers-by | 2-3 | C-D | R7-R10<br><br>**Med risk** | **Prevention of leaks:**<br><br>• Factory testing includes pressure test of all parts in the fuelling station to at least 1.43 × maximum allowable pressure (PS) where appropriate, and where not already tested by the individual equipment / component manufacturer.<br>• Nitrogen & hydrogen leak test of manifold to 0.9 * maximum allowable pressure (PS) once on site. | None |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Asphyxiation | Maintenance engineer | 1 | C-D | R9-R10 Low risk | • Dispenser protected against vehicular impact by bollards and kerb of raised plinth on which dispenser is located.<br>• Majority of pipework / components inside dispenser cabinet protected from tampering by locked enclosure panels.<br><br>**Detection of leaks:**<br><br>• Routine checks conducted by trained personnel.<br>• Regular inspection and leak testing of pressure systems according to Written Scheme of Examination / maintenance schedule.<br>• Large leak may be audible to passers-by, with emergency contact details on the fences around the station and break-glass alarm points.<br><br>**Dilution of leaks:**<br><br>• Natural ventilation to dissipate minor leakage, although this is restricted within the dispenser enclosure.<br><br>**Prevention of ignition:**<br><br>• Quantity of hydrogen that can be released into the fuelling area minimised by isolation valves between the storage and the pipework leading to the dispenser that are closed outside of fuelling.<br>• Dispenser enclosure process compartment defined as Zone 2 and all electrical components are appropriately HAZLOC rated to reduce likelihood of ignition sources being present in the case of a leak. | |

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| | | | | | | | • Non-HAZLOC electrical equipment in the dispenser is located inside a sealed compartment.<br>• Electrical equipment mounted onto the dispenser enclosure is HAZLOC rated.<br>• No smoking, etc. signage on dispenser<br>• Site boundary fence / wall minimises unauthorised access to vicinity of hydrogen dispenser, and no hazardous areas that extend outside the boundary fence / wall.<br>• No portable non-HAZLOC electrical items permitted in hazardous areas when hydrogen equipment and manifold pressurised.<br>• ITM maintenance staff trained of requirement to ensure ignition sources are kept out of HAZLOC hazardous areas.<br>• Hazardous area drawing indicates locations of Zones.<br>• Ex-signage on door to dispenser compartment.<br><br>**Detection of ignited jet**<br><br>• Flame detector trained on dispenser area instigates fire alarm sounder for the fuelling station, and notifies the monitoring company, who in turn can notify the fire brigade and security.<br><br>**Protection of personnel**<br><br>• Clearly defined emergency procedure.<br>• Emergency stop push buttons easily accessible in the refuelling area.<br>• Site “global e-stop” push button positioned close to entrance/exit for easy fire service access. | |

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| | | | | | | | • If activated, any e-stop isolates the storage vessels (see hydrogen sensor alarm in 4.2.1 above for details) and de-energises the compressor.<br>• Additional plant electrical isolation available, as explained in the emergency procedure.<br>• "Break-glass" fire alarm activator located by the exit point(s) from the compound, which notify the monitoring company, who in turn can notify the fire brigade and security.<br>• Dispenser process compartment is too small to enter (from asphyxiation perspective).<br>• Lights (HAZLOC rated in the hydrogen compound and the dispensing area) remain on at all times, even when there is a hydrogen leak detected or emergency stop button pressed. Street lighting (outside of zones) will also be unaffected.<br>• Restricted maintenance allowed when only one member of maintenance staff present. | |
| | Leakage from tube trailer connection equipment (inlet / outlet) outside of use | Ignition causing jet fire or explosion<br><br>Asphyxiation | Maintenance engineer / fuelling operative / passers-by<br><br>Maintenance engineer | 2-3<br><br>1 | C-D<br><br>C-D | R7-R10 **Med risk**<br><br>R9-R10 **Low risk** | **Prevention of leaks:**<br>• Factory testing includes pressure test of all parts in the fuelling station to at least 1.43 × maximum allowable pressure (PS) where appropriate, and where not already tested by the individual equipment / component manufacturer.<br>• Nitrogen & hydrogen leak test of manifold to 0.9 * maximum allowable pressure, PS, once on site.<br>• Tube trailer connection point enclosure protected against vehicular impact by bollards and kerb. | None |

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| | | | | | | | • Pipework / components inside tube trailer connection point cabinet protected from tampering by locked enclosure panels.<br><br>**Detection of leaks:**<br><br>• Routine checks conducted by trained personnel.<br>• Regular inspection and leak testing of pressure systems according to Written Scheme of Examination / maintenance schedule.<br>• Large leak may be audible to passers-by, with emergency contact details on the fences around the station and break-glass alarm points.<br><br>**Dilution of leaks:**<br><br>• Limited natural ventilation only.<br><br>**Prevention of ignition:**<br><br>• Enclosure compartment defined as Zone 2 and all electrical components are appropriately HAZLOC rated to reduce likelihood of ignition sources being present in the case of a leak.<br>• Site boundary fence / wall minimises unauthorised access to vicinity of hydrogen dispenser, and no hazardous areas that extend outside the boundary fence / wall.<br>• Ex-signage on door to tube trailer connection point compartment.<br>• ITM maintenance staff trained of requirement to ensure ignition sources are kept out of HAZLOC hazardous areas.<br>• No smoking etc signage on tube trailer connection point. | |

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| | | | | | | | **Detection of ignited jet**<br><br>• Flame detector trained on tube trailer connection area instigates fire alarm sounder for the fuelling station, and notifies the monitoring company, who in turn can notify the fire brigade and security.<br><br>**Protection of personnel**<br><br>• Clearly defined emergency procedure.<br>• Emergency stop push buttons easily accessible in the refuelling area.<br>• Site “global e-stop” push button positioned close to entrance/exit for easy fire service access.<br>• If activated, any e-stop isolates the storage vessels (see hydrogen sensor alarm in 4.2.1 above for details) and de-energises the compressor.<br>• Additional plant electrical isolation available, as explained in the emergency procedure.<br>• “Break-glass” fire alarm activator located by the exit point(s) from the compound, which notify the monitoring company, who in turn can notify the fire brigade and security.<br>• Tube trailer connection enclosure is too small to enter (from asphyxiation perspective).<br>• Lights (HAZLOC rated in the hydrogen compound and the dispensing area) remain on at all times, even when there is a hydrogen leak detected or emergency stop button pressed. Street lighting (outside of zones) will also be unaffected.<br>• Restricted maintenance allowed when only one member of maintenance staff present. | |

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| | On-site collision of passing vehicle with refuelling station, (or vehicle being refuelled) causing pressurised pipework / vessel rupture and hydrogen leakage | Ignition causing fire or explosion | Maintenance engineer / fuelling operative / passers-by | 1-2 | C-E | R8-R11 Low risk | • 20 mph speed limit on site to reduce likelihood of crash into dispenser, or into a vehicle being fuelled, leading to damage to the dispenser.<br>• Storage vessels located inside the container, with the container in a separate fenced off compound with locked gates, and protected by firewall.<br>• Raised kerb and bollards located between fuelling area and the dispenser.<br>• When dispensing not in progress, process isolation valves reduce the volume of gas that would escape in the case of a collision with external components of the dispensing system.<br>• Container offers degree of protection to internal manifold and compressor, and is located behind firewall.<br>• Hydrogen sensor instigates safety system in case of leakage inside compressor compartment of container (see hydrogen sensor alarm in 4.2.1 above for details).<br>• Signage around refueller.<br>• Restricted access to refuelling station with automated gates at the entrance operated by entry card. | None |
| | Vandalism leading to release of hydrogen | Ignition of flammable gas mixture / electrocution of personnel | Maintenance engineer / fuelling operative / passers-by | 2 | C-E | R8-R10 Low risk | • Hydrogen equipment and dispenser in separate fenced off compounds with locked gates. Fence located at least 1 m from any hydrogen equipment.<br>• Public access to dispensing area limited by entry key-fob to those with hydrogen vehicles. The staff working in the area are likely to approach anyone obviously out of place.<br>• Doors to compartments of refuelling station compressor / storage container, tube trailer | None |

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| | | | | | | | connection point and dispenser locked by key outside of operational checks / maintenance.<br>• When not refuelling, process isolation valves reduce the volume of gas that would escape in the case of vandalism of components of the dispensing system external to the hydrogen compound.<br>• Site security cameras are active and monitored.<br>• Refueller is on patrol route of site security.<br>• Security signage on each side of refuelling station.<br>• Dispensing system (accessible to public) leak checked in control logic prior to refuelling. | |
| | Hydrogen leak from worn / damaged filling nozzle and hose or from incorrectly attached filling nozzle to form potentially explosive atmosphere | Ignition causing fire or explosion | Fuelling operative / passers-by | 1-2 | C-E | R8 -R11<br><br>**Low risk** | **Prevention of damage / wear:**<br><br>• Nozzle stored on side of dispenser in dedicated location when not in use.<br>• "Customer refuelling manual" includes visual inspection of refuelling nozzle and hose prior to refuelling, checking for damaged components / debris.<br><br>**Prevention / minimisation of leak**<br><br>• Refuelling nozzle and receptacle certified to SAE J2600 that only allows connection with 700 bar rated vehicle system.<br>• Positive engagement required for gas flow. Red indicator ring when correctly fitted.<br>• Refuelling control logic includes initial leak test on dispensing manifold, hose and components, and vehicle in accordance with ISO / DIS 20100:2011. Refuelling line is open to storage tank for maximum of 3 seconds during leak test. | Test of earthing connection through fuelling pad<br><br>Test of earth connection through nozzle to ground |

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| | | | | | | | • Average pressure ramp rate expected that would indicate the presence of a major leak, as the ramp rate would not be achieved.<br>• Fill carried out by operator trained according to "Customer refuelling manual" (D925-00xx).<br>• Anything above a minor leak will be audible and fuelling can be halted using the emergency stop push button at the dispenser (see hydrogen sensor alarm in 4.2.1 above for details).<br>**Prevention of ignition**<br>• Conductive fuelling pad bonds vehicle to refueller earth to avoid static discharge.<br>• Outdoor refuelling only to ensure adequate ventilation.<br>• Area around dispenser is zone 2, with appropriate electrical equipment used.<br>• Vehicle engine and power electronics turned off during refuelling. (Other than when fuelling data is recorded, when fuelling is monitored by a member of ITM staff)<br>**Protection of personnel**<br>• All non-approved personnel outside 5m separation distance during refuelling - station not on a publically accessible site.<br>• Site "global e-stop" push button positioned close to entrance/exit for easy fire service access. | |
| | Hydrogen leak from vehicle during filling | Ignition causing fire or explosion | Fuelling operative / passers-by | 2-3 | C-E | R7-R10<br>Med risk | **Prevention / minimisation of leak:**<br>• Control of vehicles being filled by issue of access cards by ITM to enable access, with vehicle | Seek additional maintenance information from |

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| | | | | | | | manufacturers having pre-approved the vehicles to be filled to ensure vehicles are suitable.<br>• Hyundai and Toyota vehicle hydrogen system components rated for temperatures as low as -40 °C.<br>• Identified Revolve vehicles suitable for filling, and registration numbers known and agreed with the operator Commercial Group.<br>• Vehicles under manufacturer's maintenance schedules.<br>• Short initial refuel (several seconds) followed by pause in refuelling protocol will identify leaks.<br>• Anything above a minor leak will be audible.<br>• "Customer refuelling manual" includes direction to carry out visual inspection of vehicle receptacle prior to refuelling, checking for debris, and training given to users.<br>• Additional controls to prevent overheating and over-pressurisation<br><br>**See Prevention of ignition and Protection of Personnel**<br><br>Note: Additional risk assessment to be prepared for prior to filling any new vehicles to help identify any potential issues with vehicles. | FCEV manufacturers |
| | Driving away / vehicle moving when refuelling nozzle attached - leading to breakage of | Ignition causing fire or explosion | Fuelling operative / passers-by | 1-2 | C-E | R8 -R11<br>**Low risk** | • Break-away coupling between nozzle and refuelling station minimises hydrogen leakage should the vehicle move whilst connected to the dispensing equipment, by sealing both the line from the dispenser and the line from the vehicle. | None |

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| | filling line and hydrogen leak | Whipping of unattached hose leading to personnel injuries. | Fuelling operative | 1 | C-D | R9 -R10<br>**Low risk** | • A check valve in the vehicle fill line further protects from hydrogen loss from the vehicle tank.<br>• Fill carried out by operator trained according to "Customer refuelling manual", which includes measures to minimise risk of vehicle movement, including ensuring handbrake is engaged.<br>• Filling carried out on flat road surface.<br>• Vehicle access to site controlled by automated gate, with entry to authorised users only.<br>• 20 mph speed limit on site to reduce likelihood of crash leading to movement of the vehicle being refuelled.<br>• Manually operated emergency stop isolates flow to refuelling dispenser.<br>• Remote emergency stop push-button at other points on site, including by the entrance / exit.<br>• In case of break-away coupling failure to seal, the PLC logic has a high flow alarm on the dispensing line mass flow meter that would halt refuelling, also failure to achieve the minimum Average Pressure Ramp Rate would cause an alarm and shut the isolation valves.<br>• Some vehicles (Hyundai & Toyota) prevent driving when the fuel cap is open. | |
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| **Over-Pressurisation Hazards** | | | | | | | | |
| | Hydrogen generation leads to over-pressurisation of stack / hydrogen manifold in generation room / | Failure of components leads to projectile risk and un-ignited low pressure wave or, in the case of ignition, fire or explosion. | ITM operator | 1-2 | C-E | R8-R11 | Only the controls to protect against the over pressure and resulting pressure wave / projectiles are listed here. For the controls to protect against external releases. See above risks for controls to protect against external and internal hydrogen leaks. | None |

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| | hydrogen system in gas handling room | Pressure wave from resulting explosion may blow out doors / roof fans, which could become a projectile risk if detached.<br><br>Personnel external to the plant most at risk from projectiles.<br><br>Personnel in container have a high risk of harm to due to pressure wave from explosion and projectiles.<br><br>Likely damage to equipment. | | | | Low Risk | **Pressure Control:**<br><br>• The control system stops generation, setting the stack PSUs at 0 % output, when the combined manifold pressure transducer PT005 reaches 20 bar<br>• If this fails to prevent further hydrogen generation, alarm on pressure transducers PT001-5 reaching 22 bar, instigates a controlled shutdown.<br>• Adequately sized pressure relief valves fitted to each stack vent over pressure to a safe location. These protect the stacks in case of pressure transmitter or control system failure.<br>• Further adequately sized pressure relief valves fitted on the hydrogen process vessel S002 and gas dryer vent over-pressure to a safe location. These protect the vessels in case of pressure transmitter or control system failure.<br>• Pressure testing of systems to at least 1.43 x maximum allowable pressure (PS) carried out (1.3 times for stacks).<br>• On site commissioning includes helium leak test of systems to working pressure.<br><br>**Personnel Controls:**<br><br>• Commissioning personnel are not allowed in generation compartment when the hydrogen system is pressurised.<br>• Doors to gas generation room are locked, or access by tool, to minimise unauthorised access.<br>• Audible / visual alarm located on container roof warns staff in the case of a Shutdown 1 / 2, for instance an over-pressure alarm.<br><br>**Control of ignited hydrogen:** | |

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| | | | | | | | • Temperature sensors mounted to stack compartment ceiling alarm above 40 ºC and instigate shutdown.<br><br>**Control of projectiles:**<br><br>• Container walls provide enclosure to contain projectiles.<br>• Container louvres provide some pressure relief to an internal pressure wave.<br>• Personnel not permitted inside gas generation room whilst hydrogen system is pressurised. | |
| | Hydrogen PRV vent blockage during operation. | Inability of PRVs to relieve over pressure leading to a catastrophic loss of containment and subsequent injury to personnel. | ITM operator | 2-3 | D-F | R8-R11<br><br>**Low Risk** | See above risk analysis for measures for preventing over-pressurisation. In addition:<br><br>• Vent lines are protected to prevent rain ingress. | None |
| | Reverse flow of high pressure hydrogen from the Buffer Tank assembly to the gas handling room | Over pressurisation of equipment leading to loss of containment and deflagration. | ITM operators | 1 | C-D | R9-R10<br><br>**Low Risk** | • Non-return valve NRV006 on hydrogen process line to Buffer Tank assembly minimises backflow to ITM system. This will be regularly tested for functionality in accordance with the Maintenance Schedule.<br>• HRS has a non-return valve to prevent back flow of gas from high pressure systems.<br>• PRV008 set at 24 bar located in the hydrogen system to protect the HGas180 components from over pressure.<br>• Buffer tank assembly PRV009/10 set at 24 bar | None |
| | Reverse flow of high pressure hydrogen from the refuelling station high | Over pressurisation of equipment leading to loss of containment and deflagration. | ITM operator, public refuellers, nearby public | 1 | C-D | R9-R10 | • HRS non-return valves prevent hydrogen backflow to Buffer Tank assembly.<br>• PRV009/10 set at 24 bar located in the buffer tank panel to protect components from over pressure. | None |

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| | pressure vessels to the Buffer Tank assembly | | | | | Low Risk | • A high pressure alarm will be communicated to the HRS and shut an isolation valve between systems | |
| | Over-pressurisation during refilling of high pressure hydrogen storage tanks, leading to rupture | Un-ignited pressure wave or ignition causing fire or explosion. | Maintenance engineer / fuelling operative / passers-by | 1 | B-D | R8-R10 Low risk | • PLC stalls compression at 945 bar through pressure transmitters 40A20PT708, with redundancy through 50A20PT026, 50B20PT026, 50C20PT026 and 50D20PT026.<br>• Alarm through safety PLC monitoring 40A20PT708, at 950 bar leading to de-energisation of compressor.<br>• Adequately sized PED Cat IV pressure relief valves fitted after the compressor, set at 1000 bar, protect the high pressure storage and are regularly tested in accordance with Written Scheme of Examination.<br>• All vessels compliant with PED and pressure tested to 1.43 × maximum working pressure.<br>• Each pressure system assembly pressure tested to 1.43 × maximum allowable pressure.<br>• Relief gas vented to safe place (no ignition sources), vent exit is >5 m above container.<br>• Site separation distances conform to NFPA2 (though not appropriate for catastrophic failure of a vessel). | None |
| | Backflow from tube trailer inlet / high pressure storage vessels leading to over-pressurisation and rupture of electrolyser buffer storage / manifold from storage. | Un-ignited pressure wave or ignition causing fire or explosion | Maintenance engineer / fuelling operative / passers-by | 1 | C-D | R9–R10 Low risk | • Manifold from buffer storage cylinder protected from over-pressurisation by check valve 00B20CV008 between tube trailer inlet line (which could be up to 250 bar under normal operation if hydrogen is supplied from cylinders / a tube trailer) and the manifold.<br>• Backflow from the high pressure storage through the compressor prevented by numerous compressor check valves and 10A20CV032. | None |

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| | | | | | | | • Buffer storage has additional protection, with an alarm on PT03, and PSV01 set at 24 bar.<br>• Electrolyser protected by additional check valve and other measures, see separate ITM risk assessment | |
| | Over-pressurisation of vehicle hydrogen storage system during fuelling causing tank / component failure and hydrogen leakage | Tank rupture, ignition causing fire or explosion<br><br>Component failure, ignition causing fire or explosion | Fuelling operative / passers-by<br><br>Fuelling operative / passers-by | 1<br><br>1 | B-D<br><br>C-E | R8-R10<br>**Low risk**<br><br>R9-R11<br>**Low risk** | • Maximum fill pressure limited by PLC logic to 720 bar. This is significantly less than the maximum operating pressure permitted for the vehicle high pressure hydrogen systems of 875 bar (at up to 85 deg C). An emergency stop is carried out if the pressure in the dispenser reaches 720 bar.<br>• Pressure transducer PT10 halts refuelling at the desired "target" pressure through the PLC by closing process solenoid valves<br>• Refuelling carried out to SAE TIR J2601: 2010 fuelling protocol that takes into account the ambient temperature and starting pressure of the vehicle, to avoid over-filling of the vehicle under conditions that could lead to the vehicle equilibrating to ambient temperature and exceeding the rated pressure of the vehicle compressed hydrogen storage system (CHSS).<br>• PSV 08 in dispensing line set at 875 bar.<br><br>**See Prevention of ignition and Protection of Personnel in previous examples** | |
| **Heat Leading to Catastrophic Failure of Vessels** | | | | | | | | | |

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| | Heater in gas purification module fails to turn off | Softening of pressure vessel walls leading to catastrophic failure | ITM operator, public refuellers, nearby public | 1 | E-C | R10-R12<br>**Low risk** | **Preventing overheating**<br>• Heater is controlled and monitored by PLC<br>• Independent process control thermostat within the heater controls the temperature<br>• Second independent thermostat acts as a high level switch<br>• Downstream process temperature sensor will shutdown above 40C<br><br>**Controlling failure**<br>• Volume of vessel is small and pressure only 20 bar<br>• Mesh screen over gas handling area will help to reduce projectiles<br>• Limited number of people within range of projectiles<br>• Projectiles not expected to extend beyond site boundary | |
| | External fire in refuelling station spreading to HGas or buffer tank assembly | Significant damage to plant leading to a loss of containment of hydrogen and subsequent deflagration | ITM operator, public refuellers, nearby public | 1-2 | C-E | R8-R11<br>**Low Risk** | • A fire detected at the refuelling station will result in the HGas receiving a signal to shut down and vent its inventory.<br>• HGas will shut down and vent its inventory if a fire is detected via smoke detectors or high temperature in the stack compartment.<br>• If there were a significant fire in the refuelling station, it is unlikely that personnel would be in HGas or around the Buffer Tank assembly | None |
| | Arson | Ignition of flammable gas mixture | Passers-by | 2 | C-E | R8-R10<br>**Low risk** | • Hydrogen equipment and dispenser in separate fenced off compounds with locked gates. Fence located at least 1 m from any hydrogen equipment.<br>• Public access to dispensing area limited by entry key-fob to those with hydrogen vehicles. The staff working in the area are likely to approach anyone obviously out of place.<br>• Doors to compartments of refuelling station compressor / storage container, tube trailer connection point and dispenser locked by key outside of operational checks / maintenance. | None |

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| | | | | | | | • When not refuelling, process isolation valves reduce the volume of gas that would escape in the case of vandalism of components of the dispensing system external to the hydrogen compound.<br>• Flame detectors in hydrogen compound, also on the dispenser and tube trailer areas instigate emergency shutdown, halt hydrogen generation and vents hydrogen from electrolyser.<br>• Site security cameras are active and monitored.<br>• Refueller is on patrol route of site security.<br>• Security signage on each side of refuelling station. | |
| | Overheating of the vehicle storage vessel(s) due to compressive heating during fuelling exceeding natural heat loss.<br><br>Potential reduction in pressure safety factor of components leading to leak / burst, or activation of TPRD at 104-109°C and | Unignited pressure shock wave or ignition causing fire or explosion | Fuelling operative / passers-by | 1-2 | B-C | R8-R10<br>**Low risk** | • Fuelling carried out to SAE TIR J2601: 2010 fuelling protocol that takes into account the ambient temperature and starting pressure of the vehicle, to avoid over-heating of the vehicle compressed hydrogen storage system (CHSS) above 85 °C during filling.<br>• For 70 MPa fuelling, the CHSS temperature is monitored by the dispenser using SAE J2799 communications, with an abort signal sent to the dispenser to halt fuelling at 85 °C.<br>• Hydrogen supplied to vehicle is pre-cooled before entering the vehicle.<br>• Control of vehicles being filled by issue of entry cards by ITM to enable access, with vehicle manufacturers having pre-approved the vehicles to be filled to ensure vehicles are suitable. | None |

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| | complete venting of vehicle storage vessel(s). | | | | | | • Vehicle TPRD activates at 104-109°C to protect storage vessels – however to be avoided to prevent venting of all stored hydrogen on vehicle.<br><br>**See Prevention of ignition and Protection of Personnel in 4.2.22** | |
| **Miscellaneous** | | | | | | | | |
| | Domino effect of refueller cylinder explosion / leakage & jet-fire on near-by hazards | Setting fire to adjacent buildings / harm to passers-by | Maintenance engineer / fuelling operative / passers-by | 1 | B-E | R8-R11 **Low risk** | Safety systems as described in 4.2.1 – 4.2.4 above to reduce likelihood of ignition and minimise gas volume leaked.<br><br>• High pressure hydrogen storage cylinders protected from impingement of ignited jets from process equipment.<br>• Minimal manifold joints in the vicinity of the storage cylinders to protect from impingement of ignited jets.<br>• Site separation distances conform to NFPA2.<br>• Emergency stop push buttons located at different locations around refuelling station, these isolate storage vessels (see hydrogen sensor alarm in 4.2.1 above for details) and de-energise the compressor.<br>• Separate site specific fire risk assessment carried out.<br>• Clearly defined emergency procedure.<br>• Fire detection in appropriate places around the site, and "break-glass" fire alarm activators accessible close to refuelling area entrance, which notify the monitoring company, who in turn can notify the fire brigade and security. | Ensure location of and signage for evacuation point is clear |

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| | | | | | | | • Low pressure buffer storage area open air, with easy access for fire brigade to spray water onto the storage vessel to cool it in case of a fire.<br>• Explosion relief designed into the roof of the container.<br>• Fire extinguisher provided in case of electrical fire whilst personnel present. | |

## 8.12 Operating Procedures

In addition to policies, ITM operations are governed by over 200 procedures. A summary of the procedures and how they are implemented for an HRS build through each part of the life cycle is provided below. The procedures form part the training that all staff undertake, copies of the procedures are available on the site and the procedures are periodically reviewed and modified as required to ensure a high level of safety, applicability and user accessibility:

| Life cycle phase | Sample of key procedures | Enforced by |
|---|---|---|
| Design | QMS OP03 Product Design<br>QMS OP04 Purchasing<br>QMS OP22 Technical file process | Operations director enforcing design stage gates<br>All documentation stored in technical file<br>Audits |
| Build | QMS OP7 Manufacturing<br>SP3-03 Orbital welding<br>SP3-27 Working at heights<br>SP3-36 Assembly of high pressure LEP stack<br>SP3-39 Inspection and Handling components | Supervisor overseeing operations.<br>H&S Manager conducting workplace inspections<br>Quality manager inspecting finished components |
| Factory commissioning | SP3-30 Hydrostatic pressure testing<br>SP6-04 PRV Setting procedure<br>SP6-05 Stack pressure testing<br>SP6-47 Isolation and Lockoff of electricity to containerised electrolyser | Commissioning team leader<br>Commissioning check lists<br>H&S Manager conducting workplace inspections<br>Quality manager signing off completed systems |
| Site groundworks and installation | QMS OP10 Control of Outsourced Services and Processes<br>HSMS OP05 Managing Contractors<br>SP5.2 Visitors and Contractors | Risk assessment and method statements from subcontractor.<br>Regular site visits. |
| Site commissioning | SP6-50 ITM Activities on a Customer Site<br>SP3-30 Hydrostatic Pressure Testing<br>SP6-04 PRV Setting Procedure<br>SP6-05 Stack Pressure Testing<br>SP6-47 Isolation and Lockoff of electricity to containerised electrolyser | Commissioning team leader<br>Commissioning check lists |
| Commercial operation and maintenance | HRS User Manual<br>Refuelling User Guide<br>Maintenance manual | Regular site inspections.<br>Maintenance team<br>Monitoring of site data. |
| Decommissioning | EMS OP02 Waste disposal and recycling<br>HSMS OP07 COSHH | Environmental Manager.<br>Waste disposal notes. |

## 8.13 Equipment Mechanical Integrity

This section describes how the mechanical integrity pressure systems (vessels, tubes etc) is ensured.

### 8.13.1 Written Procedures

For every plant, ITM prepare a 'Pressure Safety Case' which details the pressure system, the calculations used to prove its safety and compiles all of the relevant supplier certificates and

declarations of conformity into a single location. This is in a set format to ensure that the documentation for each site is to the same standard. Rather than include a full safety case, the table of contents is provided below to provide an indication of the information contained.

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*Figure 7. A table of contents from a typical pressure safety case*

### 8.13.2 Proper Design, Testing and Commissioning

ITM do not manufacture pressure vessels and therefore rely on suppliers to provide declarations of conformity, as opposed to conducting the full design calculations ourselves. These declarations are compiled and supplied as the appendices in the pressure safety case.

Once pressure systems (vessels, piping, sensors etc) are assembled by ITM staff, they undergo a proof pressure test and then leak tests using helium as part of commissioning. Test certificates (detailing the procedure and results) are then issued for each test. These are then stored in the technical file.

### 8.13.3 Validation of Materials Compatibility

On all purchase orders, ITM specify if a material needs to operate in contact with hydrogen (or any other fluid) in addition to standard information such as pressure range, temperature range, hazardous location classification etc. In addition, ITM request materials certificates for all pressure vessels to confirm both the material and its quality. These are retained in the technical file.

### 8.13.4 Preventative Maintenance Plan

ITM compile the maintenance plans for all components on the HRS into a single site maintenance plan. This is them implemented during regular service intervals.

### 8.13.5 Calibration of Safety Related Devices

The key safety devices in the pressure system are the Pressure Relief Devices. These are calibrated annually in line with manufacturers' recommendations. The calibration is logged in a Test Record detailing the procedure followed and the results. These are then stored in the technical file.

### 8.13.6 Testing and Inspection

Pressure systems are inspected for corrosion or damage, and leak tested annually. These are logged in Test Records, detailing the procedure followed and the results. These are then stored in the technical file.

### 8.13.7 Training for Maintenance, Calibration, Testing and Inspection Personnel

As detailed in the H&S Policy, ITM have detailed processes to ensure staff competence. In addition to HR holding all training records, each manager has a matrix of skills that staff require to complete their job. New staff are trained in the essential and then receive on-going training to complete the matrix. With time and training (and if appropriate to their role) staff can move from testing existing systems, to performing like-for-like swaps of components on a system, to building systems and then designing systems. Additional details are provided in Section 4.1.

### 8.13.8 Documentation

As described above, all calibrations, tests and inspections are recorded on forms which detail the methodology required, have sections for the date, equipment, location, results of test and then the operators signature. These are then stored in the product's technical file. Any failures are highlighted to their manager and the Quality Manager.

### 8.13.9 Correcting Deficiencies that are Outside Acceptable Limits

If a system had failed a test that is easy to rectify (eg a pressure test or calibration test) staff are trained in how to resolve (ie check the system for leaks or recalibrate a PRV). If a failed test requires more significant intervention (eg the replacement of a part), then this requires a Change Note, as described in the following section.

## 8.14 Management of Change (MOC) Procedures

Management of change at ITM is governed by procedure QMS OP23 Management of Change (changes to documentation are managed under a separate process). The key processes are described in Figure 2.

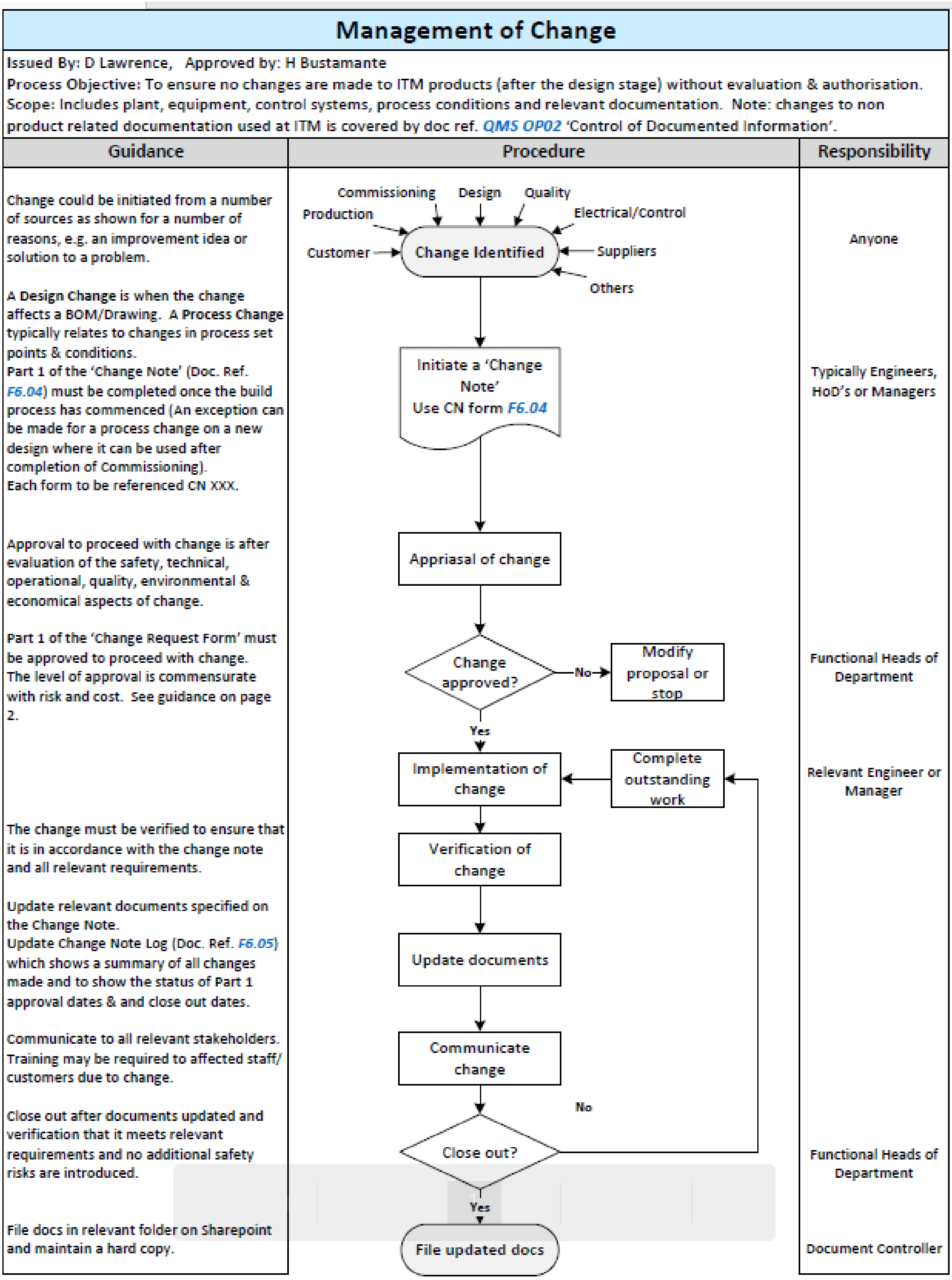



*Figure 8. The flow diagram for the management of change*

The procedure also specifies who must give approval for changes to different aspects of the system, with final approval being that of the Quality Manager, as shown in Figure 3 below.

APPROVAL GUIDANCE

The table below provides guidance on the required approvals on the Change Note.

In addition, it may be required to obtain specialists to review the Change Note proposal e.g. those of a safety critical nature.

| Change Type | Approval 1 | Approval 2 | Approval 3 |
|---|---|---|---|
| Drawing change (mechanical) | Design Engineer | | Quality Manager |
| Drawing change (stack related) | Design Engineer | Chief Engineer | Quality Manager |
| Drawing change (electrical) | Design Engineer | Control Systems Eng. | Quality Manager |
| Process change | Process Engineer | Lead Process Eng<br>( if complexity requires) | Quality Manager |
| | | | |

*Figure 9. Approval guidance for ITM's Management of Change procedure*

The form to apply for a change is presented in Figure 4.

| Quality Management System - Form | ITM POWER Energy Storage \| Clean Fuel<br>Document Ref: F6.04 Issue E |
|---|---|
| Title: Equipment Change Note | |

This form is to be used for changes to ITM plant to ensure changes are evaluated & authorised.
See Doc. Ref. QMS OP17 'Management of Change' procedure for further guidance on the process.

## PART 1 – TO BE COMPLETED BY ORIGINATOR

| CHANGE No. | ORIGINATOR | POSITION | DATE |
|---|---|---|---|
| CNXXX | | | |

**APPLICABILITY** *(State Y below where applicable)*

| DESIGN<br>*Change to an ITM part on a BOM/Drawing once the build process has commenced* | PROCESS<br>*Change to a process condition or set point* | OTHER<br>*Please specify* |
|---|---|---|
| | | |

**PLANT/PART AFFECTED**

| PLANT SERIAL No(s) | DESCRIPTION | TOP LEVEL ASSEMBLY No. | DRAWING / PART No. / DOCUMENT REF. No. |
|---|---|---|---|
| | | | |
| **DOCUMENT No's.** (*list below if additional space is required*): | | | |
| **DOES CHANGE AFFECT OTHER PLANT?** (*Please specify*): | | | |

| DESCRIPTION OF CHANGE |
|---|
| |

| REASON / JUSTIFICATION FOR CHANGE |
|---|
| |

**WHO IS AFFECTED** *(State Y below for all applicable)*

| DESIGN ENGINEERING | PROCESS ENGINEERING | E & I | STACK | PRODUCTION | COMMISSIONING |
|---|---|---|---|---|---|
| | | | | | |
| **EXTERNAL / OTHER** (*Please specify*): | | | | | |

| APPROVAL TO PROCEED WITH CHANGE | | | |
|---|---|---|---|
| NAME | POSITION | SIGNATURE | DATE |
| | | | |
| | | | |
| | | | |

*See Doc. Ref. QMS OP17 'Management of Change' procedure for guidance on appropriate approval level*

| PART 2 – VERIFICATION OF CHANGE |
|---|

| **WHAT WAS ACTUALLY IMPLEMENTED** *(State any variations to original change proposal)* |
|---|
| |

| **VERIFICATION OF CHANGE** *(Did it work/is it safe?)* |
|---|
| |

| **WHAT DOCUMENTATION HAS BEEN UPDATED** (*Also state by who, when & new revision status*) |
|---|
| |

| CHANGE NOTICE CLOSEOUT | | | |
|---|---|---|---|
| NAME | POSITION | SIGNATURE | DATE |
| | | | |
| | | | |
| | | | |

The Originator to complete the 'Change Log' (Form F6.05) and pass signed form to Document Controller for uploading to Sharepoint.

*Figure 10. The form to request a change*

## 8.15 Project Safety Documentation

All project documentation (safety and non-safety) are stored in the project's technical file. This is an electronic folder held on ITMs servers that contain all of the information about the project, including hard copies of documents that are scanned in).

Document numbering is used to track individual documents, with version control employed to ensure that the most recent version is used.

Each product has a document register where all of the documents are recorded. A blank register is presented in Figure 5 below; the titles of the documents provide an indication of the documents that will populate the technical file.

| New Doc. Number | Latest Revision | Revision Date | Author | Document title |
|---|---|---|---|---|
| D9xx - 0001 | 02 | 01/06/16 | DL | Document numbering register (This one) |
| D9xx - 0002 | 05 | 01/01/16 | DL | Project file structure |
| D9xx - 0003 | | | | Project initiation form (F6.09) |
| D9xx - 0004 | | | | Project plan |
| D9xx - 0005 | | | | Reserved for home docs. |
| D9xx - 0006 | | | | Reserved for home docs. |
| D9xx - 0007 | | | | Reserved for home docs. |
| D9xx - 0008 | | | | Reserved for home docs. |
| D9xx - 0009 | | | | Reserved for home docs. |
| **PRODUCT DESIGN DOCUMENTS** | | | | |
| D9xx - 0010 | | | | Block diagram (Process Flow Diagram) |
| D9xx - 0011 | | | | Piping and Instrument Diagram |
| D9xx - 0012 | | | | Water regulation drawing |
| D9xx - 0013 | | | | Trace heating & thermal insulation drawing |
| D9xx - 0014 | | | | Equipment List |
| D9xx - 0015 | | | | Instrument and calibration List |
| D9xx - 0016 | | | | Valve list |
| D9xx - 0017 | | | | Pressure system test requirements **(NEW DOC)** |
| D9xx - 0018 | | | | Reserved for product design docs. |
| D9xx - 0019 | | | | Reserved for product design docs. |
| D9xx - 0020 | | | | Reserved for product design docs. |
| D9xx - 0021 | | | | Reserved for product design docs. |
| D9xx - 0022 | | | | PED safety case |
| D9xx - 0023 | | | | PED safety case - Full (If Required) |
| D9xx - 0024 | | | | Pressure relief valve sizing calculations: EN ISO 4126-1 |
| D9xx - 0025 | | | | PED category of main elements |
| D9xx - 0026 | | | | Hazardous area drawing 1 (state if internal or external) |
| D9xx - 0027 | | | | Hazardous area drawing 2 (state if internal or external) |
| D9xx - 0028 | | | | Hazardous area drawing 3 (state if internal or external) |
| D9xx - 0029 | | | | Hazardous area drawing 4 (state if internal or external) |
| D9xx - 0030 | | | | ATEX safety case |
| D9xx - 0031 | | | | HAZ I report |
| D9xx - 0032 | | | | HAZ 2 matrix |

| | | | | |
|---|---|---|---|---|
| D9xx - 0033 | | | | HAZ 3 matrix |
| D9xx - 0034 | | | | HazOp III report |
| D9xx - 0035 | | | | LOPA worksheet/analysis |
| D9xx - 0036 | | | | LOPA report |
| D9xx - 0037 | | | | DSEAR risk assessment |
| D9xx - 0038 | | | | Sign layout - container |
| D9xx - 0039 | | | | Reserved |
| D9xx - 0040 | | | | Reserved |
| D9xx - 0041 | | | | Reserved |
| D9xx - 0042 | | | | Reserved |
| D9xx - 0043 | | | | Reserved |
| D9xx - 0044 | | | | Reserved |
| D9xx - 0045 | | | | Reserved |
| D9xx - 0046 | | | | Reserved |
| D9xx - 0047 | | | | Reserved |
| D9xx - 0048 | | | | Reserved |
| D9xx - 0049 | | | | Reserved |
| D9xx-0050>59 | | | | Reserved |
| **MECHANICAL ASSEMBLY DRAWINGS** | | | | |
| **Use Part No** | - | - | - | - |
| | | | | |
| | | | | |
| **ELECTRICAL DESIGN** | | | | |
| D9xx - 0060 | | | | User requirement specification |
| D9xx - 0061 | | | | Emergency shutdown response matrix |
| D9xx - 0062 | | | | PLC hardware list |
| D9xx - 0063 | | | | IO Schedule |
| D9xx - 0064 | | | | Electrical connections |
| D9xx - 0065 | | | | Electrical equipment list |
| D9xx - 0066 | | | | PSU requirements |
| D9xx - 0067 | | | | Main control panel drawing (supplied by sub contractor) |
| D9xx - 0068 | | | | Emergency stop layout |
| D9xx - 0069 | | | | Motor ratings |
| D9xx - 0070 | | | | Cable block diagram |
| D9xx - 0071 | | | | Alarms and warnings list |
| D9xx - 0072 | | | | Logic flow diagram |
| D9xx - 0073 | | | | Setpoints and timers list |
| D9xx - 0074 | | | | Data transfer |

| | | | | |
|---|---|---|---|---|
| D9xx - 0075 | | | | Shutdown modes |
| D9xx - 0076 | | | | Electrical drawing review |
| D9xx - 0077 | - | | | Reserved for process control docs. |
| D9xx - 0078 | - | | | Reserved for process control docs. |
| D9xx - 0079 | - | | | Reserved for process control docs. |
| D9xx-0080>89 | - | | | Reserved for process control docs. |
| **ELECTRICAL/CONTROL SUB CONTRACTOR SUPPLIED INFORMATION** | | | | |
| - | | | | Schematics drawing |
| - | | | | FDS functional design specification |
| - | | | | Electrical data dossier (BOM) |
| - | | | | Cable testing certificates |
| - | | | | |
| - | | | | |
| - | | | | |
| **PRODUCTION DOCUMENTS** | | | | |
| D9xx - 0090 | | | | Stack test report |
| D9xx - 0091 | | | | Component traceability details |
| D9xx - 0092 | | | | CE data plate |
| D9xx - 0093 | | | | Certificate of Conformity by NoBo- Pressure Equipment Regs. |
| D9xx - 0094 | | | | Declaration of Conformity by ITM |
| D9xx - 0095 | | | | Reserved for production docs. |
| D9xx - 0096 | | | | Reserved for production docs. |
| D9xx - 0097 | | | | Reserved for production docs. |
| D9xx - 0098 | | | | Reserved for production docs. |
| D9xx - 0099 | | | | Reserved for production docs. |
| | | | | |
| **COMMISSIONING DOCUMENTS** | | | | |
| D9xx - 0100 | | | | Installation, commissioning and operation risk assessment |
| D9xx - 0101 | | | | General risk assessment (FAT, On-site Commissioning & Operation) |
| D9xx - 0102 | | | | Lifting plan at ITM |
| D9xx - 0103 | | | | RA for lifting plan at ITM - **To be a generic Doc filed in Sharepont RA** |
| D9xx - 0104 | | | | Method statement for installation and commissioning of HGas180 |
| D9xx - 0105 | | | | Reserved for Commissioning - RA's & method statements |
| D9xx - 0106 | | | | Reserved for Commissioning - RA's & method statements |
| D9xx - 0107 | | | | SOP – Alarms and warnings testing procedure |
| D9xx - 0108 | | | | Reserved for Commissioning - procedures |
| D9xx - 0109 | | | | Reserved for Commissioning - procedures |
| D9xx - 0110 | | | | Equipment list - Commissioning checklist |
| D9xx - 0111 | | | | Instrument list - Commissioning checklist |
| D9xx - 0112 | | | | Valve list - Commissioning checklist |
| D9xx - 0113 | | | | Alarms and warnings checklist |

| | | | | |
|---|---|---|---|---|
| D9xx - 0114 | | | | FAT checklist - Part 1 - Pre-commissioning |
| D9xx - 0115 | | | | FAT checklist - Part 2 - Commissioning |
| D9xx - 0116 | | | | SAT checklist - Part 1 - Pre-commissioning |
| D9xx - 0117 | | | | SAT checklist - Part 2 - Commissioning |
| D9xx - 0118 | | | | Reserved for Commissioning - checklists |
| D9xx - 0119 | | | | Reserved for Commissioning - checklists |
| D9xx - 0120 | | | | PED Hydraulic proof pressure test - Hydrogen assembly |
| D9xx - 0121 | | | | Helium leak test - Hydrogen assembly |
| D9xx - 0122 | | | | Ventilation fans - Air flow measurement |
| D9xx - 0123 | | | | Hydraulic, pneumatic and PRV setpoints report |
| D9xx - 0124 | | | | Pneumatic pressure test of MT001 assembly test report |
| D9xx - 0125 | | | | On-site leak test - Hydrogen assembly |
| D9xx - 0126 | | | | Reserved for Commissioning - test reports |
| D9xx - 0127 | | | | Reserved for Commissioning - test reports |
| D9xx - 0128 | | | | Reserved for Commissioning - test reports |
| D9xx - 0129 | | | | Reserved for Commissioning - test reports |
| D9xx -0130>159 | | | | Reserved for Commissioning |
| **OPERATION & MAINTENANCE DOCUMENTS** | | | | |
| | | | | |
| | | | | |
| | | | | |
| D9xx-0160 | | | | Maintenance Plan |
| | | | | SOP - Maintenance activities procedure |
| | | | | |
| | | | | |
| | | | | De-commissioning procedure |
| | | | | De-commissioning checklist |
| | | | | De-commissioning risk assessment |
| | | | | Reserved |
| D9xx-0170-199 | | | | Reserved |
| | | | | |
| **CUSTOMER & SITE DOCUMENTS** | | | | |
| D9xx -0201 | | | | User documentation manual contents pages |
| D9xx -0202 | | | | ITM - User manual |
| D9xx -0203 | | | | Customer refuelling manual |
| D9xx -0204 | | | | Customer maintenance manual |
| D9xx -0205 | | | | Reserved |
| D9xx -0206 | | | | Reserved |
| D9xx -0207 | | | | Reserved |
| D9xx -0208 | | | | Reserved |
| D9xx -0209 | | | | Reserved |
| D9xx -0210 | | | | Reserved |

| STAGE GATE & TECHNICAL REVIEW DOCUMENTS | | | | |
|---|---|---|---|---|
| - | | | | TECHNICAL REVIEW 1: Ensure key docs are created to allow progress to product design (Form F6.14) |
| - | | | | GATE 2: Product design review (Form F6.12) |
| - | | | | GATE 3: Production review (Form F6.33) |
| - | | | | TECHNICAL REVIEW 2: Ensure factory commissioning checks, tests & reports completed (Form F6.34) |
| - | | | | GATE 4: OK to ship (Form F6.35) |
| - | | | | TECHNICAL REVIEW 3: Ensure commissioning site acceptance test reports completed (Form F6.36) |
| - | | | | GATE 5: Customer product acceptance form (Form F6.37) |
| - | | | | 12 month review after introduction of new product platform (Form F6.38) |

*Figure 11. Documents in a typical technical file*

The editing of documents is covered by procedure QMS OP21 Document Control. This is enforced through a dedicated Document Controller and a version control system.

Files are backed up in the following manner:

- Within the server via a RAID array
- Within the site to another server in real time (so a server failure will result in only a few minutes of disruption)
- Nightly, to a second ITM site
- Four removable discs in quarterly rotation to ensure up to a year of data is available

# 9 Communication Plan

## 9.1 Training

The people exposed to hazardous substances (ie hydrogen) will be:

- ITM Engineers, who will be exposed to the largest hazards
- Commissioning engineers from partners supplying the compressor/dispenser and maintenance engineers
- The public refuelling operatives

The competency of these groups will be determined in the following ways.

### 9.1.1 ITM Engineers

As detailed in Section 3.13.7, ITM have detailed processes to ensure staff competence. During recruitment, staff are chosen for their skills, often having been an engineer in the military.

All new starters are provided with basic H&S information common to all ITM employees. They are required to sign procedures and then complete a questionnaire based on what they have learnt, on which they must score 100%.

Once in the job, each manager has a matrix of skills that their staff require to complete their job. New staff are trained in the essential requirements and then receive on-going training to complete the matrix. With time and training (and if appropriate to their role) staff can move from testing existing systems, to performing like-for-like swaps of components on a system, to building systems and then designing systems.

Competency at a task is assured in various other ways, depending on the level of risk. For low risk activities, reading and signing a procedure is acceptable. For high risk activities, ITM have Competency Assessments, where staff are shown an activity by a trainer and are then required to demonstrate it back to them to a required standard. Ongoing training is provided by Toolbox talks (short training sessions on the shop floor provided by a supervisor) on particular subjects. These are backed up by a questionnaire to ensure they understood their training. Scores are logged to note trends in data.

Alternatively, employees may be sent on training courses, either internal or run by external companies. Feedback is sought from attendees after the course and those judged to be inadequate are not used again.

Despite these procedures, it is acknowledged that staff competency will grow with time, thus a novice commissioning engineer will not be allowed on site without being accompanied by someone with over a year of experience.

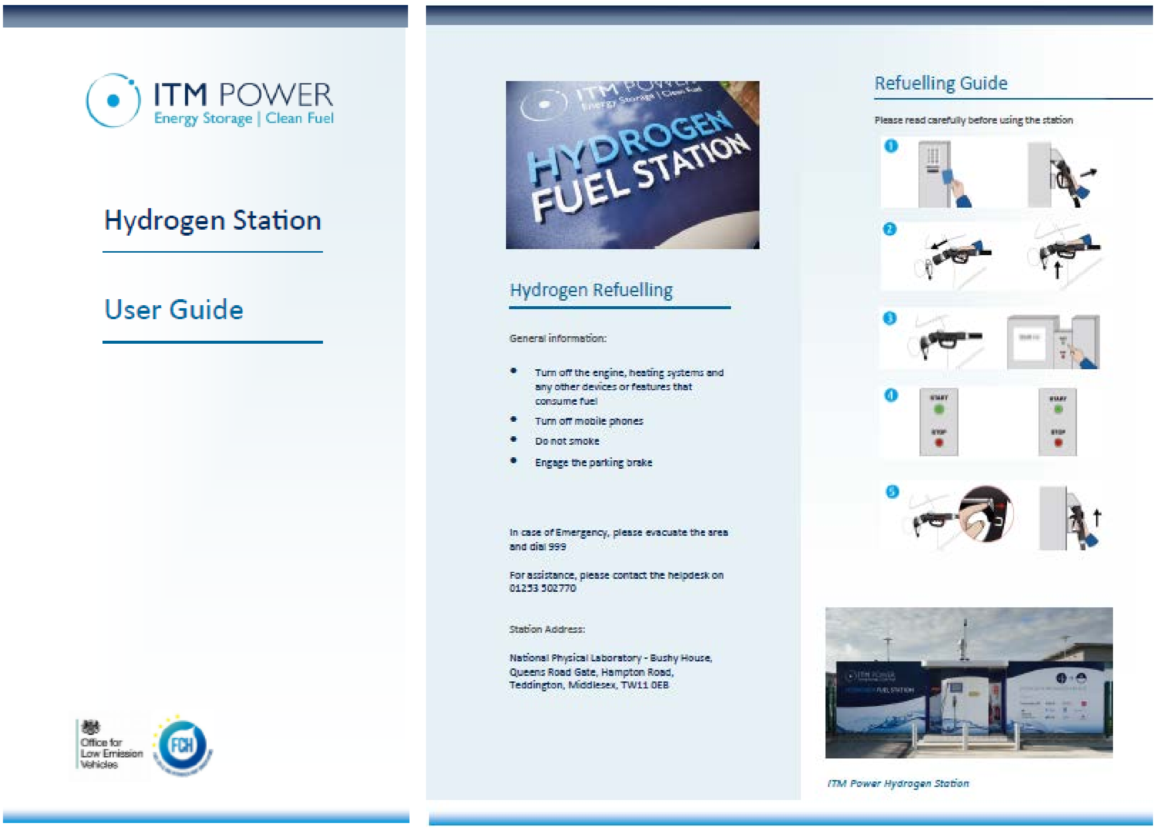
### 9.1.2 Commissioning Engineers from Partner Companies

The suppliers of the compressor/disperser will be required to come on site for several days to commission their equipment. ITM will treat them as any other contractor and follow the requirements of procedure HSMS OP05 Managing Contractors. This requires them to provide method statements, risk assessments and evidence of competency ahead of their arrival at site.

Key H&S information is shared between partners on a shared Cloud drive, with regular meetings to discuss progress.

### 9.1.3 Public Refuelling Operatives

They will be provided with training and handed documentation, a copy of which (for another refuelling station) is provided below:


ITM POWER
Energy Storage | Clean Fuel

Hydrogen Station

User Guide

Office for Low Emission Vehicles

Hydrogen Refuelling

General information:

- Turn off the engine, heating systems and any other devices or features that consume fuel
- Turn off mobile phones
- Do not smoke
- Engage the parking brake

In case of Emergency, please evacuate the area and dial 999

For assistance, please contact the helpdesk on 01253 502770

Station Address:

National Physical Laboratory - Bushy House, Queens Road Gate, Hampton Road, Teddington, Middlesex, TW11 0EB

Refuelling Guide

Please read carefully before using the station

ITM Power Hydrogen Station

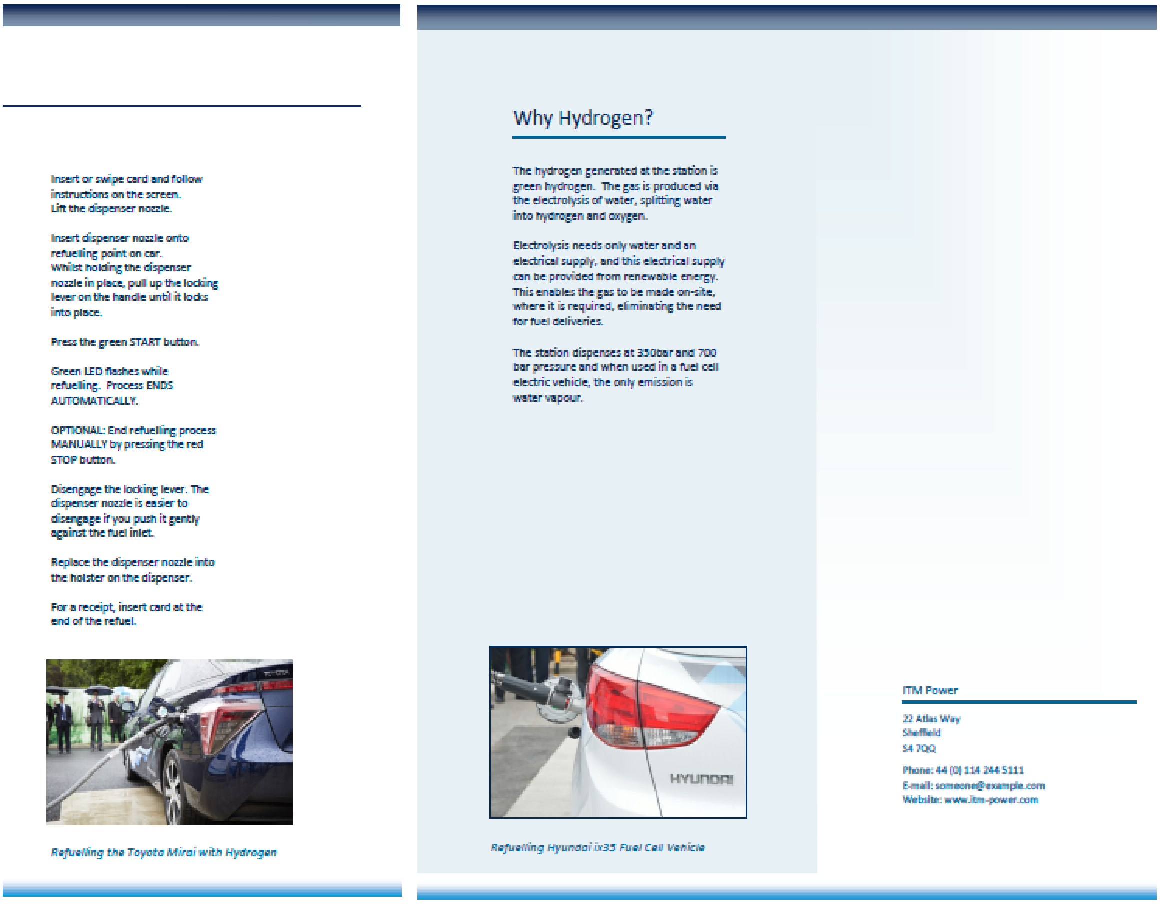



*Figure 12. User guide supplied to the public*

Refresher courses will be provided.

## 9.2 Safety Reviews

There are several stages in the project where the safety of the system will be reviewed. These include:

### 9.2.1 Design review

Usually an informal process early in the design where a team of engineers from different disciples discuss the design and highlight any obvious problems. This enables the formal hazard studies to work from a better design and not end up redesigning during the studies.

### 9.2.2 HazID:

A high level examination of the equipment and site looking for a wide range of hazards. This has been described in detail in Section 3.3

### 9.2.3 HazOp:

A methodical risk-based review of the process system looking for every possible way it could fail. This has been described in detail in Section 3.1

### 9.2.4 LOPA:

A method to quantify the risk that a plant presents, to be compared to government acceptable levels. This has been described in detail in Section 3.2

### 9.2.5 Risk Assessment:

A semi-quantitative method of risk binning for both process and non-process risks. This has been described in detail in Section 3.4

### 9.2.6 Pressure Safety Case

A document in a set format that describes the pressure systems, calculations for things such as pressure relief valve sizing, and all certificates and declarations of compliance from suppliers. This is described further in Section. 3.13

### 9.2.7 HazLoc Safety Case

This is a document in a set format that describes the system and possible ignition sources and how they are controlled. It includes assumptions of hole sizes and calculations of jet lengths and the requirements of NFPA2. The document concludes with the hazardous area drawings and the declarations of conformance from the suppliers of all HazLoc equipment.

### 9.2.8 Project Stage Gates:

A total of 7 reviews and stage gates are built into the project to ensure that all of the requirements are met before the project can move on. This will prevent the design/build moving forward without the correct studies having taken place. The stage gates include:

- Technical Review 1: Ensure key docs are created to allow progress to product design. Recorded on form F6.14. Signed by the CTO and Operations Director
- Gate 2: Production design review. Recorded on form F6.12. Signed by the CTO and Operations Director
- Gate 3: Production review. Recorded on form F6.33. Signed by the Production Manager, CTO and Operations Director
- Technical Review 2: Ensure factory commissioning checks, tests and reports completed. Recorded on form F6.34. Signed by the Head of Commissioning and Operations Director
- Gate 4: Product readiness for Shipping. Recorded on form F6.35. Signed by the CTO and Operations Director
- Technical Review 3: Ensure site commissioning checks, tests and reports completed. Recorded on form F6.36. Signed by the Head of Commissioning and Operations Director
- Gate 5: Customer product acceptance form. Recorded on form F6.37. Signed by the customer and a representative of ITM.

### 9.2.9 Workplace Inspections:

These are regularly undertaken by the site H&S Manager and a second senior manager to ensure that H&S procedures are being adhered to.

### 9.2.10 Site Inspections during Ground Works:

During the building phase the site manager will make regular visits to the site to ensure that the build is on target and that contractors are adhering to ITM H&S procedures, specifically HSMS OP05 Managing Contractors.

### 9.2.11 Site Inspections During Operation:

Once operational, ITM require the site to be visited once per week to make a series of basic checks, such as water / hydrogen leaks, check pressures in bottles air and whether the site is secure. This will be conducted by a subcontractor who is familiar with hydrogen technology and is trained by ITM.

### 9.2.12 Maintenance Visits

ITM require a major and minor services each year, each offset by 6 months. These will be conducted by trained ITM engineers and will involve the review of a range of equipment including:

- Inspection of the system, looking for corrosion or damage
- Leak testing of pressure systems
- Calibration of sensors
- Functional testing of all safety systems

### 9.2.13 Document Reviews

Safety documents will be reviewed under the following circumstances:

- After a set period: HazOps and LOPAs are reviewed every 5 years and risk assessments are reviewed annually.
- If the system changes: As described in Section 3.14, documents are updated as part of the change management procedure
- In response to an accident, incident, reactive audit, proactive audit or changes in:
    - Legislation
    - Industry practice / guidance
    - Hazards associated with adjacent properties

## 9.3 Safety Events and Lessons Learned:

While Section 3.3 of ITMs H&S Policy describes the generality of dealing with and investigating incidents, specific guidance is provided in SP7.8 Standard Procedure for Reporting Investigating and Analysing Incidents. The forms for investigating the incident depend on the type of incident:

- Form 8.22 Accident Reporting Form should be used if there was an injury
- Form 8.23 Near Miss and Incident Reporting Form should be used if there was not an injury

The summary of the procedure is:

### 9.3.1 The reporting procedure within the organization

**For minor injuries:**

- Obtain first aid treatment/assistance for any injuries
- Investigate the accident using the form F8.23 as soon as possible after the occurrence and within 12 hours by the Health and Safety Manager, with any relevant staff.

**For Reportable Injuries** (as defined by OSHA)**:**

- Take patient to hospital
- Preserve the accident scene, take witness statements
- Complete Form 300, and summary Form 300A

**For severe Injuries** (as defined by OSHA):

- Take patient to hospital
- Preserve the accident scene, take witness statements
- For fatalities, report to OSHA within 8hrs, otherwise within 24hrs.

In all but the most minor or cases (cuts and abrasions) an investigation should be conducted to establish the causes and root causes.

### 9.3.2 The Method and Procedure used to Investigate Events

If there was an injury, use Form 8.22 Accident Reporting Form, otherwise use Form 8.23 Near Miss and Incident Reporting Form, however, both forms follow a similar format. Key sections from the accident form is provided below:

- Address of company
- Location of accident
- Details of injured person
    - Name
    - Works number
    - Position
    - Address
    - Normal hours of work
- Details of the accident
    - Place
    - Time of accident
    - Time reported
    - Sketch or photograph of the scene
    - Was the person authorised to conduct the task?
    - Was the person trained to conduct the task?
    - A description of the accident
    - Do risk assessments, toolbox talks or standard procedures exist that cover the incident?
    - Was the injured person aware of the assessments, toolbox talks and standard procedures?
    - Was the injured person adhering to the risk assessment and / or tool box talk and / or safe system of work?
- Witnesses
    - Name
    - Position
- Was the injured person able to continue normal duties
- Could protective clothing / equipment have prevented the injury?
- Treatment details
    - Type of injury
    - Treatment given by
    - Treatment
- Statement of the injured person
- Statements of witnesses
- Interim conclusion:
    - Immediate cause of accident
    - Underlying cause of accident
    - Root cause of accident
- Actions
- Review of recommended action (completed by appropriate manager / director)

### 9.3.3 How Corrective Measures will be Implemented

As can be seen from the detail for the accident / near miss investigation detailed above, it requires actions to be written down and then confirmed by a manager / director that they have been completed.

In addition, all accidents are discussed at the company's monthly H&S Committee meeting and accident statistics are compiled annually, looking for trends which could indicate an underlying problem.

### 9.3.4 How lessons learned from incidents and near-misses are documented and disseminated

As previously described, the actions to prevent a reoccurrence are written down on the accident investigation form and are disseminated to ITM's H&S Committee. This includes senior managers, directors, and representatives of employee safety, all of whom disseminate relevant information to staff.

Incidents involving hydrogen are reported to the h2tools/lessons website for international dissemination.

## 9.4 Emergency Response

The response to an emergency is determined by the HRS's Emergency Plan. This is a document (based on a set format) that ITM put together for each HRS and comprises two parts:

- The main document which is shared between ITM, contractors, first responders, the landlord and other stakeholders. This provides details of:
    - Background information of the site
        - Equipment
        - Volumes and pressures of hydrogen on site
    - Roles and responsibilities at the HRS
    - Fire plan
        - Fire plan principles
        - Fire prevention procedures
        - Means of escape
        - Process for raising an alarm (including interaction between the sites automated system for dialling the fire service, site security, the fire service and ITM)
        - Testing of the fire alarm
    - How to turn off power to the site (E-Stops and at the local substation)
    - Evacuation of adjacent buildings
- A simpler appendix to be shared with members of the public using the refuelling station as well as being displayed at the HRS. This includes:
    - Simple instructions for what to do in the event of an emergency
    - Location of evacuation point
    - Location of Fire glass break points, Equipment E-Stops and Global E-Stops.

ITM recognise the critical role that first responders have in an Emergency Response. As well as having a familiarisation visit to the station before it is operational, they will be provided with key pieces of information including the Emergency Plan, Maintenance Plan and the guide for users of the station.

## 9.5 Self Audits

In line with ITM's Health and Safety and Quality management systems, ITM proactively look for potential problems with paperwork and physical systems through the use of internal audits, based on procedure QMS OP26 Internal Audit. In addition, ITM may conduct a reactive audit in response to an event, (eg a supplier has alerted ITM to a problem with a part).

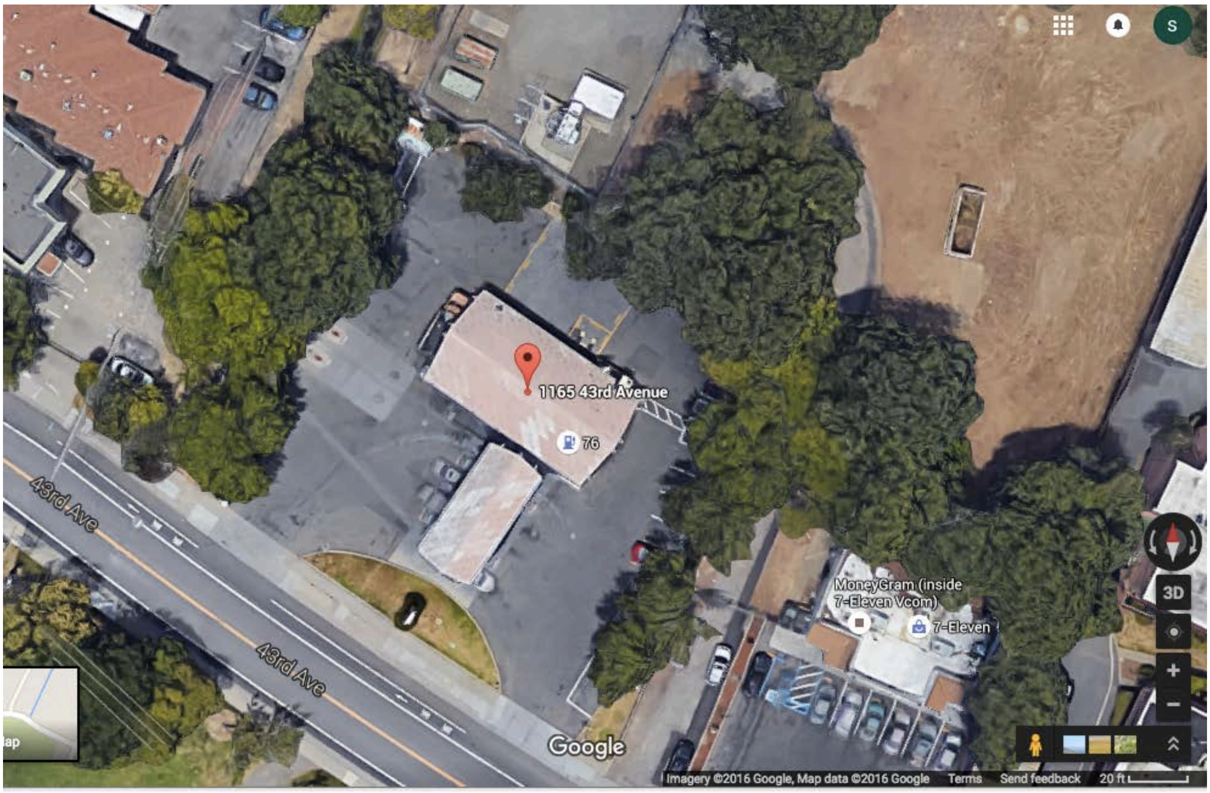
ITM have several members of staff who are trained to conduct internal audits and have forms to complete to record results (Form F2.02).

## 9.6 Process Flow Diagram

The PFD for the stations will be provided as a separate document.

# 10 Appendix A – site specific factors

## 10.1 Site 2 – Sacramento




This site is located on an existing fuel station and is next door to commercial space. The station will be constructed in the North-West corner of the lot and fire walls will be used to limit the extent of setbacks on the site.

The site has good access for engineering staff and the public and is not backed onto by any local residences or occupied space.  There are trees/vegetation overhanging the site which will need to be cleared but this is not anticipated to be a major issue.

The area that will house the hydrogen equipment on this site is set back from the main building and the electricity service panel and so electrical zoning is not considered to be a problem.

It is not anticipated that this site will cause any additional/specific safety concerns.

# Safety Plan

## 11 Scope of Work

### 11.1 Background

This document describes the safety plan for the ITM Power hydrogen refuelling station (HRS) located at the following address:

| Site # | Location |
|---|---|
| 3 | 16400 San Pablo Ave, San Pablo, CA 94806 |

Each station has the capability to dispense a minimum of 180kg of high quality hydrogen at 700 bar to fuel cell electric vehicles (FCEVs) each day. This hydrogen can be generated on-site via the electrolysis of water by renewable electricity, or the importing of hydrogen via a tube trailer.

ITM Power Inc. (ITM) are the station owner and provider of the electrolysis equipment and thus have a duty to ensure the safety of its staff, customers and others affected by the operation of this equipment. This document, based on Safety Planning for Hydrogen and Fuel Cell Projects[7], summarises the key evidence that ITM use to justify that the hazards on site are controlled and minimised to As Low As Reasonably Practicable (ALARP).

### 11.2 General Site Layout

Each site will comprise of the following components:

- A parking / refuelling area for vehicles
- A hydrogen dispenser
- A secure compound which will contain:
  - A hydrogen generator (electrolyser) in a shipping container
  - A low pressure (50 bar) buffer tank
  - A compressor in a shipping container
  - High pressure (up to 1000 bar) storage
  - A parking area for a hydrogen tube trailer
  - A connection panel for the tube trailer
  - E-stop and safety system including UV/IR detectors and hydrogen leak detection devices

### 11.3 Site Specific Layout

The specific layouts of each site are described in section 5 together with a description of any site specific safety related factors

[7] By the Hydrogen Safety Panel

## 11.4 Project Phases

This will be a commercial HRS with the work divided into distinct phases of:

- Design
- Assembly
- Factory commissioning
- Site installation
- Site commissioning
- Commercial operation
- Eventual site decommissioning

Of these phases, only site commissioning and commercial operation will generate significant quantities of hazardous material (hydrogen). The amount of hydrogen generated, stored and used for each of these phases is summarised below:

| Phase | $H_2$ Generated | $H_2$ Stored | $H_2$ Used |
|---|---|---|---|
| Site commissioning | ~50kg | 95kg | None |
| Commercial operation | Max 180kg per day | 95kg | max 180kg per day |

For all other phases of the project, safety will be ensured through compliance with ITMs ISO9001 quality management system and OHSAS 18001 Occupational Health and Safety Management System, and by following regulatory codes, such as NFPA2. As this safety plan is focussed on hydrogen specific safety, the remainder of this document will focus on the commissioning and operation phases of the project – this approach was discussed and agreed with the hydrogen safety panel (Nick Barilo).

Several types of personnel will be on-site:

- Public users of the refuelling station. They will receive both written and verbal training in the use of the equipment before they are allowed to use the station. They will also be required to attend a periodic refresher course.
- Site staff: The HRS will utilise local staff to respond to shutdowns and perform regular basic checks of the system (primarily checking for loss of containment of water or hydrogen). They will be trained by ITM (including verbal training and being supplied with documentation) but will be subcontracted to a company offering this service to a range of HRS. Thus they will be familiar with the general hazards of hydrogen and have some specific knowledge of the site. They will be required to attend an annual refresher training course.
- Commissioning / servicing staff. These are ITM engineers who have a detailed understanding of the equipment and are very familiar with the hazards associated with hydrogen and its associated technology. They have had extensive training and will continue to have a rolling program of updates (see Section 4.1)
- Builders. These will be on-site for several months preparing the location. They will be selected, and their OH&S training confirmed before they enter site, in line with ITM's written procedures. However, no hydrogen will be present.

Additional details of training are provided in Section 4.1.

Until commercial operation, the phases will be managed by ITM's Operation Director, Helio Bustamante. Once in the commercial phase, the site will be managed as a business by Steve Jones, ITM's Managing Director.

## 11.5 Permitting

The following permits will be required before operations on site can commence, this varies from city to city but each of the components listed below are incorporated into the permitting process, this section is described in more detail in the project narrative section of the GFO proposal. Each location will be assigned an Authority Having Jurisdiction (AHJ) and ITM has made initial contact will all relevant AHJ's in our station locations:

- Planning Permit
- Building Permit
- Electrical Permit
- Fire & Safety Permit

# 12 Organisational Policies and Procedures

ITM have an extensive Health and Safety Policy, which governs all of its operations. It includes a policy statement, the company objectives, the organisational structure and arrangements in place to ensure the prevention of harm. The full document is too long to include here, but is available on request. However, a copy of the Statement of Intent signed by ITM Power's CEO is presented below:

**STATEMENT OF INTENT**

**HEALTH & SAFETY POLICY STATEMENT**

ITM Power Plc is involved in the research and development and supply of clean fuel technology. Our aim is to provide the technology necessary to make the hydrogen economy a commercial reality and replace hydrocarbon fuels and hence society's total reliance on their constant supply.
We recognise that our employees are our most valuable assets and we are therefore committed to ensuring that the highest possible standards of Health, Safety and Welfare are maintained.

ITM is committed to-

- Ensuring so far as is reasonably practicable, the health, safety and welfare of all employees at work and of all persons not directly employed by the company, but who may be directly affected by its activities
- Identifying and managing hazards and associated risks for all activities carried out at ITM or by ITM employees
- Complying with all applicable OH & S legislation, codes of practice and any other requirements to which ITM subscribes
- Continual improvement to deliver improved OH & S Standards and performance

ITM will achieve these commitments by-

- Adhering to the OH&S Management System specifications outlined in the international standard ISO 18001
- Setting and reviewing OH&S objectives, targets and management programmes;
- Implementing an internal audit programme to measure compliance with our planned OH&S arrangements and the requirements of ISO 18001
- Providing training for all personnel working for and on behalf of ITM, including contractors to ensure they are aware of the requirements of this OH&S policy statement, how their activities can impact on the Safety of themselves and others, and their OH&S responsibilities
- Regularly reviewing both the Policy and the OH&S management system to ensure continued relevance to the organisation

This policy is publicly available on demand.

Signed..........................................

Dr. Graham Cooley
CEO ITM Power (PLC)

06/11/15

In addition, it is felt useful to include the contents pages to provide an indication of the topics covered:

# CONTENTS

In addition to the overall policy, each process through the design, manufacturing, factory commissioning and site commissioning are governed by over 200 procedures that cover quality, H&S and environmental management. .

## 12.1 Hydrogen and Fuel Cell Experience

ITM have been operating for 15 years, initially as a research company (studying fuel cells and electrolysers) and then as a manufacturers of electrolysers and as system integrators. This has allowed ITM to gain knowledge of range of hydrogen technologies including (but not limited to):

### 12.1.1 Electrolysers:

- PEM electrolysers
- Liquid alkaline electrolysers
- APEM electrolysers
- Connection of electrolysers to PV, wind turbines and tidal turbines

### 12.1.2 Fuel Cells:

- Static Hydrogen fuel cells
- Mobile hydrogen fuel cells (cars, vans, fork lifts, pallet trucks)
- Marine based fuel cells
- Methanol fuel cells
- Sodium borohydride fuel cells

### 12.1.3 Compressors:

- Mechanical compressors

- Ionic compressors

### 12.1.4 Storage:

- Stainless steel hydrogen storage (Type I)
- Composite hydrogen storage (Type II to IV)
- Metal hydride storage
- Hydrogen tube trailers

### 12.1.5 Hydrogen Transportation:

- Transporting of hydrogen by road (ADR)
- Transporting of hydrogen by sea (IMDG)

### 12.1.6 End Uses of Hydrogen:

- Hydrogen combustion in vehicles
- Hydrogen combustion in static boilers
- Hydrogen dispensing (including protocols, and design and operation of hydrogen refuelling stations)
- Injection of hydrogen into the gas grid

### 12.1.7 Conversion of hydrogen to other fuels

- Reacting of hydrogen to form methane (via both chemical and biological methanation)
- Reacting of hydrogen to form ammonia and urea
- Reacting of hydrogen to form diesel

With specific reference to this application, ITM has 15 current hydrogen station projects either built or in the process of being built. While some of these have been sold to and are operated by third parties, most are owned and operated by ITM. As such, ITM are very familiar with the processes and technology required to make a safe and reliable HRS.

Engineers will be on site for commissioning, which is identified as an activity with increased risk. As such, work will always be conducted with pairs of engineers, able to discuss potential problems. One engineer will always have at least 1 year of experience.

In addition to practical experience of designing, building and operating refuelling stations, ITM are heavily involved in the writing of national, regional and international standards for HRS:

- ITM staff also lead the UK delegation to ISO TC 197 and are secretary of ISO TC 197 WG24, covering hydrogen vehicle fueling station safety standards (ISO 19880-1).
- ITM contributes to ISO TC 197 WG26, covering electrolyser safety standards (ISO 22734); WG27 & WG28, covering hydrogen quality standards for fuel cell use (ISO 14687 & ISO 19880-8); and WG19, covering the safety standard for hydrogen dispensers (ISO 19880-2).
- An ITM staff member currently serves as chair of British Standards Institute (BSI) committee PVE/3/8 and the UK lead expert to the Comité Européen de Normalization (CEN) TC 268, WG5 preparing hydrogen refueling station standards to be harmonized to the European Directive 2014/94/EU on the deployment of alternative fuels infrastructure.
- ITM staff also serve as secretary of the British Compressed Gases Association (BCGA) Technical Sub-Committee (TSC) 9, and led the development of the industry code of practice (CP) BCGA CP41 - The design, construction, maintenance and operation of filling stations dispensing gaseous fuels. Additionally, through the BCGA, ITM are involved with the Energy Institute (EI) and Association for Petroleum and Explosives Administration (APEA) in the development of an Addendum to the Blue Book to facilitate hydrogen fueling co-located with petrol dispensing forecourts in the UK.

# 13 Identification of Safety Vulnerabilities

ITM rely on several techniques to identify safety vulnerabilities within its hydrogen refuelling stations, these are executed at different stages of the project to ensure constant analysis of risk and to allow any new risks to be highlighted and considered as the project develops.

## 13.1 Hazard and Operability (HazOp) Studies

ITM conduct two HazOps – one at the design stage and one at the as-built stage (which takes into account any code or assembly modifications introduced during the build and factory commissioning process). Each study is conducted by a team of several engineers, with representatives, from the Process, Electrical and Safety Engineering teams to ensure a wide spread of skills. While novice engineers are encouraged to participate, there will always at least three team members who have conducted at least 10 previous studies, to ensure the correct depth of knowledge. Teams are led by a chairperson who has considerable HazOp experience and has attended a HazOp Leaders course.

The studies require the process and instrumentation diagrams (P&IDs) of the site to be divided into nodes (often based around the fluid media or pressure). Keywords are then considered for each node, such flow, temperature and pressure. Then for each keyword, deviations are studied, such as No Flow, More Flow, Flow Elsewhere etc., where the possible causes, consequences and prevention systems for each are detailed. Each of these deviations are conducted as semi-quantitative risk assessments, with numbers assigned for likelihood, consequence and final risk for both the safety and operability of the plant. Rules are then applied to determine whether the system is adequate, or whether an action is required to lower the risk. Any deviation that could result in a fatality (no matter how small the likelihood) is referred for further consideration in a Layer of Protection Analysis (LOPA).

Several HazOps have been conducted that cover the HRS. These are available on request.

## 13.2 Layer of Protection Analysis (LOPA)

LOPA is a standard tool within the process engineering industry, but as yet, is not widely used within the hydrogen industry. The technique takes specific scenarios (such as overpressure) and initiators that could cause the scenario (such as sensor failure) from the HazOp study and attempts to determine the likely frequency of a fatality based on such things as the frequency of an initiator occurring, the independent layers of protection in place to prevent that deviation resulting in the scenario (hydrogen detectors, pressure relief valves, HazLoc equipment etc) and the likelihood of someone being on site.

The risks are then totalled and compared to government standards, which have thresholds for:

- Risk is unacceptable
- Risk is tolerable if As Low As Reasonably Practicable (ALARP)
- Risk is broadly acceptable

A site will usually be found to be within the 'tolerable if ALARP' region. Therefore a Cost / Benefit Analysis (CBA) will be conducted. Again, this follows an approved methodology to determine whether the cost of introducing a risk reduction measure is worth the incremental benefit it will bring. If all of the high risk initiators are shown to be ALARP, then the risk that the site presents is considered tolerable.

The LOPA and CBA studies are normally written by an engineer experienced in the technique, but are then reviewed as a team exercise, usually with process engineers. This may go through several iterations until all team members are happy with the study.

The LOPA and CBA studies are site specific and therefore will be conducted for the each HRS after a contract is awarded. Examples of previous LOPA and CBAs for similar HRS can be provided on request.

## 13.3 Hazard Identification (HazID)

While HazOps and LOPAs are good at identifying weaknesses in the sites process engineering, they do not consider non-process dangers, such as slips, trips and falls, adverse weather, vandalism etc.

The purpose of a Hazard Identification (HazID) study is to take a high level examination of the risks (particularly non-process risks) that the system presents to ensure that they will be considered in detail during subsequent studies, in many ways it is similar to both fault and event tree analysis. This ensures that the hazards considered in the Risk Assessment are based on an objective assessment, and not the subjective views of the author.

ITM use a standardised list of hazards (published by Burk, 1992, as referenced in DOE Handbook, 2004). While it is acknowledged that pre-prescribed lists can limit thinking about hazards, this is out-weighted by the benefits of having an objective list and not overlooking a risk.

The HazID study is site specific and will therefore be completed for each HRS once a contract is awarded. Examples of previous HazIDs for similar HRS can be provided on request.

## 13.4 Risk Assessment (RA)

The ITM risk assessments are designed to be compliant with ISO 14121-1 Safety of Machinery, as required in Section 5.1 of ISO 22734-1 Hydrogen Generators using Water Electrolysis Process.

The ITM RA is semi-quantitative and considers the hazards for the site (both process and non-process), their likelihood of occurring the consequences of an occurrence, and then calculates the risk. Based, on this risk, it considers if additional risk control measures are required.

The RA study is site specific and will therefore be completed for each HRS once a contract is awarded. Examples of previous RAs for similar HRS can be provided on request.

## 13.5 Safety Critical Equipment

Control for the plant is overseen by a Site PLC, which communicates with individual equipment PLCs, particularly the electrolyser, dispenser and the compressor. Equipment PLCs will automatically shut themselves down for process errors that could result in safety problems (e.g. flow of water to stacks too low) are communicated to the site PLC, which in turn triggers a site-wide shutdown.

In addition, there are specific safety PLCs/circuits which are independent of the process PLCs. These monitor key safety equipment which if triggered indicate that an emergency situation is already present such as  smoke alarms, hydrogen alarms, fire detectors and E-Stops (full list is below) and can initiate a site-wide shutdown. Non-instrumented safety systems include earth bonding and pressure relief valves.

All safety critical equipment is guaranteed to be functional in a hydrogen environment, ITM never use generic safety equipment. If there is any doubt to a products applicability to a hydrogen environment the product will not be used.

All safety systems are functionally tested during regular servicing and are highlighted within the maintenance manuals to ensure ongoing safety is maintained. Replacement and/or recalibration of all safety critical equipment is conducted in line with or sooner that the manufacturers guidelines.

The full list of equipment on monitors on safety circuits (not the process PLCs) is provided below:

**Electrolyser**:

- 4x PRV
- Smoke detector
- 2x $H_2$ detector

**Buffer tank**:

- 2x PRV
- Fire detector

**Compressor/dispenser**

- 4x PRV
- 3x Fire detector
- 4x Pressure transducers
- 3x Temperature transducers

## 13.6 Hazardous Materials

The key hazardous material considered here is hydrogen. Other hazardous materials are present on the plant (ambient pressure oxygen, hydraulic oil and glycol), but are considered low risk.

### 13.6.1 Source:

- Hydrogen generation via electrolysis at a maximum rate of 85kg per day
- Hydrogen supply via a tube trailer.

### 13.6.2 Storage:

Materials will be stored on site in certified vessels at the following approximate volumes and pressures:

| Description | Pressure (bar) | Mass $H_2$ stored (kg) |
|---|---|---|
| Buffer tank | 50 | 2 |
| Intermediate pressure storage | 200 | 4 |
| High Pressure storage | 85 | 1000 |
| Tube trailer | 350max | 250 |

In addition, small volumes of hydrogen will be located in the electrolyser, compressor and interconnecting pipework.

### 13.6.3 Ignition Sources:

The site is compliant with NFPA2, and therefore there should be no ignition sources. A full HazLoc safety study will be conducted for each site, but in summary:

- For high pressure fittings, there are no ignition sources within the hazardous area zone extents defined in NFPA2
- For the high-level hydrogen vents, there are no ignition sources within the hazardous area zone extents defined in NFPA2
- Where electrical equipment is used within a hazardous area, it is appropriately HazLoc rated for the class and division required.
- The dispenser is vented after use, in line with refuelling station guidance

- Fire walls are provided to reduce zone extents and prevent hazardous areas extending into uncontrolled areas
- Commissioning / maintenance engineers are trained to operate around high pressure flammable gases and have appropriate personal protective equipment.

### 13.6.4 Explosion Hazards:

There are several potential explosion hazards identified in the HazOp and LOPA:

- Catastrophic leak, followed by ignition in the electrolyser or compressor containers
- Catastrophic leak from an external fitting, followed by ignition
- The heater in the gas dryer remains engaged, softening the pressure vessel, leading to catastrophic failure
- External fire, softens pressure vessels on site, leading to catastrophic failure
- Jet fire from a fitting leak impinges on pressure vessels, locally softening them and leading to catastrophic failure
- Failure of logic/equipment controlling the ramp rate of hydrogen into the vehicle, leading to overheating of the vehicle tank, softening and catastrophic failure.
- Failure of logic/equipment controlling the pre-chilling of the hydrogen entering the vehicle, leading to overheating of the vehicle tank, softening and catastrophic failure.
- Failure of the logic to stop hydrogen generation / compression at the required pressures, leading to over pressurisation and catastrophic failure of equipment

All of these have been assessed in detail as part of the LOPA and the risks are within tolerable levels.

### 13.6.5 Material Interactions

All materials used have been selected to be compatible with each other and the media they will be exposed to. The obvious potential material interaction is the embrittlement of materials with hydrogen. An example of where this went wrong is the Emeryville refuelling station fire in 2012. ITM process engineers go to great lengths to ensure that all of the parts that will be exposed to hydrogen will not embrittle; this is backed up by manufacture declarations and, where appropriate, material compatibility reports which are stored in the project technical file.

### 13.6.6 Possible Leakage

There are numerous possible sources of hydrogen leaks in the site. This includes:

- From all mechanical fittings (this is minimised where possible by using welded fittings)
- From valve seats (both between different parts of the hydrogen system, and between the hydrogen system and vents)
- From the compressor seals
- Through non-return valves failing to check

The likelihood (based on industry data) and consequence of leaks from all sources have been considered at two levels:

- Non-catastrophic. This is required for HazLoc calculations (which specifically excludes catastrophic failure). ITM use a hole size of $0.25mm^2$
- Catastrophic (100% of area)

The risks of these have been semi-quantitatively assessed by ITM, and determined to be tolerable.

### 13.6.7 Accumulation

The HRS is designed to prevent the gas becoming trapped and is equipped with effective high and low level ventilation openings. Any points of possible leakage are either covered by appropriate gas detection, in an area where a leak cannot accumulate or is freely ventilated.

### 13.6.8 Detection:

The detection of a hydrogen leak is achieved in many ways, including:

- Direct detection with hydrogen detectors in indoor locations, where the detector is located at the highest point.
- Indirect detection by:
  - Unexpected pressure drop during operation
  - Pressure hold test (where electrolyser generation or flow to the vehicle is paused and the system monitors the pressure for evidence of leaks)
  - Failure to pressurize the system within certain durations

Should the leak become ignited, this can be detected in other ways including:

- Smoke sensors
- Heat sensors
- UV/IR flame sensors

## 13.7 Site Specific Hazards

While each HRS is built to a common standard with similar hazards, each will present individual hazards associated with factors such as other fuels on site, the proximity of hazardous materials on adjacent sites or the proximity of the public to the site. The hazards for each site are described in Section 5.

## 13.8 What hazard associated with this system design, installation and operation is most likely to occur?

Based on ITM experience and numerous safety studies the hazards most likely to occur are:

- Minor hydrogen leak which pose minimal risk to the system
- Slips, trips and falls (although they will not be considered further here as this report is focussing on the specifics of hydrogen hazards)

Leak risks are mitigated by diligent maintenance procedures and leak detection strategies such as routine leak tests by staff. Slips trips and falls are mitigated by maintaining a clean and clear site and posting appropriate signage and hazard markings on the site.

## 13.9 What hazard associated with this system design, installation and operation has the potential to result in the worst consequence?

Based on the numerous safety studies the hazard with the highest consequence is:

Catastrophic failure, followed by ignition of a pressurised hydrogen store, brought about by external fire, vehicle collision or impingement by ignited hydrogen jets.
These risks are mitigated by the use of bollards and curb stones for crash protection, posting of appropriate signage on the site, the installation of shields to prevent jet impingement, UVIR sensors and by maintaining a high level of record keeping and test records for pressurised components.

## 13.10 Updates

In line with industry practice, the HazOp and LOPA will be re-assessed every 5 years, or when something on the site materially changes (see Section 4.2.13 for details)

The risk assessment will the reviewed every year, or when something on the site materially changes.

## 13.11 Risk Reduction Plan

The methods used to identify safety vulnerabilities considered hundreds of potential hazards. As requested in Safety Planning for Hydrogen and Fuel Cell Projects, only the significant safety vulnerabilities related to hydrogen will be described here in a risk binning format. As such, insignificant safety vulnerabilities or those not directly related to hydrogen will not be discussed.

**Risk Matrix** [8]

| Consequence Category | | Likelihood | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **1** Extremely Unlikely | **2** Very Unlikely | **3** Unlikely | **4** Quite Unlikely | **5** Somewhat Likely | **6** Fairly Probable | **7** Probable |
| **Very Major Catastrophic**<br>>100 fatalities | **A** | **R8** | **R7** | **R6** | **R5** | **R4** | **R3** | **R2** |
| **Catastrophic**<br>Overall 11 to 100 fatalities, fatalities to workers and/or public, international media exposure | **B** | **R9** | **R8** | **R7** | **R6** | **R5** | **R4** | **R3** |
| **Extremely Serious**<br>Overall 1-10 fatalities, worker fatality, major injury to member of public. National news, prosecution and fine. | **C** | **R10** | **R9** | **R8** | **R7** | **R6** | **R5** | **R4** |
| **Major**<br>Serious injury to worker (permanent disability). Injury to member of public. | **D** | **R11** | **R10** | **R9** | **R8** | **R7** | **R6** | **R5** |
| **Serious**<br>Significant injury to worker. Minor injury to member of public. Adverse local publicity. | **E** | **R12** | **R11** | **R10** | **R9** | **R8** | **R7** | **R6** |
| **Minor**<br>Minor injury to worker. Few complaints. | **F** | **R12** | **R11** | **R10** | **R9** | **R8** | **R7** | **R6** |

*Table 5 The Risk Matrix based on the likelihood and consequence of a hazard*

[8] As used in HSL report PS/08/01 "Assessing the safety of delivery and storage of hydrogen", also "Moonis, Wilday, Wardman - Process Safety and Environmental Protection, 88, 2010, 2, 97-108 - Semi-quantitative risk assessment of commercial scale supply chain of hydrogen fuel and implications for industry and society".

**RISK RATING = CONSEQUENCE CATEGORY x LIKELIHOOD**

Score 'Likelihood' from 1 to 7 where 1 is "Extremely Unlikely" and 7 is "Probable".

Score 'Consequence Category' from A to F where A is "Very Major Catastrophic" and F is "Minor".

Consider harm to people, the environment, damage to buildings, etc. and other potential losses to ITM such as share price.

| RISK RATING | PRIORITY | REQUIRED ACTION [9] |
|---|---|---|
| **High (R1-R5)** | **1** | High risk, not acceptable. Further analysis should be performed to give a better estimate of the risk. If this analysis still shows unacceptable or medium risk redesign or other changes should be introduced to reduce the criticality. |
| **Medium (R6-R7)** | **2** | The risk may be acceptable but redesign or other changes should be considered if reasonably practical. Further analysis should be performed to give a better estimate of the risk. When assessing the need of remedial actions, the number of events falling into this risk level should be taken into consideration to assure that the risk is as low as reasonable practical (ALARP). |
| **Low (R8-R12)** | **3** | The risk is low and further risk reducing measures are not necessary. |

*Table 6. The risk rating and required actions*

[9] Taken from Table 2 of DNV report "Hydrogen Applications – Risk Acceptance Criteria and Risk Assessment Methodology": http://www.eihp.org/public/Reports/Final_Report/Sub-Task_Reports/ST5.2/EHEC%20paper_final.pdf

**Definitions:**

| | |
|---|---|
| **Hazard:** | A potential source of harm. Must be a reasonably foreseeable hazard, defined as use of a machine in a way not intended by the designer, but which may result from readily predictable human behaviour. A hazard is either permanently present during the intended use of the machine (e.g. motion of hazardous moving elements, electric arc during a welding phase, unhealthy posture, noise emission, high temperature), or can appear unexpectedly (e.g. explosion, crushing hazard as a consequence of an unintended / unexpected startup, ejection as a consequence of a breakage, or fall as a consequence of acceleration / deceleration) |
| **Consequence**: | What will happen if the hazard is realised? |
| **To Whom**: | Consider all of the people who could be injured: The operator, those in the vicinity, visitors, cleaners, contractors etc. |
| **Likelihood:** | This is the likelihood of the harm being realised in the time before the RA is next reviewed (generally a year), with all of the present control measures in place. The definition of the grades of likelihood is provided in Table 1. |
| **Severity:** | This is the severity of the accident, with all of the present control measures in place. The definition of the grades of severity is provided in the Table 1. |
| **Risk Factor:** | The product of the likelihood and severity. The definition of the grades of risk is provided in the Risk Table and the required action is summarised in Table 2. |
| **Existing Controls**: | Detail of all present control measures to prevent the harm being realised |
| **Action needed**: | Should the risk factor be too high, further control measures should be detailed. The effect of these actions on the risk factor should be considered. |

## Loss of Hydrogen Containment

| # | Hazard | Consequence | To Whom | Likelihood | Severity | Risk Factor | Existing Controls | Action Needed |
|---|---|---|---|---|---|---|---|---|
| | Loss of containment of hydrogen from **external** fittings. | Minor leaks may result in a small jet fire.<br><br>This may affect personnel and equipment that is in direct contact with it (such as the hydrogen dryer vessels – potentially leading to an escalation to a significant release).<br><br>Significant releases followed by ignition could result in deflagration and subsequent jet fire<br><br>The deflagration would be expected to cause minimal damage and only result in significant injuries to personnel in close proximity to it. | ITM operator | 2-3 | E-F | R9-R11<br><br>**Low Risk** | **Control of releases:**<br><br>• Installation of manifold connections carried out according to manufacturer's instructions.<br>• FAT includes pressure test of all parts in $H_2$ system to at least 1.43x maximum allowable pressure (unless pressure tested previously).<br>• Vessels are pre-tested for leaks as part of suppliers ASME conformance testing.<br>• Pre-commissioning prior to hydrogen production and following any invasive maintenance, includes helium pressure test of system to maximum working pressure.<br>• Regular inspection and leak testing of pressure systems according to maintenance schedule and written scheme of examination.<br>• Major leaks would result in a pressure drop, resulting in a shutdown.<br>• Assuming no additional upstream failures of check valves, the release would be limited to downstream vessel size<br>• Open air - natural ventilation to dissipate minor leakage.<br><br>**Control of ignition sources:**<br><br>• Area around potential hydrogen leak points defined as Zone 2 and all electrical components within this area are appropriately HazLoc rated to reduce likelihood of ignition sources being present.<br>• Signage warning of the presence of a hazardous area.<br>• No ignition sources or flammable materials within hazardous area.<br>• No air intakes within hazardous area. | Confirm no site pipe work runs have leak points around ignition sources or air intakes |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | **Personnel Controls:**<br><br>• A significant release would be audible to personnel in vicinity. They can instigate a shutdown from an E-Stop.<br>• Pressing E-Stop push buttons, located around HRS, immediately shots down the system, closing all valves<br>• Visual alarm located on container roof alerts staff in the case of a Shutdown<br>• Escalation of a jet fire into a fire of the adjacent properties considered unlikely. | |
| | Hydrogen leak **inside** the electrolyser stack compartment | Ignition of explosive atmosphere.<br><br>Pressure wave from resulting explosion may blow out doors / roof fans, which could become a projectile risk if detached.<br><br>Likely damage to internal equipment. | ITM operator | 2-3 | D-E | R8 -R10<br><br>**Low Risk** | **Control of Releases:**<br><br>• Installation of manifold connections carried out according to manufacturer's instructions.<br>• Pressure testing of hydrogen system to 1.43x maximum allowable pressure (PS) during FAT and SAT (1.3x for stacks differential pressure).<br>• Regular helium leak testing of pressure systems according to maintenance schedule.<br>• Pressure sensors continuously monitor hydrogen system pressure through PLC. An unexpected drop in pressure (resulting from a 'major' leak in the HGas) instigates a fast shutdown (Shutdown 2), causing de-energisation of the PSU and fast venting of the HGas hydrogen.<br>• Regular automated pressure decay test undertaken to identify presence of 'minor' HGas pipework leaks.<br>• Forced air flow rate through the stack compartment sufficient to justify a Zone 2 NE for any 'negligible' release not detected by the pressure decay test.<br>• Power to the electrolyser stacks is isolated in the case of any alarm instigating a shutdown, preventing further $H_2$ generation<br>• Non-return valves in gas handling room to minimise backflow into stack compartment in the case of a leak (limiting stored volume to less than 100 normal litres). | Ensure that labelling is in place to warn personnel to not enter the generation compartment when the system is pressurised.<br><br>Installation of signage according to D934-0041. |

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| | | | | | | | • Limited stored hydrogen in the HGas, below a quantity of ~2750 normal litres (backflow $H_2$ from HRS prevented by NRV006).<br>• Functionality of check valves will be regularly tested in accordance with Maintenance Plan.<br><br>**Control of ignition sources**<br><br>• Forced ventilation from roof fans to dissipate “negligible” leakage (i.e. not identified by pressure decay test) provide sufficient air flow for generation room to be classified a Zone 2 NE. Fans monitored by pressure switches which will shut down the HGas if the fans fail.<br>• Hydrogen sensor mounted on roof of stack compartment alarms above 25% LFL and instigates emergency shutdown through PLC. This will rapidly depressurise the electrolyser stacks and hydrogen system through the hydrogen vent to a safe location, whilst removing electrical power to the plant.<br>• Forced ventilation is sufficient that if the entire output of all three stacks were to enter the stack compartment, the release would be diluted to below the LFL. Note – ventilation fans are HazLoc and don’t present an ignition source.<br>• Audible / visual alarm located on container roof warns staff in the case of a Shutdown 1 / 2, for instance a pressure drop alarm.<br><br>**Control of ignited hydrogen:**<br><br>• Temperature sensors mounted to stack compartment ceiling alarm above 40 ºC and instigate shutdown.<br><br>**Control of projectiles:** | |

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| | | | | | | | • Container walls provide enclosure to contain projectiles.<br>• Container louvres provide some pressure relief to an internal pressure wave.<br>• Personnel not permitted inside gas generation room whilst hydrogen system is pressurised. | |
| | Hydrogen leakage from process equipment / storage inside compressor / storage compartment of the container during operation (not including dispensing system) | Ignition causing jet fire or explosion<br><br>Asphyxiation | Maintenance engineer / fuelling operative / passers-by<br><br>Maintenance engineer | 1-2<br><br>1 | B-E<br><br>C-D | R7-R11<br>**Med risk**<br><br>R9-R10<br>**Low risk** | **Prevention of leaks:**<br><br>• Factory testing includes pressure test of all parts in the fuelling station to at least 1.43 × maximum allowable pressure (PS) where appropriate, and where not already tested by the individual equipment / component manufacturer.<br>• Nitrogen & hydrogen leak test of manifold to 0.9 * maximum allowable pressure (PS) once on site.<br><br>**Detection of leaks:**<br><br>• Hydrogen sensor located inside compressor / storage compartment.<br>• Routine checks conducted by trained personnel.<br>• Regular inspection and leak testing of pressure systems according to Written Scheme of Examination / maintenance schedule.<br>• Large leak may be audible to passers-by, with emergency contact details on the fences around the station and break-glass alarm points.<br><br>**Prevention of ignition:**<br><br>• Compressor / storage compartment of the container defined as Zone 2 and all electrical components are appropriately HazLoc rated to | Prepare site specific emergency plan<br><br>Put label on compressor / storage compartment door to highlight entry limitations<br><br>Ensure a personnel emergency exit is included for each compound |

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| | | | | | | | reduce likelihood of ignition sources being present in the case of a leak.<br>• Intermittent forced ventilation to dissipate minor leakage.<br>• Hydrogen sensor, to increase forced ventilation at 20% LFL, and to shut down plant at 40% LFL- instigates de-energisation of compressor, closes valves that isolate high pressure storage vessels from the majority of potential leak points, closes the inlet valve from electrolyser buffer store (though this is located inside the container, the electrolyser shutdown will close the externally located buffer store isolation valve), and displays a red light above the door to the compressor compartment. Alarm also instigates emergency shut down of HGas.<br>• HazLoc-rated glands to prevent hydrogen entering adjacent control compartment from compressor / storage compartment.<br>• Compressor / storage compartment doors locked by key outside of operational checks / maintenance, also in fenced compound with locked gate.<br>• Container walls / doors contain releases inside compressor / storage compartment to prevent hydrogen released inside the container impinging on / being drawn into the air intake louvres into the control room.<br>• Compound wall between container and dispensing area minimises likelihood of ignition sources (e.g. vehicle) being in a hazardous area created by a release from within the container. Non-HazLoc rated equipment excluded from the manufacturer defined hazardous areas.<br>• Compound fence / wall preventing unauthorised access to vicinity of hydrogen | |

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| | | | | | | | equipment (other than dispenser and tube trailer connection point), and no hazardous areas that extend outside the compound boundary fence / wall.<br>• No fixed ignition sources in the hazardous areas associated with the container that extend outside the compound fence / wall (from the venting systems, above head height).<br>• No portable non-HazLoc electrical items permitted in hazardous areas when hydrogen equipment and manifold pressurised.<br>• ITM maintenance staff trained of requirement to ensure ignition sources are kept out of HazLoc hazardous areas.<br>• Hazardous area drawing indicates locations of Zones.<br>• Signage on door to compressor compartment.<br><br>**Detection of ignited jet**<br><br>• Flame detector inside compound instigates fire alarm sounder for the fuelling station, and notifies the monitoring company, who in turn can notify the fire brigade and security.<br><br>**Mitigation of ignited releases:**<br><br>• Storage cylinders protected from impingement of ignited jets from process equipment.<br>• Explosion relief designed into the roof of the container.<br>• Site separation distances conform to NFPA2<br><br>**Protection of personnel** | |

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| | | | | | | | • No personnel in compartment whilst compressor in operation or during refuelling.<br>• Only trained personnel permitted to enter container and recommended to be wearing anti-static boots in the compressor compartment.<br>• Visual alarm located on compartment door to indicate whether “safe” to enter, that turns red if 20 or 40% LFL is reached.<br>• Clearly defined emergency procedure.<br>• Emergency stop push buttons inside both compressor / storage compartment and control compartment, and on dispenser and tube trailer connection point.<br>• Site “global e-stop” push button positioned close to entrance/exit for easy fire service access.<br>• If activated, any e-stop isolates the storage vessels (see hydrogen sensor alarm above for details) and de-energises the compressor.<br>• Additional plant electrical isolation available, as explained in the emergency procedure.<br>• “Break-glass” fire alarm activator located by the exit point(s) from the compound, which notify the monitoring company, who in turn can notify the fire brigade and security.<br>• Doors to be left open during maintenance to prevent asphyxiation. Relatively small compartment and easy to exit. Whilst ladders may be required, a step is built into the design to provide an alternative.<br>• Lights (HazLoc rated in compressor / storage compartment, in the hydrogen compound and the dispensing area) remain on at all times, even when there is a hydrogen leak detected or emergency stop button pressed. Street lighting (outside of zones) will also be unaffected. | |

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| | | | | | | | • Restricted maintenance allowed when only one member of maintenance staff present. | |
| | Hydrogen leakage in manifold between buffer store, tube trailer incoming connection, and pipework leading to container hydrogen inlet, or<br><br>hydrogen leakage from pipework between container and dispenser, between container and tube trailer outgoing connection, or from the heat exchanger<br><br>(not including the pipework / manifold on the refuelling area side of the boundary wall) | Ignition causing fire or explosion | Maintenance engineer / fuelling operative / passers-by | 1-2 | C-E | R8-R11<br><br>Low risk | **Prevention of leaks:**<br><br>• Factory testing includes pressure test of all parts in the fuelling station to at least 1.43 × maximum allowable pressure (PS) where appropriate, and where not already tested by the individual equipment / component manufacturer.<br>• Nitrogen & hydrogen leak test of manifold to 0.9 * maximum allowable pressure (PS) once on site.<br>• Equipment and piping in fenced compound with locked gate.<br><br>**Detection of leaks:**<br><br>• Routine checks conducted by trained personnel.<br>• Regular inspection and leak testing of pressure systems according to Written Scheme of Examination / maintenance schedule.<br>• Large leak may be audible to passers-by, with emergency contact details on the fences around the station and break-glass alarm points.<br><br>**Dilution of leaks:**<br><br>• Natural ventilation – located outdoors<br><br>**Prevention of ignition:**<br><br>• Area surrounding potential leak points defined as Zone 2 and all electrical components are appropriately HAZLOC rated to reduce likelihood | None |

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| | | | | | | | of ignition sources being present in the case of a leak.<br>• Compound wall between container and dispensing area minimises likelihood of ignition sources (e.g. vehicle) being in a hazardous area created by a release from equipment / joints within the compound. Non-HAZLOC rated equipment excluded from the hazardous areas defined around potential release points.<br>• Compound fence / wall preventing unauthorised access to vicinity of hydrogen equipment (other than dispenser and tube trailer connection point), and no hazardous areas that extend outside the boundary fence / wall.<br>• No fixed ignition sources in the hazardous areas associated with the container that extend outside the compound fence / wall (from the venting systems, above head height).<br>• No portable non-HAZLOC electrical items permitted in hazardous areas when hydrogen equipment and manifold pressurised.<br>• ITM maintenance staff trained of requirement to ensure ignition sources are kept out of HAZLOC hazardous areas.<br>• Hazardous area drawing indicates locations of Zones.<br>• Ex signage warning of the presence of a hazardous area at entry points to compound.<br><br>**Detection of ignited jet**<br><br>• Flame detector inside compound instigates fire alarm sounder for the fuelling station, and notifies the monitoring company, who in turn can notify the fire brigade and security. | |

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| | | | | | | | **Protection of personnel**<br><br>• Clearly defined emergency procedure.<br>• Emergency stop push buttons for the electrolyser easily accessible inside the compound, which instigate a refueller shutdown.<br>• Site "global e-stop" push button positioned close to entrance/exit for easy fire service access.<br>• If activated, any e-stop isolates the storage vessels (see hydrogen sensor alarm in 4.2.1 above for details) and de-energises the compressor.<br>• Additional plant electrical isolation available, as explained in the emergency procedure.<br>• "Break-glass" fire alarm activator located by the exit point(s) from the compound, which notify the monitoring company, who in turn can notify the fire brigade and security.<br>• Lights (HAZLOC rated in the hydrogen compound and the dispensing area) remain on at all times, even when there is a hydrogen leak detected or emergency stop button pressed. Street lighting (outside of zones) will also be unaffected.<br>• Restricted maintenance allowed when only one member of maintenance staff present. | |
| | Leakage from dispenser / pipework leading to the dispenser outside of fuelling | Ignition causing jet fire or explosion | Maintenance engineer / fuelling operative / passers-by | 2-3 | C-D | R7-R10<br><br>Med risk | **Prevention of leaks:**<br><br>• Factory testing includes pressure test of all parts in the fuelling station to at least 1.43 × maximum allowable pressure (PS) where appropriate, and where not already tested by the individual equipment / component manufacturer.<br>• Nitrogen & hydrogen leak test of manifold to 0.9 * maximum allowable pressure (PS) once on site. | None |

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| | | Asphyxiation | Maintenance engineer | 1 | C-D | R9-R10 Low risk | • Dispenser protected against vehicular impact by bollards and kerb of raised plinth on which dispenser is located.<br>• Majority of pipework / components inside dispenser cabinet protected from tampering by locked enclosure panels.<br><br>**Detection of leaks:**<br><br>• Routine checks conducted by trained personnel.<br>• Regular inspection and leak testing of pressure systems according to Written Scheme of Examination / maintenance schedule.<br>• Large leak may be audible to passers-by, with emergency contact details on the fences around the station and break-glass alarm points.<br><br>**Dilution of leaks:**<br><br>• Natural ventilation to dissipate minor leakage, although this is restricted within the dispenser enclosure.<br><br>**Prevention of ignition:**<br><br>• Quantity of hydrogen that can be released into the fuelling area minimised by isolation valves between the storage and the pipework leading to the dispenser that are closed outside of fuelling.<br>• Dispenser enclosure process compartment defined as Zone 2 and all electrical components are appropriately HAZLOC rated to reduce likelihood of ignition sources being present in the case of a leak. | |

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| | | | | | | | • Non-HAZLOC electrical equipment in the dispenser is located inside a sealed compartment.<br>• Electrical equipment mounted onto the dispenser enclosure is HAZLOC rated.<br>• No smoking, etc. signage on dispenser<br>• Site boundary fence / wall minimises unauthorised access to vicinity of hydrogen dispenser, and no hazardous areas that extend outside the boundary fence / wall.<br>• No portable non-HAZLOC electrical items permitted in hazardous areas when hydrogen equipment and manifold pressurised.<br>• ITM maintenance staff trained of requirement to ensure ignition sources are kept out of HAZLOC hazardous areas.<br>• Hazardous area drawing indicates locations of Zones.<br>• Ex-signage on door to dispenser compartment.<br><br>**Detection of ignited jet**<br><br>• Flame detector trained on dispenser area instigates fire alarm sounder for the fuelling station, and notifies the monitoring company, who in turn can notify the fire brigade and security.<br><br>**Protection of personnel**<br><br>• Clearly defined emergency procedure.<br>• Emergency stop push buttons easily accessible in the refuelling area.<br>• Site “global e-stop” push button positioned close to entrance/exit for easy fire service access. | |

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| | | | | | | | • If activated, any e-stop isolates the storage vessels (see hydrogen sensor alarm in 4.2.1 above for details) and de-energises the compressor.<br>• Additional plant electrical isolation available, as explained in the emergency procedure.<br>• "Break-glass" fire alarm activator located by the exit point(s) from the compound, which notify the monitoring company, who in turn can notify the fire brigade and security.<br>• Dispenser process compartment is too small to enter (from asphyxiation perspective).<br>• Lights (HAZLOC rated in the hydrogen compound and the dispensing area) remain on at all times, even when there is a hydrogen leak detected or emergency stop button pressed. Street lighting (outside of zones) will also be unaffected.<br>• Restricted maintenance allowed when only one member of maintenance staff present. | |
| | Leakage from tube trailer connection equipment (inlet / outlet) outside of use | Ignition causing jet fire or explosion<br><br>Asphyxiation | Maintenance engineer / fuelling operative / passers-by<br><br>Maintenance engineer | 2-3<br><br>1 | C-D<br><br>C-D | R7-R10<br>**Med risk**<br><br>R9-R10<br>**Low risk** | **Prevention of leaks:**<br>• Factory testing includes pressure test of all parts in the fuelling station to at least 1.43 × maximum allowable pressure (PS) where appropriate, and where not already tested by the individual equipment / component manufacturer.<br>• Nitrogen & hydrogen leak test of manifold to 0.9 * maximum allowable pressure, PS, once on site.<br>• Tube trailer connection point enclosure protected against vehicular impact by bollards and kerb. | None |

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| | | | | | | | • Pipework / components inside tube trailer connection point cabinet protected from tampering by locked enclosure panels.<br><br>**Detection of leaks:**<br><br>• Routine checks conducted by trained personnel.<br>• Regular inspection and leak testing of pressure systems according to Written Scheme of Examination / maintenance schedule.<br>• Large leak may be audible to passers-by, with emergency contact details on the fences around the station and break-glass alarm points.<br><br>**Dilution of leaks:**<br><br>• Limited natural ventilation only.<br><br>**Prevention of ignition:**<br><br>• Enclosure compartment defined as Zone 2 and all electrical components are appropriately HAZLOC rated to reduce likelihood of ignition sources being present in the case of a leak.<br>• Site boundary fence / wall minimises unauthorised access to vicinity of hydrogen dispenser, and no hazardous areas that extend outside the boundary fence / wall.<br>• Ex-signage on door to tube trailer connection point compartment.<br>• ITM maintenance staff trained of requirement to ensure ignition sources are kept out of HAZLOC hazardous areas.<br>• No smoking etc signage on tube trailer connection point. | |

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| | | | | | | | **Detection of ignited jet**<br><br>• Flame detector trained on tube trailer connection area instigates fire alarm sounder for the fuelling station, and notifies the monitoring company, who in turn can notify the fire brigade and security.<br><br>**Protection of personnel**<br><br>• Clearly defined emergency procedure.<br>• Emergency stop push buttons easily accessible in the refuelling area.<br>• Site "global e-stop" push button positioned close to entrance/exit for easy fire service access.<br>• If activated, any e-stop isolates the storage vessels (see hydrogen sensor alarm in 4.2.1 above for details) and de-energises the compressor.<br>• Additional plant electrical isolation available, as explained in the emergency procedure.<br>• "Break-glass" fire alarm activator located by the exit point(s) from the compound, which notify the monitoring company, who in turn can notify the fire brigade and security.<br>• Tube trailer connection enclosure is too small to enter (from asphyxiation perspective).<br>• Lights (HAZLOC rated in the hydrogen compound and the dispensing area) remain on at all times, even when there is a hydrogen leak detected or emergency stop button pressed. Street lighting (outside of zones) will also be unaffected.<br>• Restricted maintenance allowed when only one member of maintenance staff present. | |

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| | On-site collision of passing vehicle with refuelling station, (or vehicle being refuelled) causing pressurised pipework / vessel rupture and hydrogen leakage | Ignition causing fire or explosion | Maintenance engineer / fuelling operative / passers-by | 1-2 | C-E | R8-R11 Low risk | • 20 mph speed limit on site to reduce likelihood of crash into dispenser, or into a vehicle being fuelled, leading to damage to the dispenser.<br>• Storage vessels located inside the container, with the container in a separate fenced off compound with locked gates, and protected by firewall.<br>• Raised kerb and bollards located between fuelling area and the dispenser.<br>• When dispensing not in progress, process isolation valves reduce the volume of gas that would escape in the case of a collision with external components of the dispensing system.<br>• Container offers degree of protection to internal manifold and compressor, and is located behind firewall.<br>• Hydrogen sensor instigates safety system in case of leakage inside compressor compartment of container (see hydrogen sensor alarm in 4.2.1 above for details).<br>• Signage around refueller.<br>• Restricted access to refuelling station with automated gates at the entrance operated by entry card. | None |
| | Vandalism leading to release of hydrogen | Ignition of flammable gas mixture / electrocution of personnel | Maintenance engineer / fuelling operative / passers-by | 2 | C-E | R8-R10 Low risk | • Hydrogen equipment and dispenser in separate fenced off compounds with locked gates. Fence located at least 1 m from any hydrogen equipment.<br>• Public access to dispensing area limited by entry key-fob to those with hydrogen vehicles. The staff working in the area are likely to approach anyone obviously out of place.<br>• Doors to compartments of refuelling station compressor / storage container, tube trailer | None |

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| | | | | | | | connection point and dispenser locked by key outside of operational checks / maintenance.<br>• When not refuelling, process isolation valves reduce the volume of gas that would escape in the case of vandalism of components of the dispensing system external to the hydrogen compound.<br>• Site security cameras are active and monitored.<br>• Refueller is on patrol route of site security.<br>• Security signage on each side of refuelling station.<br>• Dispensing system (accessible to public) leak checked in control logic prior to refuelling. | |
| | Hydrogen leak from worn / damaged filling nozzle and hose or from incorrectly attached filling nozzle to form potentially explosive atmosphere | Ignition causing fire or explosion | Fuelling operative / passers-by | 1-2 | C-E | R8 -R11<br><br>Low risk | **Prevention of damage / wear:**<br><br>• Nozzle stored on side of dispenser in dedicated location when not in use.<br>• "Customer refuelling manual" includes visual inspection of refuelling nozzle and hose prior to refuelling, checking for damaged components / debris.<br><br>**Prevention / minimisation of leak**<br><br>• Refuelling nozzle and receptacle certified to SAE J2600 that only allows connection with 700 bar rated vehicle system.<br>• Positive engagement required for gas flow. Red indicator ring when correctly fitted.<br>• Refuelling control logic includes initial leak test on dispensing manifold, hose and components, and vehicle in accordance with ISO / DIS 20100:2011. Refuelling line is open to storage tank for maximum of 3 seconds during leak test. | Test of earthing connection through fuelling pad<br><br>Test of earth connection through nozzle to ground |

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| | | | | | | | • Average pressure ramp rate expected that would indicate the presence of a major leak, as the ramp rate would not be achieved.<br>• Fill carried out by operator trained according to "Customer refuelling manual" (D925-00xx).<br>• Anything above a minor leak will be audible and fuelling can be halted using the emergency stop push button at the dispenser (see hydrogen sensor alarm in 4.2.1 above for details).<br>**Prevention of ignition**<br>• Conductive fuelling pad bonds vehicle to refueller earth to avoid static discharge.<br>• Outdoor refuelling only to ensure adequate ventilation.<br>• Area around dispenser is zone 2, with appropriate electrical equipment used.<br>• Vehicle engine and power electronics turned off during refuelling. (Other than when fuelling data is recorded, when fuelling is monitored by a member of ITM staff)<br>**Protection of personnel**<br>• All non-approved personnel outside 5m separation distance during refuelling - station not on a publically accessible site.<br>• Site "global e-stop" push button positioned close to entrance/exit for easy fire service access. | |
| | Hydrogen leak from vehicle during filling | Ignition causing fire or explosion | Fuelling operative / passers-by | 2-3 | C-E | R7-R10<br>**Med risk** | **Prevention / minimisation of leak:**<br>• Control of vehicles being filled by issue of access cards by ITM to enable access, with vehicle | Seek additional maintenance information from |

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| | | | | | | | manufacturers having pre-approved the vehicles to be filled to ensure vehicles are suitable.<br>• Hyundai and Toyota vehicle hydrogen system components rated for temperatures as low as -40 °C.<br>• Identified Revolve vehicles suitable for filling, and registration numbers known and agreed with the operator Commercial Group.<br>• Vehicles under manufacturer's maintenance schedules.<br>• Short initial refuel (several seconds) followed by pause in refuelling protocol will identify leaks.<br>• Anything above a minor leak will be audible.<br>• "Customer refuelling manual" includes direction to carry out visual inspection of vehicle receptacle prior to refuelling, checking for debris, and training given to users.<br>• Additional controls to prevent overheating and over-pressurisation<br><br>**See Prevention of ignition and Protection of Personnel**<br><br>Note: Additional risk assessment to be prepared for prior to filling any new vehicles to help identify any potential issues with vehicles. | FCEV manufacturers |
| | Driving away / vehicle moving when refuelling nozzle attached - leading to breakage of | Ignition causing fire or explosion | Fuelling operative / passers-by | 1-2 | C-E | R8 -R11<br>**Low risk** | • Break-away coupling between nozzle and refuelling station minimises hydrogen leakage should the vehicle move whilst connected to the dispensing equipment, by sealing both the line from the dispenser and the line from the vehicle. | None |

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| | filling line and hydrogen leak | Whipping of unattached hose leading to personnel injuries. | Fuelling operative | 1 | C-D | R9 -R10<br>**Low risk** | • A check valve in the vehicle fill line further protects from hydrogen loss from the vehicle tank.<br>• Fill carried out by operator trained according to “Customer refuelling manual”, which includes measures to minimise risk of vehicle movement, including ensuring handbrake is engaged.<br>• Filling carried out on flat road surface.<br>• Vehicle access to site controlled by automated gate, with entry to authorised users only.<br>• 20 mph speed limit on site to reduce likelihood of crash leading to movement of the vehicle being refuelled.<br>• Manually operated emergency stop isolates flow to refuelling dispenser.<br>• Remote emergency stop push-button at other points on site, including by the entrance / exit.<br>• In case of break-away coupling failure to seal, the PLC logic has a high flow alarm on the dispensing line mass flow meter that would halt refuelling, also failure to achieve the minimum Average Pressure Ramp Rate would cause an alarm and shut the isolation valves.<br>• Some vehicles (Hyundai & Toyota) prevent driving when the fuel cap is open. | |
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| **Over-Pressurisation Hazards** | | | | | | | | |
| | Hydrogen generation leads to over-pressurisation of stack / hydrogen manifold in generation room / | Failure of components leads to projectile risk and un-ignited low pressure wave or, in the case of ignition, fire or explosion. | ITM operator | 1-2 | C-E | R8-R11 | Only the controls to protect against the over pressure and resulting pressure wave / projectiles are listed here. For the controls to protect against external releases. See above risks for controls to protect against external and internal hydrogen leaks. | None |

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| | hydrogen system in gas handling room | Pressure wave from resulting explosion may blow out doors / roof fans, which could become a projectile risk if detached.<br><br>Personnel external to the plant most at risk from projectiles.<br><br>Personnel in container have a high risk of harm to due to pressure wave from explosion and projectiles.<br><br>Likely damage to equipment. | | | | **Low Risk** | **Pressure Control:**<br><br>• The control system stops generation, setting the stack PSUs at 0 % output, when the combined manifold pressure transducer PT005 reaches 20 bar<br>• If this fails to prevent further hydrogen generation, alarm on pressure transducers PT001-5 reaching 22 bar, instigates a controlled shutdown.<br>• Adequately sized pressure relief valves fitted to each stack vent over pressure to a safe location. These protect the stacks in case of pressure transmitter or control system failure.<br>• Further adequately sized pressure relief valves fitted on the hydrogen process vessel S002 and gas dryer vent over-pressure to a safe location. These protect the vessels in case of pressure transmitter or control system failure.<br>• Pressure testing of systems to at least 1.43 x maximum allowable pressure (PS) carried out (1.3 times for stacks).<br>• On site commissioning includes helium leak test of systems to working pressure.<br><br>**Personnel Controls:**<br><br>• Commissioning personnel are not allowed in generation compartment when the hydrogen system is pressurised.<br>• Doors to gas generation room are locked, or access by tool, to minimise unauthorised access.<br>• Audible / visual alarm located on container roof warns staff in the case of a Shutdown 1 / 2, for instance an over-pressure alarm.<br><br>**Control of ignited hydrogen:** | |

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| | | | | | | | • Temperature sensors mounted to stack compartment ceiling alarm above 40 ºC and instigate shutdown.<br><br>**Control of projectiles:**<br><br>• Container walls provide enclosure to contain projectiles.<br>• Container louvres provide some pressure relief to an internal pressure wave.<br>• Personnel not permitted inside gas generation room whilst hydrogen system is pressurised. | |
| | Hydrogen PRV vent blockage during operation. | Inability of PRVs to relieve over pressure leading to a catastrophic loss of containment and subsequent injury to personnel. | ITM operator | 2-3 | D-F | R8-R11<br><br>Low Risk | See above risk analysis for measures for preventing over-pressurisation. In addition:<br><br>• Vent lines are protected to prevent rain ingress. | None |
| | Reverse flow of high pressure hydrogen from the Buffer Tank assembly to the gas handling room | Over pressurisation of equipment leading to loss of containment and deflagration. | ITM operators | 1 | C-D | R9-R10<br><br>Low Risk | • Non-return valve NRV006 on hydrogen process line to Buffer Tank assembly minimises backflow to ITM system. This will be regularly tested for functionality in accordance with the Maintenance Schedule.<br>• HRS has a non-return valve to prevent back flow of gas from high pressure systems.<br>• PRV008 set at 24 bar located in the hydrogen system to protect the HGas180 components from over pressure.<br>• Buffer tank assembly PRV009/10 set at 24 bar | None |
| | Reverse flow of high pressure hydrogen from the refuelling station high | Over pressurisation of equipment leading to loss of containment and deflagration. | ITM operator, public refuellers, nearby public | 1 | C-D | R9-R10 | • HRS non-return valves prevent hydrogen backflow to Buffer Tank assembly.<br>• PRV009/10 set at 24 bar located in the buffer tank panel to protect components from over pressure. | None |

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| | pressure vessels to the Buffer Tank assembly | | | | | Low Risk | • A high pressure alarm will be communicated to the HRS and shut an isolation valve between systems | |
| | Over-pressurisation during refilling of high pressure hydrogen storage tanks, leading to rupture | Un-ignited pressure wave or ignition causing fire or explosion. | Maintenance engineer / fuelling operative / passers-by | 1 | B-D | R8-R10 Low risk | • PLC stalls compression at 945 bar through pressure transmitters 40A20PT708, with redundancy through 50A20PT026, 50B20PT026, 50C20PT026 and 50D20PT026.<br>• Alarm through safety PLC monitoring 40A20PT708, at 950 bar leading to de-energisation of compressor.<br>• Adequately sized PED Cat IV pressure relief valves fitted after the compressor, set at 1000 bar, protect the high pressure storage and are regularly tested in accordance with Written Scheme of Examination.<br>• All vessels compliant with PED and pressure tested to 1.43 × maximum working pressure.<br>• Each pressure system assembly pressure tested to 1.43 × maximum allowable pressure.<br>• Relief gas vented to safe place (no ignition sources), vent exit is >5 m above container.<br>• Site separation distances conform to NFPA2 (though not appropriate for catastrophic failure of a vessel). | None |
| | Backflow from tube trailer inlet / high pressure storage vessels leading to over-pressurisation and rupture of electrolyser buffer storage / manifold from storage. | Un-ignited pressure wave or ignition causing fire or explosion | Maintenance engineer / fuelling operative / passers-by | 1 | C-D | R9–R10 Low risk | • Manifold from buffer storage cylinder protected from over-pressurisation by check valve 00B20CV008 between tube trailer inlet line (which could be up to 250 bar under normal operation if hydrogen is supplied from cylinders / a tube trailer) and the manifold.<br>• Backflow from the high pressure storage through the compressor prevented by numerous compressor check valves and 10A20CV032. | None |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | • Buffer storage has additional protection, with an alarm on PT03, and PSV01 set at 24 bar.<br>• Electrolyser protected by additional check valve and other measures, see separate ITM risk assessment | |
| | Over-pressurisation of vehicle hydrogen storage system during fuelling causing tank / component failure and hydrogen leakage | Tank rupture, ignition causing fire or explosion<br><br>Component failure, ignition causing fire or explosion | Fuelling operative / passers-by<br><br>Fuelling operative / passers-by | 1<br><br>1 | B-D<br><br>C-E | R8-R10 **Low risk**<br><br>R9-R11 **Low risk** | • Maximum fill pressure limited by PLC logic to 720 bar. This is significantly less than the maximum operating pressure permitted for the vehicle high pressure hydrogen systems of 875 bar (at up to 85 deg C). An emergency stop is carried out if the pressure in the dispenser reaches 720 bar.<br>• Pressure transducer PT10 halts refuelling at the desired "target" pressure through the PLC by closing process solenoid valves<br>• Refuelling carried out to SAE TIR J2601: 2010 fuelling protocol that takes into account the ambient temperature and starting pressure of the vehicle, to avoid over-filling of the vehicle under conditions that could lead to the vehicle equilibrating to ambient temperature and exceeding the rated pressure of the vehicle compressed hydrogen storage system (CHSS).<br>• PSV 08 in dispensing line set at 875 bar.<br><br>**See Prevention of ignition and Protection of Personnel in previous examples** | |
| **Heat Leading to Catastrophic Failure of Vessels** | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Heater in gas purification module fails to turn off | Softening of pressure vessel walls leading to catastrophic failure | ITM operator, public refuellers, nearby public | 1 | E-C | R10-R12<br>Low risk | **Preventing overheating**<br>• Heater is controlled and monitored by PLC<br>• Independent process control thermostat within the heater controls the temperature<br>• Second independent thermostat acts as a high level switch<br>• Downstream process temperature sensor will shutdown above 40C<br><br>**Controlling failure**<br>• Volume of vessel is small and pressure only 20 bar<br>• Mesh screen over gas handling area will help to reduce projectiles<br>• Limited number of people within range of projectiles<br>• Projectiles not expected to extend beyond site boundary | |
| | External fire in refuelling station spreading to HGas or buffer tank assembly | Significant damage to plant leading to a loss of containment of hydrogen and subsequent deflagration | ITM operator, public refuellers, nearby public | 1-2 | C-E | R8-R11<br>Low Risk | • A fire detected at the refuelling station will result in the HGas receiving a signal to shut down and vent its inventory.<br>• HGas will shut down and vent its inventory if a fire is detected via smoke detectors or high temperature in the stack compartment.<br>• If there were a significant fire in the refuelling station, it is unlikely that personnel would be in HGas or around the Buffer Tank assembly | None |
| | Arson | Ignition of flammable gas mixture | Passers-by | 2 | C-E | R8-R10<br>Low risk | • Hydrogen equipment and dispenser in separate fenced off compounds with locked gates. Fence located at least 1 m from any hydrogen equipment.<br>• Public access to dispensing area limited by entry key-fob to those with hydrogen vehicles. The staff working in the area are likely to approach anyone obviously out of place.<br>• Doors to compartments of refuelling station compressor / storage container, tube trailer connection point and dispenser locked by key outside of operational checks / maintenance. | None |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | • When not refuelling, process isolation valves reduce the volume of gas that would escape in the case of vandalism of components of the dispensing system external to the hydrogen compound.<br>• Flame detectors in hydrogen compound, also on the dispenser and tube trailer areas instigate emergency shutdown, halt hydrogen generation and vents hydrogen from electrolyser.<br>• Site security cameras are active and monitored.<br>• Refueller is on patrol route of site security.<br>• Security signage on each side of refuelling station. | |
| | Overheating of the vehicle storage vessel(s) due to compressive heating during fuelling exceeding natural heat loss.<br><br>Potential reduction in pressure safety factor of components leading to leak / burst, or activation of TPRD at 104-109°C and | Unignited pressure shock wave or ignition causing fire or explosion | Fuelling operative / passers-by | 1-2 | B-C | R8-R10<br>**Low risk** | • Fuelling carried out to SAE TIR J2601: 2010 fuelling protocol that takes into account the ambient temperature and starting pressure of the vehicle, to avoid over-heating of the vehicle compressed hydrogen storage system (CHSS) above 85 °C during filling.<br>• For 70 MPa fuelling, the CHSS temperature is monitored by the dispenser using SAE J2799 communications, with an abort signal sent to the dispenser to halt fuelling at 85 °C.<br>• Hydrogen supplied to vehicle is pre-cooled before entering the vehicle.<br>• Control of vehicles being filled by issue of entry cards by ITM to enable access, with vehicle manufacturers having pre-approved the vehicles to be filled to ensure vehicles are suitable. | None |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | complete venting of vehicle storage vessel(s). | | | | | | • Vehicle TPRD activates at 104-109°C to protect storage vessels – however to be avoided to prevent venting of all stored hydrogen on vehicle.<br><br>**See Prevention of ignition and Protection of Personnel in 4.2.22** | |
| **Miscellaneous** | | | | | | | | |
| | Domino effect of refueller cylinder explosion / leakage & jet-fire on near-by hazards | Setting fire to adjacent buildings / harm to passers-by | Maintenance engineer / fuelling operative / passers-by | 1 | B-E | R8-R11 **Low risk** | Safety systems as described in 4.2.1 – 4.2.4 above to reduce likelihood of ignition and minimise gas volume leaked.<br><br>• High pressure hydrogen storage cylinders protected from impingement of ignited jets from process equipment.<br>• Minimal manifold joints in the vicinity of the storage cylinders to protect from impingement of ignited jets.<br>• Site separation distances conform to NFPA2.<br>• Emergency stop push buttons located at different locations around refuelling station, these isolate storage vessels (see hydrogen sensor alarm in 4.2.1 above for details) and de-energise the compressor.<br>• Separate site specific fire risk assessment carried out.<br>• Clearly defined emergency procedure.<br>• Fire detection in appropriate places around the site, and "break-glass" fire alarm activators accessible close to refuelling area entrance, which notify the monitoring company, who in turn can notify the fire brigade and security. | Ensure location of and signage for evacuation point is clear |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | • Low pressure buffer storage area open air, with easy access for fire brigade to spray water onto the storage vessel to cool it in case of a fire.<br>• Explosion relief designed into the roof of the container.<br>• Fire extinguisher provided in case of electrical fire whilst personnel present. | |

## 13.12 Operating Procedures

In addition to policies, ITM operations are governed by over 200 procedures. A summary of the procedures and how they are implemented for an HRS build through each part of the life cycle is provided below. The procedures form part the training that all staff undertake, copies of the procedures are available on the site and the procedures are periodically reviewed and modified as required to ensure a high level of safety, applicability and user accessibility:

| Life cycle phase | Sample of key procedures | Enforced by |
|---|---|---|
| Design | QMS OP03 Product Design<br>QMS OP04 Purchasing<br>QMS OP22 Technical file process | Operations director enforcing design stage gates<br>All documentation stored in technical file<br>Audits |
| Build | QMS OP7 Manufacturing<br>SP3-03 Orbital welding<br>SP3-27 Working at heights<br>SP3-36 Assembly of high pressure LEP stack<br>SP3-39 Inspection and Handling components | Supervisor overseeing operations.<br>H&S Manager conducting workplace inspections<br>Quality manager inspecting finished components |
| Factory commissioning | SP3-30 Hydrostatic pressure testing<br>SP6-04 PRV Setting procedure<br>SP6-05 Stack pressure testing<br>SP6-47 Isolation and Lockoff of electricity to containerised electrolyser | Commissioning team leader<br>Commissioning check lists<br>H&S Manager conducting workplace inspections<br>Quality manager signing off completed systems |
| Site groundworks and installation | QMS OP10 Control of Outsourced Services and Processes<br>HSMS OP05 Managing Contractors<br>SP5.2 Visitors and Contractors | Risk assessment and method statements from subcontractor.<br>Regular site visits. |
| Site commissioning | SP6-50 ITM Activities on a Customer Site<br>SP3-30 Hydrostatic Pressure Testing<br>SP6-04 PRV Setting Procedure<br>SP6-05 Stack Pressure Testing<br>SP6-47 Isolation and Lockoff of electricity to containerised electrolyser | Commissioning team leader<br>Commissioning check lists |
| Commercial operation and maintenance | HRS User Manual<br>Refuelling User Guide<br>Maintenance manual | Regular site inspections.<br>Maintenance team<br>Monitoring of site data. |
| Decommissioning | EMS OP02 Waste disposal and recycling<br>HSMS OP07 COSHH | Environmental Manager.<br>Waste disposal notes. |

## 13.13 Equipment Mechanical Integrity

This section describes how the mechanical integrity pressure systems (vessels, tubes etc) is ensured.

### 13.13.1 Written Procedures

For every plant, ITM prepare a 'Pressure Safety Case' which details the pressure system, the calculations used to prove its safety and compiles all of the relevant supplier certificates and

declarations of conformity into a single location. This is in a set format to ensure that the documentation for each site is to the same standard. Rather than include a full safety case, the table of contents is provided below to provide an indication of the information contained.

## Table of Contents



*Figure 13. A table of contents from a typical pressure safety case*

#### 13.13.2 Proper Design, Testing and Commissioning

ITM do not manufacture pressure vessels and therefore rely on suppliers to provide declarations of conformity, as opposed to conducting the full design calculations ourselves. These declarations are compiled and supplied as the appendices in the pressure safety case.

Once pressure systems (vessels, piping, sensors etc) are assembled by ITM staff, they undergo a proof pressure test and then leak tests using helium as part of commissioning. Test certificates (detailing the procedure and results) are then issued for each test. These are then stored in the technical file.

#### 13.13.3 Validation of Materials Compatibility

On all purchase orders, ITM specify if a material needs to operate in contact with hydrogen (or any other fluid) in addition to standard information such as pressure range, temperature range, hazardous location classification etc. In addition, ITM request materials certificates for all pressure vessels to confirm both the material and its quality. These are retained in the technical file.

#### 13.13.4 Preventative Maintenance Plan

ITM compile the maintenance plans for all components on the HRS into a single site maintenance plan. This is them implemented during regular service intervals.

#### 13.13.5 Calibration of Safety Related Devices

The key safety devices in the pressure system are the Pressure Relief Devices. These are calibrated annually in line with manufacturers' recommendations. The calibration is logged in a Test Record detailing the procedure followed and the results. These are then stored in the technical file.

#### 13.13.6 Testing and Inspection

Pressure systems are inspected for corrosion or damage, and leak tested annually. These are logged in Test Records, detailing the procedure followed and the results. These are then stored in the technical file.

#### 13.13.7 Training for Maintenance, Calibration, Testing and Inspection Personnel

As detailed in the H&S Policy, ITM have detailed processes to ensure staff competence. In addition to HR holding all training records, each manager has a matrix of skills that staff require to complete their job. New staff are trained in the essential and then receive on-going training to complete the matrix. With time and training (and if appropriate to their role) staff can move from testing existing systems, to performing like-for-like swaps of components on a system, to building systems and then designing systems. Additional details are provided in Section 4.1.

#### 13.13.8 Documentation

As described above, all calibrations, tests and inspections are recorded on forms which detail the methodology required, have sections for the date, equipment, location, results of test and then the operators signature. These are then stored in the product's technical file. Any failures are highlighted to their manager and the Quality Manager.

#### 13.13.9 Correcting Deficiencies that are Outside Acceptable Limits

If a system had failed a test that is easy to rectify (eg a pressure test or calibration test) staff are trained in how to resolve (ie check the system for leaks or recalibrate a PRV). If a failed test requires more significant intervention (eg the replacement of a part), then this requires a Change Note, as described in the following section.

### 13.14 Management of Change (MOC) Procedures

Management of change at ITM is governed by procedure QMS OP23 Management of Change (changes to documentation are managed under a separate process). The key processes are described in Figure 2.

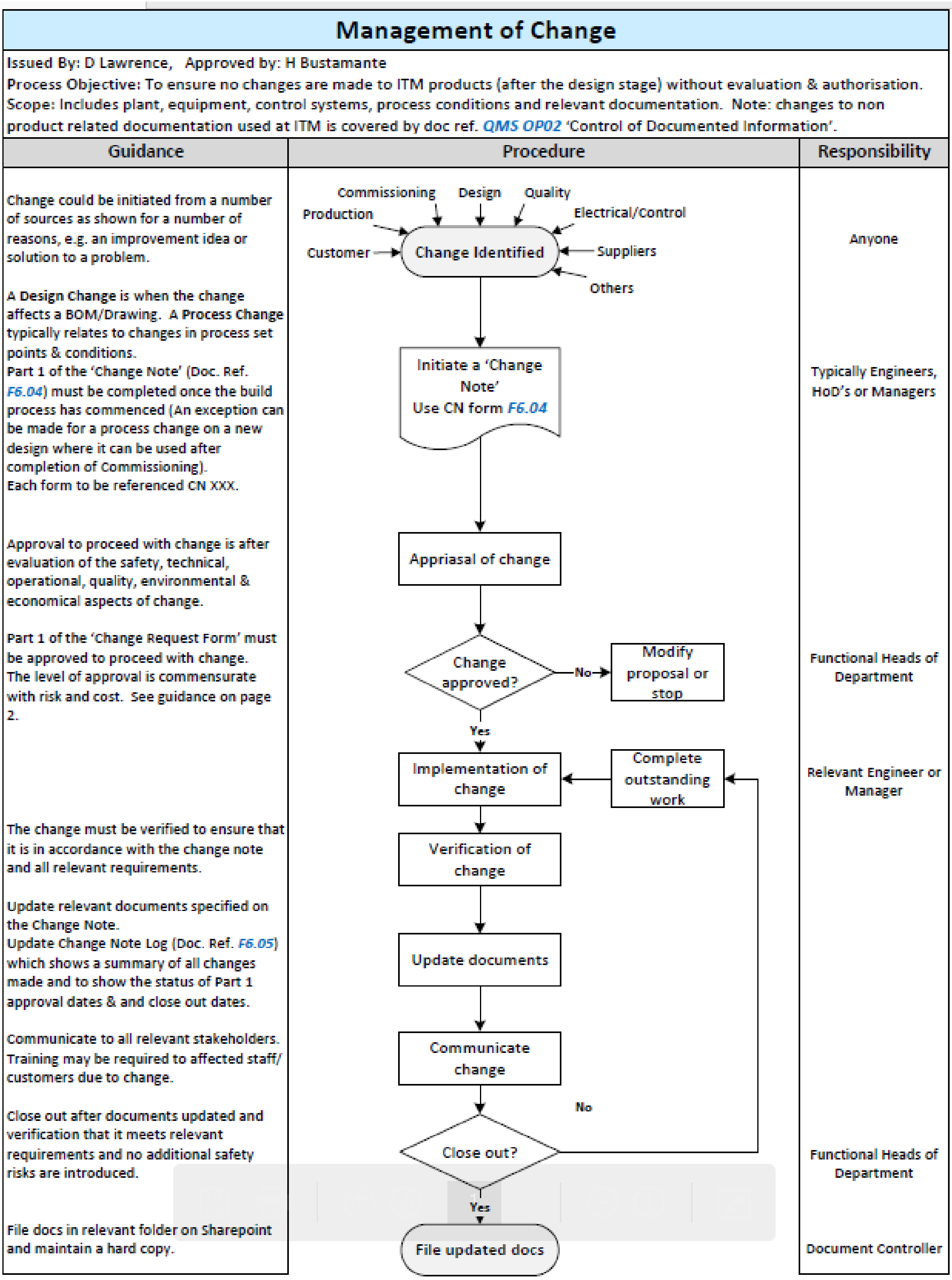



*Figure 14. The flow diagram for the management of change*

The procedure also specifies who must give approval for changes to different aspects of the system, with final approval being that of the Quality Manager, as shown in Figure 3 below.

APPROVAL GUIDANCE

The table below provides guidance on the required approvals on the Change Note.

In addition, it may be required to obtain specialists to review the Change Note proposal e.g. those of a safety critical nature.

| Change Type | Approval 1 | Approval 2 | Approval 3 |
|---|---|---|---|
| Drawing change (mechanical) | Design Engineer | | Quality Manager |
| Drawing change (stack related) | Design Engineer | Chief Engineer | Quality Manager |
| Drawing change (electrical) | Design Engineer | Control Systems Eng. | Quality Manager |
| Process change | Process Engineer | Lead Process Eng ( if complexity requires) | Quality Manager |
| | | | |

*Figure 15. Approval guidance for ITM's Management of Change procedure*

The form to apply for a change is presented in Figure 4.

| Quality Management System - Form | ITM POWER Energy Storage \| Clean Fuel<br>Document Ref: F6.04 Issue E |
|---|---|
| Title: Equipment Change Note | |

This form is to be used for changes to ITM plant to ensure changes are evaluated & authorised.
See Doc. Ref. QMS OP17 'Management of Change' procedure for further guidance on the process.

## PART 1 – TO BE COMPLETED BY ORIGINATOR

| CHANGE No. | ORIGINATOR | POSITION | DATE |
|---|---|---|---|
| CNXXX | | | |

**APPLICABILITY** *(State Y below where applicable)*

| DESIGN<br>*Change to an ITM part on a BOM/Drawing once the build process has commenced* | PROCESS<br>*Change to a process condition or set point* | OTHER<br>*Please specify* |
|---|---|---|
| | | |

**PLANT/PART AFFECTED**

| PLANT SERIAL No(s) | DESCRIPTION | TOP LEVEL ASSEMBLY No. | DRAWING / PART No. / DOCUMENT REF. No. |
|---|---|---|---|
| | | | |
| **DOCUMENT No's.** (*list below if additional space is required*): | | | |
| **DOES CHANGE AFFECT OTHER PLANT?** (*Please specify*): | | | |

**DESCRIPTION OF CHANGE**

**REASON / JUSTIFICATION FOR CHANGE**

**WHO IS AFFECTED** *(State Y below for all applicable)*

| DESIGN ENGINEERING | PROCESS ENGINEERING | E & I | STACK | PRODUCTION | COMMISSIONING |
|---|---|---|---|---|---|
| | | | | | |
| **EXTERNAL / OTHER** (*Please specify*): | | | | | |

| APPROVAL TO PROCEED WITH CHANGE | | | |
|---|---|---|---|
| NAME | POSITION | SIGNATURE | DATE |
| | | | |
| | | | |
| | | | |

*See Doc. Ref. QMS OP17 'Management of Change' procedure for guidance on appropriate approval level*

| PART 2 – VERIFICATION OF CHANGE |
|---|

| WHAT WAS ACTUALLY IMPLEMENTED *(State any variations to original change proposal)* |
|---|
| |

| VERIFICATION OF CHANGE *(Did it work/is it safe?)* |
|---|
| |

| WHAT DOCUMENTATION HAS BEEN UPDATED (*Also state by who, when & new revision status*) |
|---|
| |

| CHANGE NOTICE CLOSEOUT | | | |
|---|---|---|---|
| NAME | POSITION | SIGNATURE | DATE |
| | | | |
| | | | |
| | | | |

The Originator to complete the 'Change Log' (Form F6.05) and pass signed form to Document Controller for uploading to Sharepoint.

*Figure 16. The form to request a change*

## 13.15 Project Safety Documentation

All project documentation (safety and non-safety) are stored in the project's technical file. This is an electronic folder held on ITMs servers that contain all of the information about the project, including hard copies of documents that are scanned in).

Document numbering is used to track individual documents, with version control employed to ensure that the most recent version is used.

Each product has a document register where all of the documents are recorded. A blank register is presented in Figure 5 below; the titles of the documents provide an indication of the documents that will populate the technical file.

| New Doc. Number | Latest Revision | Revision Date | Author | Document title |
|---|---|---|---|---|
| D9xx - 0001 | 02 | 01/06/16 | DL | Document numbering register (This one) |
| D9xx - 0002 | 05 | 01/01/16 | DL | Project file structure |
| D9xx - 0003 | | | | Project initiation form (F6.09) |
| D9xx - 0004 | | | | Project plan |
| D9xx - 0005 | | | | Reserved for home docs. |
| D9xx - 0006 | | | | Reserved for home docs. |
| D9xx - 0007 | | | | Reserved for home docs. |
| D9xx - 0008 | | | | Reserved for home docs. |
| D9xx - 0009 | | | | Reserved for home docs. |
| **PRODUCT DESIGN DOCUMENTS** | | | | |
| D9xx - 0010 | | | | Block diagram (Process Flow Diagram) |
| D9xx - 0011 | | | | Piping and Instrument Diagram |
| D9xx - 0012 | | | | Water regulation drawing |
| D9xx - 0013 | | | | Trace heating & thermal insulation drawing |
| D9xx - 0014 | | | | Equipment List |
| D9xx - 0015 | | | | Instrument and calibration List |
| D9xx - 0016 | | | | Valve list |
| D9xx - 0017 | | | | Pressure system test requirements **(NEW DOC)** |
| D9xx - 0018 | | | | Reserved for product design docs. |
| D9xx - 0019 | | | | Reserved for product design docs. |
| D9xx - 0020 | | | | Reserved for product design docs. |
| D9xx - 0021 | | | | Reserved for product design docs. |
| D9xx - 0022 | | | | PED safety case |
| D9xx - 0023 | | | | PED safety case - Full (If Required) |
| D9xx - 0024 | | | | Pressure relief valve sizing calculations: EN ISO 4126-1 |
| D9xx - 0025 | | | | PED category of main elements |
| D9xx - 0026 | | | | Hazardous area drawing 1 (state if internal or external) |
| D9xx - 0027 | | | | Hazardous area drawing 2 (state if internal or external) |
| D9xx - 0028 | | | | Hazardous area drawing 3 (state if internal or external) |
| D9xx - 0029 | | | | Hazardous area drawing 4 (state if internal or external) |
| D9xx - 0030 | | | | ATEX safety case |
| D9xx - 0031 | | | | HAZ I report |
| D9xx - 0032 | | | | HAZ 2 matrix |

| | | | | |
|---|---|---|---|---|
| D9xx - 0033 | | | | HAZ 3 matrix |
| D9xx - 0034 | | | | HazOp III report |
| D9xx - 0035 | | | | LOPA worksheet/analysis |
| D9xx - 0036 | | | | LOPA report |
| D9xx - 0037 | | | | DSEAR risk assessment |
| D9xx - 0038 | | | | Sign layout - container |
| D9xx - 0039 | | | | Reserved |
| D9xx - 0040 | | | | Reserved |
| D9xx - 0041 | | | | Reserved |
| D9xx - 0042 | | | | Reserved |
| D9xx - 0043 | | | | Reserved |
| D9xx - 0044 | | | | Reserved |
| D9xx - 0045 | | | | Reserved |
| D9xx - 0046 | | | | Reserved |
| D9xx - 0047 | | | | Reserved |
| D9xx - 0048 | | | | Reserved |
| D9xx - 0049 | | | | Reserved |
| D9xx-0050>59 | | | | Reserved |
| **MECHANICAL ASSEMBLY DRAWINGS** | | | | |
| **Use Part No** | - | - | - | - |
| | | | | |
| | | | | |
| **ELECTRICAL DESIGN** | | | | |
| D9xx - 0060 | | | | User requirement specification |
| D9xx - 0061 | | | | Emergency shutdown response matrix |
| D9xx - 0062 | | | | PLC hardware list |
| D9xx - 0063 | | | | IO Schedule |
| D9xx - 0064 | | | | Electrical connections |
| D9xx - 0065 | | | | Electrical equipment list |
| D9xx - 0066 | | | | PSU requirements |
| D9xx - 0067 | | | | Main control panel drawing (supplied by sub contractor) |
| D9xx - 0068 | | | | Emergency stop layout |
| D9xx - 0069 | | | | Motor ratings |
| D9xx - 0070 | | | | Cable block diagram |
| D9xx - 0071 | | | | Alarms and warnings list |
| D9xx - 0072 | | | | Logic flow diagram |
| D9xx - 0073 | | | | Setpoints and timers list |
| D9xx - 0074 | | | | Data transfer |

| | | | | |
|---|---|---|---|---|
| D9xx - 0075 | | | | Shutdown modes |
| D9xx - 0076 | | | | Electrical drawing review |
| D9xx - 0077 | - | | | Reserved for process control docs. |
| D9xx - 0078 | - | | | Reserved for process control docs. |
| D9xx - 0079 | - | | | Reserved for process control docs. |
| D9xx-0080>89 | - | | | Reserved for process control docs. |
| **ELECTRICAL/CONTROL SUB CONTRACTOR SUPPLIED INFORMATION** | | | | |
| - | | | | Schematics drawing |
| - | | | | FDS functional design specification |
| - | | | | Electrical data dossier (BOM) |
| - | | | | Cable testing certificates |
| - | | | | |
| - | | | | |
| - | | | | |
| **PRODUCTION DOCUMENTS** | | | | |
| D9xx - 0090 | | | | Stack test report |
| D9xx - 0091 | | | | Component traceability details |
| D9xx - 0092 | | | | CE data plate |
| D9xx - 0093 | | | | Certificate of Conformity by NoBo- Pressure Equipment Regs. |
| D9xx - 0094 | | | | Declaration of Conformity by ITM |
| D9xx - 0095 | | | | Reserved for production docs. |
| D9xx - 0096 | | | | Reserved for production docs. |
| D9xx - 0097 | | | | Reserved for production docs. |
| D9xx - 0098 | | | | Reserved for production docs. |
| D9xx - 0099 | | | | Reserved for production docs. |
| | | | | |
| **COMMISSIONING DOCUMENTS** | | | | |
| D9xx - 0100 | | | | Installation, commissioning and operation risk assessment |
| D9xx - 0101 | | | | General risk assessment (FAT, On-site Commissioning & Operation) |
| D9xx - 0102 | | | | Lifting plan at ITM |
| D9xx - 0103 | | | | RA for lifting plan at ITM - **To be a generic Doc filed in Sharepont RA** |
| D9xx - 0104 | | | | Method statement for installation and commissioning of HGas180 |
| D9xx - 0105 | | | | Reserved for Commissioning - RA's & method statements |
| D9xx - 0106 | | | | Reserved for Commissioning - RA's & method statements |
| D9xx - 0107 | | | | SOP – Alarms and warnings testing procedure |
| D9xx - 0108 | | | | Reserved for Commissioning - procedures |
| D9xx - 0109 | | | | Reserved for Commissioning - procedures |
| D9xx - 0110 | | | | Equipment list - Commissioning checklist |
| D9xx - 0111 | | | | Instrument list - Commissioning checklist |
| D9xx - 0112 | | | | Valve list - Commissioning checklist |
| D9xx - 0113 | | | | Alarms and warnings checklist |

| | | | | |
|---|---|---|---|---|
| D9xx - 0114 | | | | FAT checklist - Part 1 - Pre-commissioning |
| D9xx - 0115 | | | | FAT checklist - Part 2 - Commissioning |
| D9xx - 0116 | | | | SAT checklist - Part 1 - Pre-commissioning |
| D9xx - 0117 | | | | SAT checklist - Part 2 - Commissioning |
| D9xx - 0118 | | | | Reserved for Commissioning - checklists |
| D9xx - 0119 | | | | Reserved for Commissioning - checklists |
| D9xx - 0120 | | | | PED Hydraulic proof pressure test - Hydrogen assembly |
| D9xx - 0121 | | | | Helium leak test - Hydrogen assembly |
| D9xx - 0122 | | | | Ventilation fans - Air flow measurement |
| D9xx - 0123 | | | | Hydraulic, pneumatic and PRV setpoints report |
| D9xx - 0124 | | | | Pneumatic pressure test of MT001 assembly test report |
| D9xx - 0125 | | | | On-site leak test - Hydrogen assembly |
| D9xx - 0126 | | | | Reserved for Commissioning - test reports |
| D9xx - 0127 | | | | Reserved for Commissioning - test reports |
| D9xx - 0128 | | | | Reserved for Commissioning - test reports |
| D9xx - 0129 | | | | Reserved for Commissioning - test reports |
| D9xx -0130>159 | | | | Reserved for Commissioning |
| **OPERATION & MAINTENANCE DOCUMENTS** | | | | |
| | | | | |
| | | | | |
| | | | | |
| D9xx-0160 | | | | Maintenance Plan |
| | | | | SOP - Maintenance activities procedure |
| | | | | |
| | | | | |
| | | | | De-commissioning procedure |
| | | | | De-commissioning checklist |
| | | | | De-commissioning risk assessment |
| | | | | Reserved |
| D9xx-0170-199 | | | | Reserved |
| | | | | |
| **CUSTOMER & SITE DOCUMENTS** | | | | |
| D9xx -0201 | | | | User documentation manual contents pages |
| D9xx -0202 | | | | ITM - User manual |
| D9xx -0203 | | | | Customer refuelling manual |
| D9xx -0204 | | | | Customer maintenance manual |
| D9xx -0205 | | | | Reserved |
| D9xx -0206 | | | | Reserved |
| D9xx -0207 | | | | Reserved |
| D9xx -0208 | | | | Reserved |
| D9xx -0209 | | | | Reserved |
| D9xx -0210 | | | | Reserved |

| STAGE GATE & TECHNICAL REVIEW DOCUMENTS | | | | |
|---|---|---|---|---|
| - | | | | TECHNICAL REVIEW 1: Ensure key docs are created to allow progress to product design (Form F6.14) |
| - | | | | GATE 2: Product design review (Form F6.12) |
| - | | | | GATE 3: Production review (Form F6.33) |
| - | | | | TECHNICAL REVIEW 2: Ensure factory commissioning checks, tests & reports completed (Form F6.34) |
| - | | | | GATE 4: OK to ship (Form F6.35) |
| - | | | | TECHNICAL REVIEW 3: Ensure commissioning site acceptance test reports completed (Form F6.36) |
| - | | | | GATE 5: Customer product acceptance form (Form F6.37) |
| - | | | | 12 month review after introduction of new product platform (Form F6.38) |

*Figure 17. Documents in a typical technical file*

The editing of documents is covered by procedure QMS OP21 Document Control. This is enforced through a dedicated Document Controller and a version control system.

Files are backed up in the following manner:

- Within the server via a RAID array
- Within the site to another server in real time (so a server failure will result in only a few minutes of disruption)
- Nightly, to a second ITM site
- Four removable discs in quarterly rotation to ensure up to a year of data is available

# 14 Communication Plan

## 14.1 Training

The people exposed to hazardous substances (ie hydrogen) will be:

- ITM Engineers, who will be exposed to the largest hazards
- Commissioning engineers from partners supplying the compressor/dispenser and maintenance engineers
- The public refuelling operatives

The competency of these groups will be determined in the following ways.

### 14.1.1 ITM Engineers

As detailed in Section 3.13.7, ITM have detailed processes to ensure staff competence. During recruitment, staff are chosen for their skills, often having been an engineer in the military.

All new starters are provided with basic H&S information common to all ITM employees. They are required to sign procedures and then complete a questionnaire based on what they have learnt, on which they must score 100%.

Once in the job, each manager has a matrix of skills that their staff require to complete their job. New staff are trained in the essential requirements and then receive on-going training to complete the matrix. With time and training (and if appropriate to their role) staff can move from testing existing systems, to performing like-for-like swaps of components on a system, to building systems and then designing systems.

Competency at a task is assured in various other ways, depending on the level of risk. For low risk activities, reading and signing a procedure is acceptable. For high risk activities, ITM have Competency Assessments, where staff are shown an activity by a trainer and are then required to demonstrate it back to them to a required standard. Ongoing training is provided by Toolbox talks (short training sessions on the shop floor provided by a supervisor) on particular subjects. These are backed up by a questionnaire to ensure they understood their training. Scores are logged to note trends in data.

Alternatively, employees may be sent on training courses, either internal or run by external companies. Feedback is sought from attendees after the course and those judged to be inadequate are not used again.

Despite these procedures, it is acknowledged that staff competency will grow with time, thus a novice commissioning engineer will not be allowed on site without being accompanied by someone with over a year of experience.

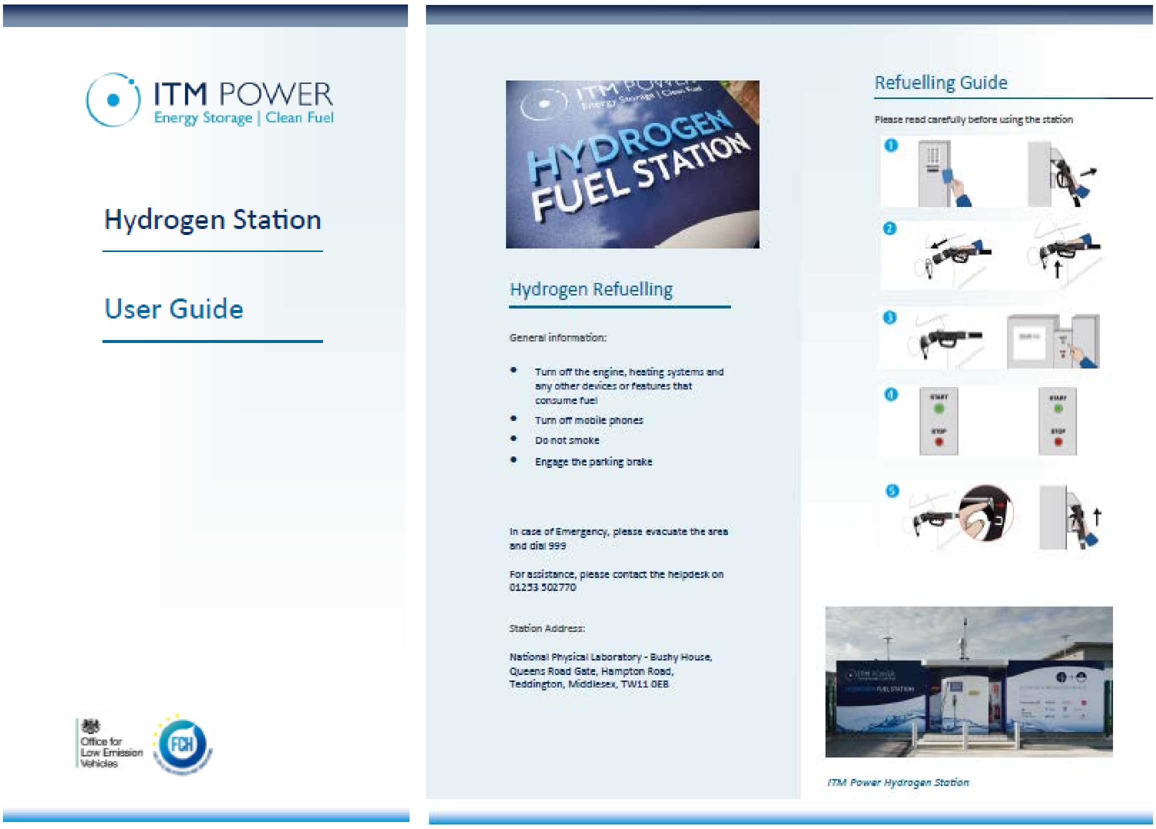
### 14.1.2 Commissioning Engineers from Partner Companies

The suppliers of the compressor/disperser will be required to come on site for several days to commission their equipment. ITM will treat them as any other contractor and follow the requirements of procedure HSMS OP05 Managing Contractors. This requires them to provide method statements, risk assessments and evidence of competency ahead of their arrival at site.

Key H&S information is shared between partners on a shared Cloud drive, with regular meetings to discuss progress.

### 14.1.3 Public Refuelling Operatives

They will be provided with training and handed documentation, a copy of which (for another refuelling station) is provided below:



ITM POWER
Energy Storage | Clean Fuel

Hydrogen Station

User Guide

HYDROGEN FUEL STATION

Hydrogen Refuelling

General information:

- Turn off the engine, heating systems and any other devices or features that consume fuel
- Turn off mobile phones
- Do not smoke
- Engage the parking brake

In case of Emergency, please evacuate the area and dial 999

For assistance, please contact the helpdesk on 01233 302770

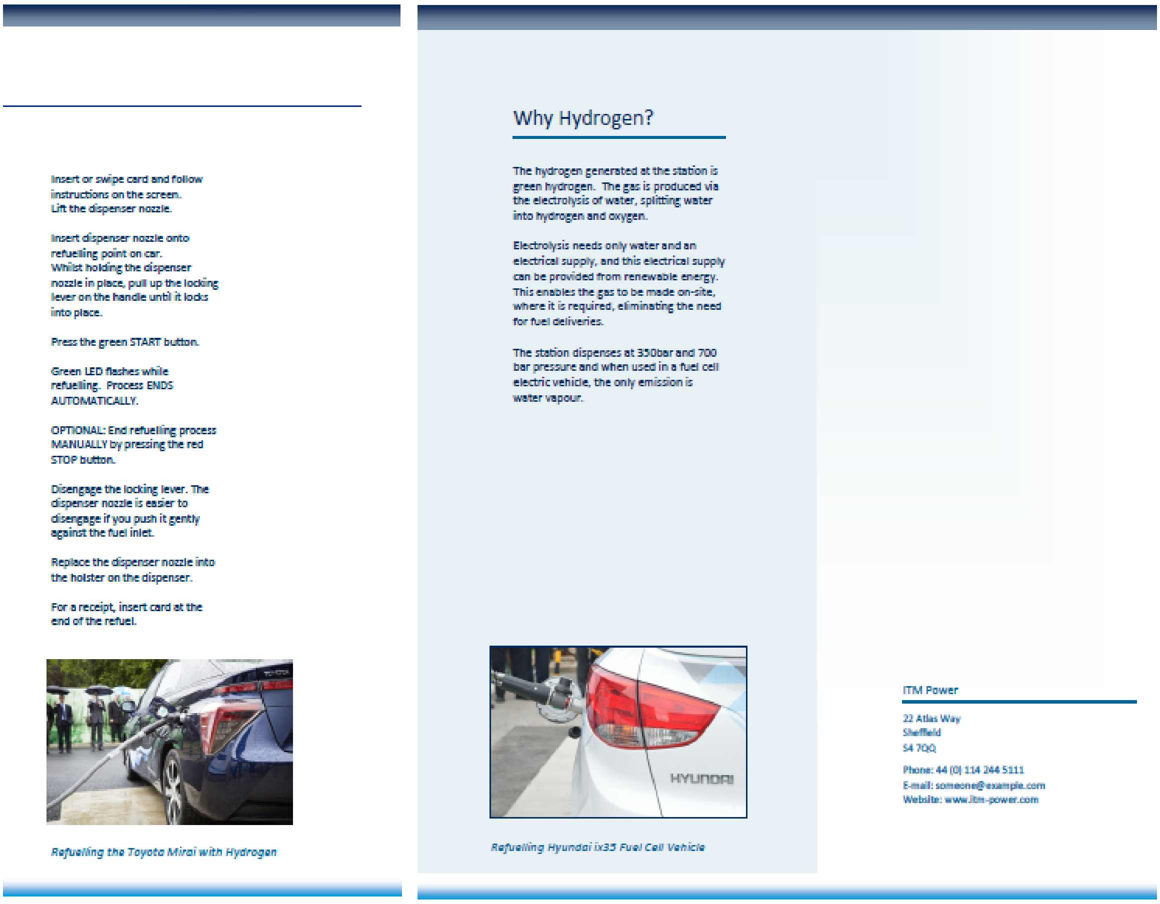
Station Address:

National Physical Laboratory - Bushy House, Queens Road Gate, Hampton Road, Teddington, Middlesex, TW11 0EB

Refuelling Guide

Please read carefully before using the station

*ITM Power Hydrogen Station*



Insert or swipe card and follow instructions on the screen.
Lift the dispenser nozzle.

Insert dispenser nozzle onto refuelling point on car.
Whilst holding the dispenser nozzle in place, pull up the locking lever on the handle until it locks into place.

Press the green START button.

Green LED flashes while refuelling. Process ENDS AUTOMATICALLY.

OPTIONAL: End refuelling process MANUALLY by pressing the red STOP button.

Disengage the locking lever. The dispenser nozzle is easier to disengage if you push it gently against the fuel inlet.

Replace the dispenser nozzle into the holster on the dispenser.

For a receipt, insert card at the end of the refuel.

*Refuelling the Toyota Mirai with Hydrogen*

Why Hydrogen?

The hydrogen generated at the station is green hydrogen. The gas is produced via the electrolysis of water, splitting water into hydrogen and oxygen.

Electrolysis needs only water and an electrical supply, and this electrical supply can be provided from renewable energy. This enables the gas to be made on-site, where it is required, eliminating the need for fuel deliveries.

The station dispenses at 350bar and 700 bar pressure and when used in a fuel cell electric vehicle, the only emission is water vapour.

*Refuelling Hyundai ix35 Fuel Cell Vehicle*

ITM Power

22 Atlas Way
Sheffield
S4 7QQ

Phone: 44 (0) 114 244 5111
E-mail: someone@example.com
Website: www.itm-power.com

*Figure 18. User guide supplied to the public*

Refresher courses will be provided.

## 14.2 Safety Reviews

There are several stages in the project where the safety of the system will be reviewed. These include:

### 14.2.1 Design review

Usually an informal process early in the design where a team of engineers from different disciples discuss the design and highlight any obvious problems. This enables the formal hazard studies to work from a better design and not end up redesigning during the studies.

### 14.2.2 HazID:

A high level examination of the equipment and site looking for a wide range of hazards. This has been described in detail in Section 3.3

### 14.2.3 HazOp:

A methodical risk-based review of the process system looking for every possible way it could fail. This has been described in detail in Section 3.1

### 14.2.4 LOPA:

A method to quantify the risk that a plant presents, to be compared to government acceptable levels. This has been described in detail in Section 3.2

#### 14.2.5 Risk Assessment:

A semi-quantitative method of risk binning for both process and non-process risks. This has been described in detail in Section 3.4

#### 14.2.6 Pressure Safety Case

A document in a set format that describes the pressure systems, calculations for things such as pressure relief valve sizing, and all certificates and declarations of compliance from suppliers. This is described further in Section. 3.13

#### 14.2.7 HazLoc Safety Case

This is a document in a set format that describes the system and possible ignition sources and how they are controlled. It includes assumptions of hole sizes and calculations of jet lengths and the requirements of NFPA2. The document concludes with the hazardous area drawings and the declarations of conformance from the suppliers of all HazLoc equipment.

#### 14.2.8 Project Stage Gates:

A total of 7 reviews and stage gates are built into the project to ensure that all of the requirements are met before the project can move on. This will prevent the design/build moving forward without the correct studies having taken place. The stage gates include:

- Technical Review 1: Ensure key docs are created to allow progress to product design. Recorded on form F6.14. Signed by the CTO and Operations Director
- Gate 2: Production design review. Recorded on form F6.12. Signed by the CTO and Operations Director
- Gate 3: Production review. Recorded on form F6.33. Signed by the Production Manager, CTO and Operations Director
- Technical Review 2: Ensure factory commissioning checks, tests and reports completed. Recorded on form F6.34. Signed by the Head of Commissioning and Operations Director
- Gate 4: Product readiness for Shipping. Recorded on form F6.35. Signed by the CTO and Operations Director
- Technical Review 3: Ensure site commissioning checks, tests and reports completed. Recorded on form F6.36. Signed by the Head of Commissioning and Operations Director
- Gate 5: Customer product acceptance form. Recorded on form F6.37. Signed by the customer and a representative of ITM.

#### 14.2.9 Workplace Inspections:

These are regularly undertaken by the site H&S Manager and a second senior manager to ensure that H&S procedures are being adhered to.

#### 14.2.10 Site Inspections during Ground Works:

During the building phase the site manager will make regular visits to the site to ensure that the build is on target and that contractors are adhering to ITM H&S procedures, specifically HSMS OP05 Managing Contractors.

#### 14.2.11 Site Inspections During Operation:

Once operational, ITM require the site to be visited once per week to make a series of basic checks, such as water / hydrogen leaks, check pressures in bottles air and whether the site is secure. This will be conducted by a subcontractor who is familiar with hydrogen technology and is trained by ITM.

### 14.2.12 Maintenance Visits

ITM require a major and minor services each year, each offset by 6 months. These will be conducted by trained ITM engineers and will involve the review of a range of equipment including:

- Inspection of the system, looking for corrosion or damage
- Leak testing of pressure systems
- Calibration of sensors
- Functional testing of all safety systems

### 14.2.13 Document Reviews

Safety documents will be reviewed under the following circumstances:

- After a set period: HazOps and LOPAs are reviewed every 5 years and risk assessments are reviewed annually.
- If the system changes: As described in Section 3.14, documents are updated as part of the change management procedure
- In response to an accident, incident, reactive audit, proactive audit or changes in:
    - Legislation
    - Industry practice / guidance
    - Hazards associated with adjacent properties

## 14.3 Safety Events and Lessons Learned:

While Section 3.3 of ITMs H&S Policy describes the generality of dealing with and investigating incidents, specific guidance is provided in SP7.8 Standard Procedure for Reporting Investigating and Analysing Incidents. The forms for investigating the incident depend on the type of incident:

- Form 8.22 Accident Reporting Form should be used if there was an injury
- Form 8.23 Near Miss and Incident Reporting Form should be used if there was not an injury

The summary of the procedure is:

### 14.3.1 The reporting procedure within the organization

**For minor injuries:**

- Obtain first aid treatment/assistance for any injuries
- Investigate the accident using the form F8.23 as soon as possible after the occurrence and within 12 hours by the Health and Safety Manager, with any relevant staff.

**For Reportable Injuries** (as defined by OSHA)**:**

- Take patient to hospital
- Preserve the accident scene, take witness statements
- Complete Form 300, and summary Form 300A

**For severe Injuries** (as defined by OSHA):

- Take patient to hospital
- Preserve the accident scene, take witness statements
- For fatalities, report to OSHA within 8hrs, otherwise within 24hrs.

In all but the most minor or cases (cuts and abrasions) an investigation should be conducted to establish the causes and root causes.

### 14.3.2 The Method and Procedure used to Investigate Events

If there was an injury, use Form 8.22 Accident Reporting Form, otherwise use Form 8.23 Near Miss and Incident Reporting Form, however, both forms follow a similar format. Key sections from the accident form is provided below:

- Address of company
- Location of accident
- Details of injured person
  - Name
  - Works number
  - Position
  - Address
  - Normal hours of work
- Details of the accident
  - Place
  - Time of accident
  - Time reported
  - Sketch or photograph of the scene
  - Was the person authorised to conduct the task?
  - Was the person trained to conduct the task?
  - A description of the accident
  - Do risk assessments, toolbox talks or standard procedures exist that cover the incident?
  - Was the injured person aware of the assessments, toolbox talks and standard procedures?
  - Was the injured person adhering to the risk assessment and / or tool box talk and / or safe system of work?
- Witnesses
  - Name
  - Position
- Was the injured person able to continue normal duties
- Could protective clothing / equipment have prevented the injury?
- Treatment details
  - Type of injury
  - Treatment given by
  - Treatment
- Statement of the injured person
- Statements of witnesses
- Interim conclusion:
  - Immediate cause of accident
  - Underlying cause of accident
  - Root cause of accident
- Actions
- Review of recommended action (completed by appropriate manager / director)

### 14.3.3 How Corrective Measures will be Implemented

As can be seen from the detail for the accident / near miss investigation detailed above, it requires actions to be written down and then confirmed by a manager / director that they have been completed.

In addition, all accidents are discussed at the company's monthly H&S Committee meeting and accident statistics are compiled annually, looking for trends which could indicate an underlying problem.

### 14.3.4 How lessons learned from incidents and near-misses are documented and disseminated

As previously described, the actions to prevent a reoccurrence are written down on the accident investigation form and are disseminated to ITM's H&S Committee. This includes senior managers, directors, and representatives of employee safety, all of whom disseminate relevant information to staff.

Incidents involving hydrogen are reported to the h2tools/lessons website for international dissemination.

## 14.4 Emergency Response

The response to an emergency is determined by the HRS's Emergency Plan. This is a document (based on a set format) that ITM put together for each HRS and comprises two parts:

- The main document which is shared between ITM, contractors, first responders, the landlord and other stakeholders. This provides details of:
  - Background information of the site
    - Equipment
    - Volumes and pressures of hydrogen on site
  - Roles and responsibilities at the HRS
  - Fire plan
    - Fire plan principles
    - Fire prevention procedures
    - Means of escape
    - Process for raising an alarm (including interaction between the sites automated system for dialling the fire service, site security, the fire service and ITM)
    - Testing of the fire alarm
  - How to turn off power to the site (E-Stops and at the local substation)
  - Evacuation of adjacent buildings
- A simpler appendix to be shared with members of the public using the refuelling station as well as being displayed at the HRS. This includes:
  - Simple instructions for what to do in the event of an emergency
  - Location of evacuation point
  - Location of Fire glass break points, Equipment E-Stops and Global E-Stops.

ITM recognise the critical role that first responders have in an Emergency Response. As well as having a familiarisation visit to the station before it is operational, they will be provided with key pieces of information including the Emergency Plan, Maintenance Plan and the guide for users of the station.

## 14.5 Self Audits

In line with ITM's Health and Safety and Quality management systems, ITM proactively look for potential problems with paperwork and physical systems through the use of internal audits, based on procedure QMS OP26 Internal Audit. In addition, ITM may conduct a reactive audit in response to an event, (eg a supplier has alerted ITM to a problem with a part).

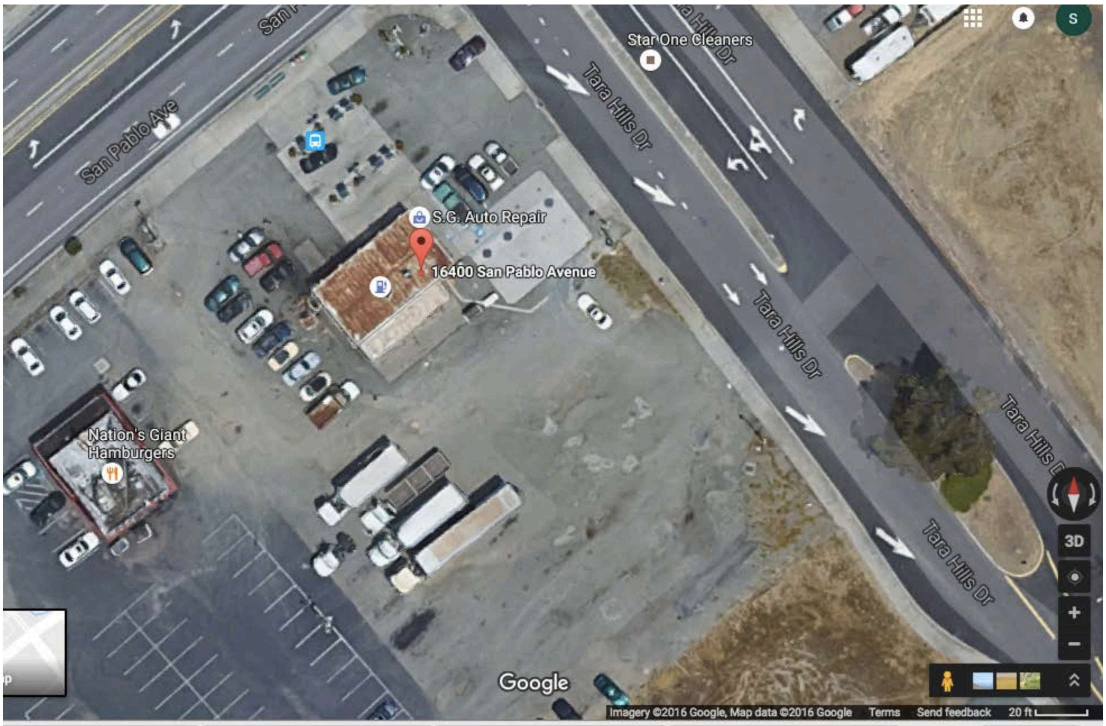
ITM have several members of staff who are trained to conduct internal audits and have forms to complete to record results (Form F2.02).

## 14.6 Process Flow Diagram

The PFD for the stations will be provided as a separate document.

# 15 Appendix A – site specific factors

## 15.1 Site 3 – San Pablo




This site is located on an existing fuel station and is next door to unoccupied or commercial space. The station will be constructed in the Souht east side of the lot and fire walls will be used to limit the extent of setbacks on the site.

The site has good access for engineering staff and the public and is not backed onto by any local residences or occupied space and has a large retaining wall at the rear perimeter.

The area that will house the hydrogen equipment on this site is set back from the main building and the electricity service panel and so electrical zoning is not considered to be a problem.

It is not anticipated that this site will cause any additional/specific safety concerns.