Mr Russell Brooks
Senior Approvals and Stakeholder Manager
Jemena Gas Networks (NSW) Ltd
Level 1, 567 Collins Street
Melbourne, VIC, 3000

19/11/2020

Dear Mr Brooks

Western Sydney Green Gas Project (SSD-10313)
Final Hazard Analysis

I refer to the Final Hazard Analysis (FHA) submitted in accordance with Condition B1(c) of Schedule 3 of the Development Consent for the Western Sydney Green Gas Project (SSD-10313).

The Department has carefully reviewed the document and is satisfied that the FHA has been prepared in accordance with the Department's Hazardous Industry Planning Advisory Paper No. 6, 'Hazard Analysis', based substantially on the final design of the project for the scope described below.

It is understood that Jemena will construct all components described in the Preliminary Hazard Analysis (PHA – EIS Appendix C) except the following scopes:

1. the hydrogen refuelling station for vehicles along with its high-pressure hydrogen storage;
2. addition of one hydrogen fuel cell for electrical power generation; and
3. change of natural gas fuel supply to the microturbine generator set from secondary mains to gas bottles supplied by trucks. No hydrogen fuel will be utilised by the microturbine generator set.

Scopes 2 and 3 above are new components which are not clearly described in the EIS and PHA. These new components can alter the risk profile of the project. In this regard, Jemena has identified the hazards from these new components and conducted sufficient analysis to verify that potential consequences from these new components will not extend beyond the project boundary.

Accordingly, the Planning Secretary has approved the Final Hazard Analysis (Revision A, dated 3 September 2020) for the scope described above, subject to Jemena:

1. implementing all safeguards described in the FHA in a timely and appropriate manner; and
2. submitting to the Secretary, at least one month prior to commencement of commissioning of the SSD (similar timing to Condition B3), a statement:
    a. specifying the maximum storage of natural gas in gas bottles within the project area;
    b. specifying the storage and staging areas of gas bottles within the project area;
    c. verifying that the arrangement specified in items 2a and 2b above complies:
        i. with all standards and legislation described in FHA Section 2.7; and
        ii. all other relevant Australian Standards not specified in FHA Section 2.7, including and not limited to Australian Standard 4332 The storage and handling of gases in cylinders; and
3. submitting a revised FHA if they wish to undertake excluded work scopes consistent with the EIS and PHA. Modification of the development consent may be required for scopes of work outside the submitted EIS and PHA

Please ensure that the approved plan is placed on the project website at the earliest convenience.

If you wish to discuss the matter further, please contact Wayne Jones on 6575 3406.

Yours sincerely

Stephen O'Donoghue
Director
Resource Assessments
As nominee of the Planning Secretary

GPA Engineering Pty Ltd
Phone 08 8299 8300
enquiries@gpaeng.com.au
gpaeng.com.au

Final Hazard Analysis

Jemena - Detailed Design for Hydrogen Generation (Western Sydney Green Gas Project)

Jemena Ltd

GPA Document No: 18667-REP-027
Client Document No: P2G-2099-RP-HZ-005

GPA Project No: 18667
Client Project No: P2G-2099

Rev	Date	By	Checked	QA	Description
A	03/09/2020	LH	SH	AS	Issued for Review

EXECUTIVE SUMMARY

Introduction

Jemena Gas Networks is the asset owner of the Horsley Park High Pressure Gas Facility, comprising of a number of pressure let down and pipeline pigging facilities, including the Eastern Gas Pipeline (EGP) pipeline, Jemena Gas Network (JGN) Trunk, Sydney Primary Loop and local secondary network, located on Chandos Road in Horsley Park, NSW.

Jemena has proposed construction of a demonstration hydrogen production plant within and adjacent to their existing high pressure gas facilities at Horsley Park in New South Wales. The project, called the Western Sydney Green Gas Trial (WSGGT), will initially produce 100 Nm^3/h of hydrogen gas with a 500 kW Hydrogenics PEM electrolyser using electricity from the local power grid. Produced hydrogen gas will either be injected into the existing natural gas distribution network for sale as blended natural gas / hydrogen or be used to generate electricity using a gas fuelled generator package.

In accordance with the NSW Department of Planning and Environment (DP&E) requirements set out in the Hazardous Industry Planning Advisory Paper (HIPAP) 6: Guidelines for Hazard Analysis and for the risk to be evaluated and compared with the risk criteria in use in NSW and as specified in HIPAP 4: Risk Criteria for Land Use Planning, GPA Engineering has been requested to prepare a Final Hazard Analysis (FHA). This is subsequent to the Preliminary Hazard Analysis that was submitted to the DP&E 31st October 2019 document number P2G-2099-RP-RM-003. The main differences from the PHA are:

- Removal of the vehicle refuelling facilities and associated hydrogen high pressure storage
- Addition of a hydrogen fuelled Fuel Cell for power generation
- Change from natural gas supply fuel supply to the Microturbine being sourced from the Secondary Mains to being sourced from natural gas supplied by a Jemena Truck with gas bottles.

There is potential for additional future scope items to be added consisting of:

- Vehicle refuelling facilities and associated hydrogen high pressure storage (as described in the PHA)
- Hydrogen cylinder filling facilities

If these scope items are going to proceed, this FHA will be amended to include them and re-submitted.

Scope and Aim of Study

The objectives of this report are to determine the risk of a major incident at the WSGGP facility affecting offsite land users and to compare this with established tolerable risk criteria.

Hazard identification and analysis has been undertaken for the site in the form of HAZID and HAZOP workshops attended by personnel with the required experience levels. In these studies, hazards were identified along with existing and proposed safeguards to be incorporated into the design. Scenarios were then developed for consequence modelling. Consequence modelling was undertaken at the specified operating conditions and leak type/size for each case.

Results

There are no potentially fatal offsite individual risks presented by the design of the Western Sydney Green Gas Project in this report. Any risk of potential injury beyond the boundary is well below the tolerable risk target for the surrounding land use. It should be noted that none of the credible consequence contours modelled are expected to impact the residential dwellings on the other side of Chandos Road approximately 250 m away from the new facility.

In conjunction with design safeguards listed in this report, Jemena will develop an integrity management plan involving inspection and maintenance of critical equipment as well as upgrading and implementing their safety management system for the site. This will be reflected in an update to the Safety Case GAS-999-PA-HSE-002 and the Asset Management System Manual, JEM-AM-MA-001.

Consequence modelling for all scenarios was performed using continuous release rates and is therefore conservative.

CONTENTS

TABLE OF FIGURES

LIST OF TABLES

1 Introduction

1.1 Background

Jemena Gas Networks is the asset owner of the Horsley Park High Pressure Gas Facility, comprising a number of pressure let down and pipeline pigging facilities, including the Eastern Gas Pipeline (EGP) pipeline, Jemena Gas Network (JGN) Trunk, Sydney Primary Loop and local secondary network, located on Chandos Road in Horsley Park, NSW.

Jemena has proposed construction of a demonstration hydrogen production plant within and adjacent to their existing high pressure gas facilities at Horsley Park in New South Wales. The project, called the Western Sydney Green Gas Project (WSGGP), will initially produce 100 Nm^3/h of hydrogen gas with a 500 kW Hydrogenics PEM electrolyser using electricity from the local power grid. Produced hydrogen gas will either be injected into the existing natural gas distribution network for sale as blended natural gas / hydrogen or used to generate electricity using a gas fuelled generator package and fuel cell.

Initially, the generator package will be run on natural gas supplied by one of Jemena's "back-up" natural gas supply trucks.

The WSGGP facility will perform the following key functions:

- Convert mains water into hydrogen gas using grid electricity through electrolysis.
- Store hydrogen gas in a buried onsite steel pipeline. This will be used for backup hydrogen gas supply and injection management.
- Control and safely manage hydrogen gas pressures, temperatures and flowrates for injection into Jemena's secondary gas pipeline network.
- Provide a hydrogen microturbine generator and fuel cell to convert stored hydrogen into electrical energy.

1.2 Scope and Aim of Study

The objectives of this report are to address the Hazard and Risk requirements of the Secretary's Environmental Assessment Requirements (SEARs) for the WSGGP by quantitatively determining the risk of a major incident affecting offsite land users and to compare this with established tolerable risk criteria.

This Final Hazard Analysis (FHA) has been prepared in accordance with the Department's Hazardous Industry Planning Advisory Paper No. 6, 'Hazard Analysis' and Multi-level Risk Assessment (Ref 2 and Ref 3).

The scope of the study includes:

- Systematic identification of hazards
- Determination of the consequences of identified hazards
- Determination of the likelihood of loss of containment hazards using published data
- Determination of the acceptability of the risk by comparison to the risk criteria specified in NSW Department of Planning HIPAP No. 4 (Ref 1)

The DP&E has advised that a Level 2 assessment is appropriate for this facility. A level 2 assessment is described below:

"A level 2 assessment is semi-quantitative, in that it should, in addition to all the elements of the level 1 analysis, include sufficient quantification of risk contributors to demonstrate that risk criteria will be met.

In particular:

- *appropriate modelling tools should be used to calculate the consequences of all events shown by the preliminary assessment to have the potential for harmful offsite effects*
- *there should be an estimate of likelihood for each event confirmed by the consequence modelling to have significant off-site effects, using appropriate failure data and techniques, such as fault and event trees*
- *there should be an indicative estimate of the off-site risk, taking into account the cumulative impact of multiple events*
- *the study must demonstrate that all relevant numerical risk criteria will be met (see also section 2.2.4)"*[1]

1.3 Abbreviations

CNG	Compressed Natural Gas
EGP	Eastern Gas Pipeline
HAZID	Hazard Identification Study
HAZOP	Hazard and Operability Study
HDCU	High Density Community Use
JGN	Jemena Gas Network (NSW Gas Asset)
LNG	Liquefied Natural Gas
LOPA	Layer of Protection Analysis
MAOP	Maximum Allowable Operating Pressure
P2G	Power to Gas
PHA	Preliminary Hazard Analysis
PLC	Programmable Logic Controller
SCADA	Supervisory Control and Data Acquisition
SCS	Station Control System
SIL	Safety Integrity Level
SIS	Safety Instrumented System
WSGGP	Western Sydney Green Gas Project

[1] Department of Planning and Environment. Assessment Guideline Multi Level Risk Assessment. 2011.

2 Site and Process Description

2.1 Site Location and Surrounding Land Uses

The facility is located within the boundaries of Jemena's current High Pressure Gas Facility, located at 194 – 202 Chandos Road, Horsley Park, NSW, Australia, 32 km west of Sydney CBD. The project location is within the Fairfield local government area.

The location of the station is shown in Figure 1 and Figure 2. All works associated with the WSGGP will occur within the boundaries of this property. The site is within the area covered by the Western Sydney Parklands. The facilities fall under the Eastern Gas Pipeline location classification of Rural Residential (R2) (Ref 1).

The facility is located 600 m to the east of the Westlink M7 toll road. Eastern Creek runs in a northerly direction in a wooded area between the M7 and the facility. The Horsley Park Meter Station is located directly north of the site (see Figure 2). A market garden is located directly east of the site and a quarry is located to the north.

Private residences are located approximately 250 m to the south of the facility along Chandos Road. The building to the east of the site is a farm shed and the residence for that property is located on Chandos Road. There are no schools, hospitals or other development referred to as *sensitive development* in HIPAP No. 4 (Ref 1) within the potential hazardous impact zone of the development.

The area adjacent to the eastern boundary fence is currently open for tender for farming purposes. There are 3 separate blocks currently being offered to be leased by one tenant. Future possible land uses may include crops, greenhouses, farm sheds, chemical storage sheds or farm gate produce sales. Jemena have engaged with the Western Sydney Parklands Trust and they are aware of the proposed hydrogen facility. The Western Sydney Parklands Trust has agreed to inform Jemena of any potential changes to land use that may result from future tenants.

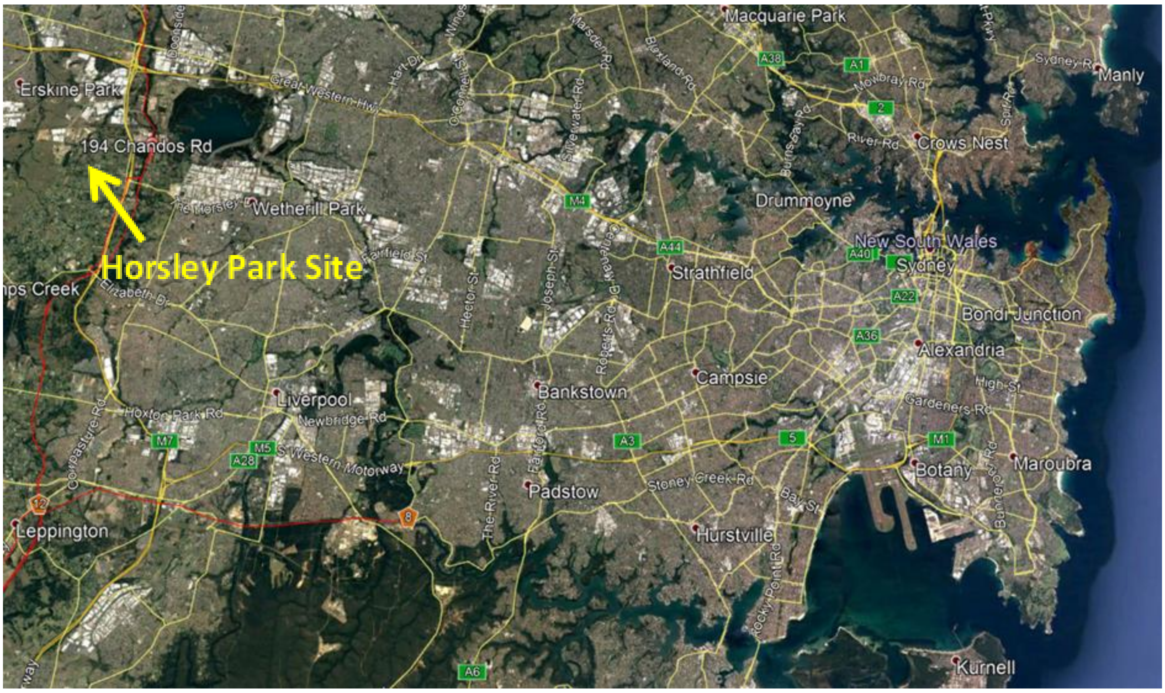


Figure 1: Project Location (32 km west of Sydney CBD)

Figure 2: WSGGP Facility Location (within existing Horsley Park Site)

2.2 Site Layout and Equipment

The main plant items and facilities in scope for this project are shown in Table 1.

Table 1: Site Equipment

Item	Description
Electrolyser	Primary plant generates hydrogen gas on-demand from feed of electricity and water.
Hydrogen buffer store (buried carbon steel pipeline)	Manages incoming flow of hydrogen gas from electrolyser for onsite storage and distribution to gas injection, hydrogen refuelling station and microturbine.
Hydrogen gas control panel	Regulates and controls the flow of hydrogen to and from the major equipment.
Hydrogen secondary mains injection panel	Regulates the injection of hydrogen into the secondary mains.
Hydrogen fuel cell	Generates electricity on-demand for power grid back-up testing.
HV Substation (including transformer) and grid connection	Voltage step between site and grid power.

Item	Description
Control and instrumentation	Overall site data acquisition, monitoring and control.
Site civil works	Site hard standing, security, weather protection, etc.
Hydrogen / natural gas microturbine	Generates electricity on demand for site standby power or for feedback into the power grid.
Hydrogen refuelling station connections	Interfaces and laydown area for future connection to plant associated with a hydrogen refuelling system.
Waste Water Disposal	Waste water from the electrolyser package is sent to the waste water disposal system for storage and removal from site as required.

A schematic of the facility is shown in Figure 3.

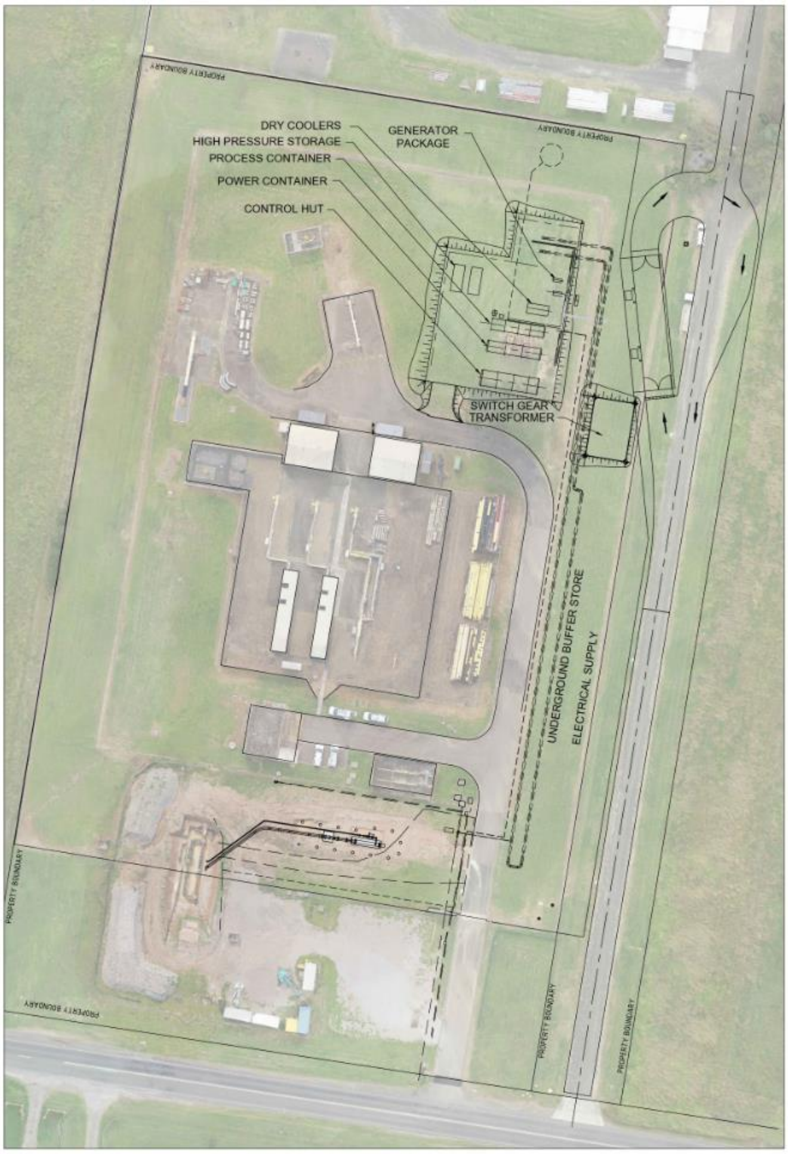


Figure 3: Schematic of WSGGP Facility Plant Design and Operation

2.2.1 Plant Design

The facilities are described in the Basis of Design (Ref 4) and are listed below. Refer to Figure 4 for the process flow diagram.

2.2.2 Gas Control Panel

The 'Gas Panel' will include actuated and manual valving to direct flow to and from the electrolyser, hydrogen fuel cell, hydrogen-powered generator, and a hydrogen buffer storage pipeline.

The gas panel will be comprised of SS316 tubing and pipe. The gas control panel structure consists of vertically mounted equipment & instrument panel and a collection hood. The semi-enclosed roof structure is openly ventilated to allow any hydrogen leaks to disperse into the atmosphere. Hydrogen leak detection is also provided.

2.2.3 Electrolyser

The function of the electrolyser is to split water into its constituent parts, oxygen and hydrogen. The oxygen is vented above the electrolyser and the hydrogen is purified before it is transmitted to the buffer store.

The electrolyser is a self-contained unit, operated from the control panel inside the control hut and remote shut down from the Jemena control room. Physical access to the unit is via key entry.

2.2.4 Buffer Store

A buffer store will be provided, in order to accumulate hydrogen inventory to ensure that sufficient quantity is available when required. This additional storage will be provided as an on-site buried pipeline. Approximately 100 – 120 kg of hydrogen can be stored as line-pack in the buried pipeline.

2.2.5 Generator Set

The purpose of the generator set (microturbine) is to demonstrate and trial its application as a grid connected back up and grid "battery" when used in conjunction with the electrolyser. The fuel supply for the generator set will come from natural gas initially. Once certified for hydrogen fuel, the fuel supply will be from the buffer store via the gas control panel.

2.2.6 Fuel Cell

A Fuel Cell will be installed to generate power from hydrogen.

Hydrogen secondary mains injection panel regulates the injection of hydrogen into the secondary mains.

2.2.7 Hydrogen Secondary Mains Injection Panel

The Hydrogen Secondary Mains Injection Panel regulates the injection of hydrogen into the secondary mains.

2.2.8 Waste Water Disposal

The waste water disposal system consists of a waste water sump, sump pump waste water storage tank and irrigation facilities. The basic philosophy is described below:

- Reject water produced from the electrolyser will be transferred and stored in Waste Water Tank (T-H10001)
- When required, the water will be distributed to a number of sprinklers via the Irrigation Pump (P-H10001).

2.2.9 Future Connections

The specification and design of a cylinder re-filling facilities, a vehicle dispenser and research and test facility is currently out of scope for this project. A subsequent FHA will be submitted if required.

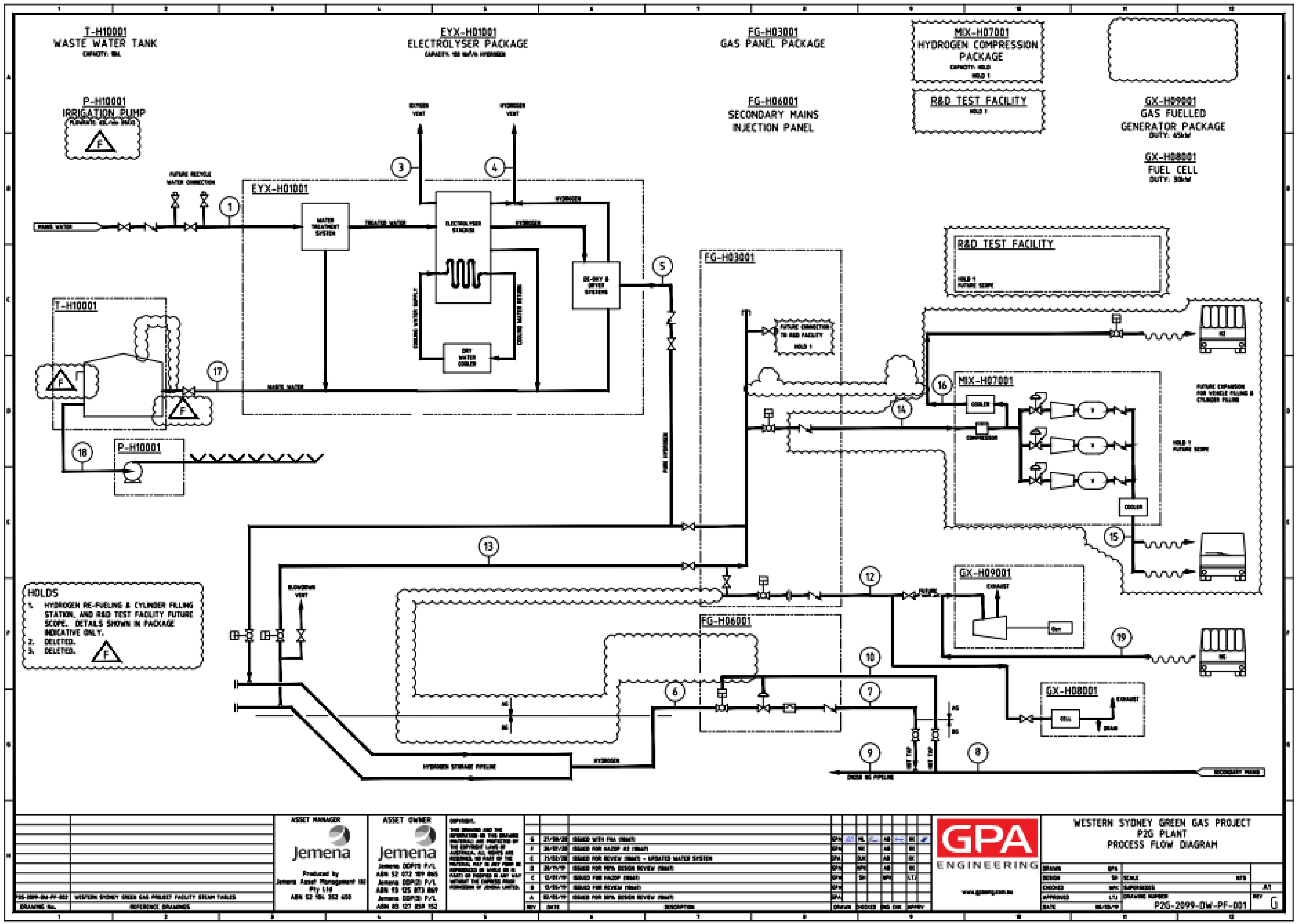


Figure 4: Process Flow Diagram

2.3 Secondary Mains Network

Jemena own and operate the Sydney Secondary Mains Network. The network directly or indirectly supplies gas to over 900,000 domestic and industrial customers across Sydney region. It has a Maximum Allowable Operating Pressure (MAOP) of 1,050 kPag. The Sydney Secondary Mains Network commenced construction in the 1960s. Sections are laid through High Density Community Use (HDCU) areas. The Sydney Secondary Mains Network consists mainly of steel either API 5L Grade B or API 5L Grade X42. Diameters range from 50 mm – 450 mm.

An overview of the location of the Secondary Mains network can be seen in Figure 5 below.

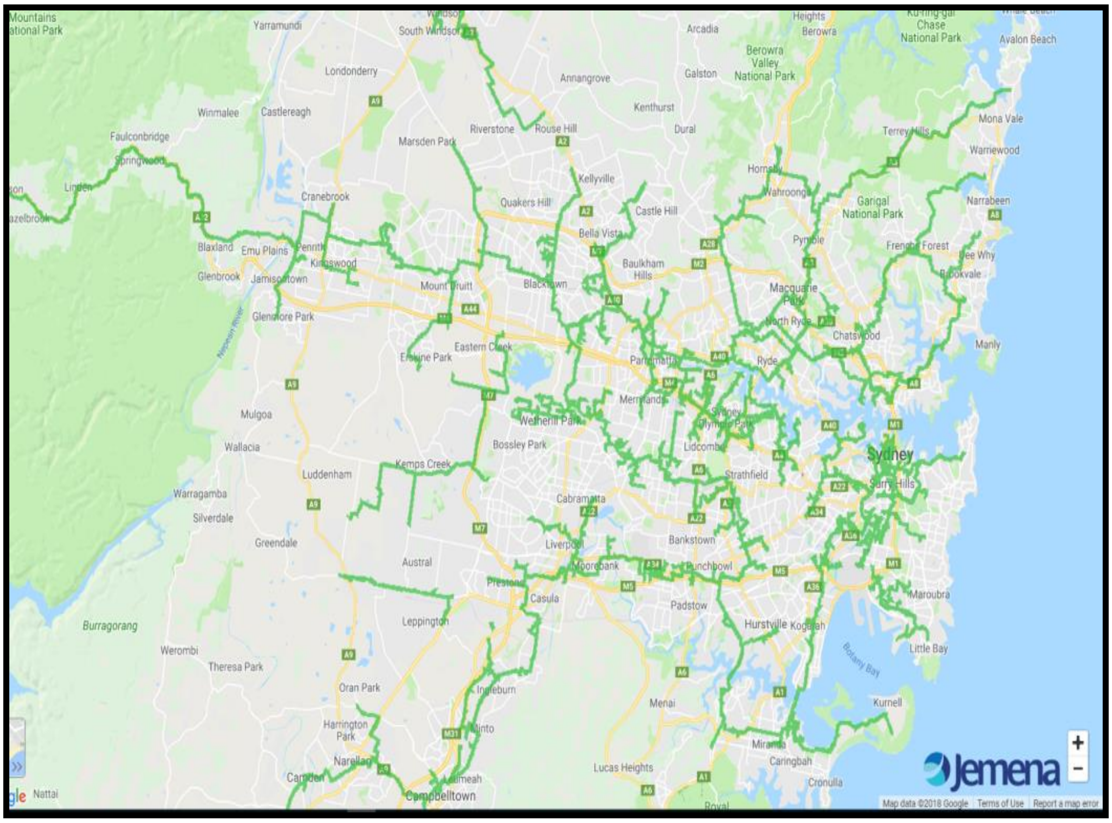


Figure 5: Overview of Secondary Mains Network

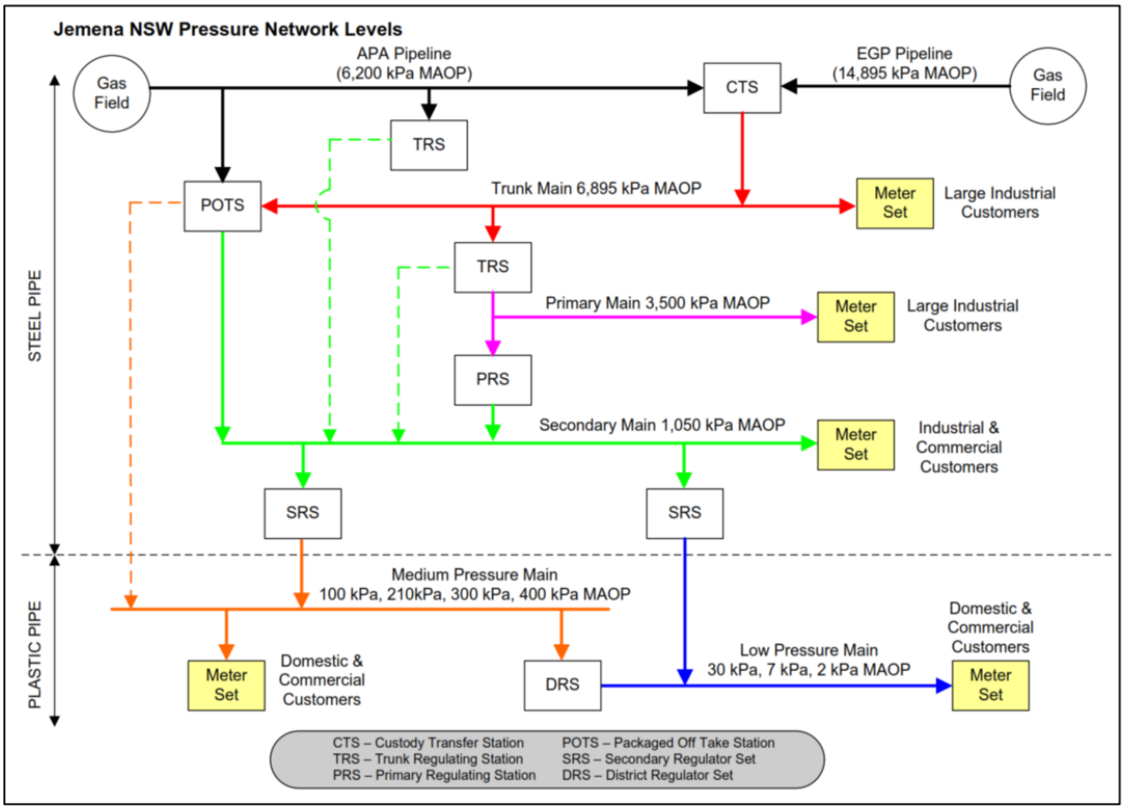


Figure 6: Jemena Network Configuration

Figure 6 shows configuration of Jemena's NSW JGN network. Supply from the Secondary Mains to the downstream medium and low pressure mains are via District Regulator Sets (DRS) or Secondary Regulator Sets (SRS). The medium and low pressure mains and services supply natural gas to domestic, industrial and commercial users.

For this facility, the Hydrogen will be injected downstream of the Horsley Park PRS directly into the Secondary Main. This network is designed to Australian Standard for Gas Distribution Networks AS4645 (Ref 5) and operated under low stress and no rupture conditions (<20% SMYS).

2.4 Site Buildings

2.4.1 Control Hut

All control and monitoring systems are located within a 20 ft demountable control hut. This hut is equipped with air conditioning, lighting and basic furnishings for 4 persons.

2.5 Process Control

The facility will incorporate both manual (local) and automatic (both local and remote) features that will allow plant and equipment to be operated safely and efficiently.

The primary objective of the control system is to provide control over processing functions, protect plant, equipment and personnel, and enable simple and reliable plant shutdown, and isolation of equipment. As the facility will be unmanned, minimal operator involvement must be required, including for start-up, shutdown, and restart. The systems shall therefore monitor and control the facility on a continuous basis under all operating and environmental conditions.

The WSGGP facility will be provided with a local PLC (station control system, SCS) designed to control all major process functions, and a safety instrumented system (SIS) that will shut down (trip) a range of equipment and equipment packages, and close major isolation valves during emergency events or process trips.

Hydrogen gas quality will be measured by an analyser within the electrolyser package, with data visible to the facility SCADA to enable plant adjustments to be made, if necessary.

Utility systems will be controlled by their respective package controllers, as mentioned above. All packages will be expected to operate without operator intervention.

Refer to the WSGGP control philosophy (P2G-2099-RP-IE-001) for further details.

2.6 Design and Operating Conditions

Table 2: Design Temperatures

Plant Item	Interface	Maximum	Normal	Minimum
Electrolyser (water)	Inlet	45 °C	21 °C	6 °C
Electrolyser (hydrogen)	Outlet	80 °C	60 °C	-20 °C
Buffer store	Inlet - Outlet	60 °C	20 °C	-10 °C
Microturbine and fuel cell	Inlet	60 °C	25 °C	-10 °C
Ambient air	NA	45 °C	21 °C	-10 °C
Stainless Steel Piping (SH3D) [3]	N/A	100 °C	20 - 60°C	-29 °C
Carbon Steel Piping (CH3D)[3]	N/A	100 °C	20C	-29 °C

Table 3: Ambient Temperatures

Parameters	Units	Value	Basis
Electrolyser package	°C	40	Selected maximum ambient temperature for cooler sizing
Microturbine generator package	°C	60	Maximum operating temperature
Lowest one day mean ambient temperature	°C	-6	BOM average data for Horsley Park
Design minimum temperature	°C	-6	BOM average data for Horsley Park

Table 4: Design Pressures

Parameters	Units	Value	Basis
Electrolyser	kPag	3,800	Electrolyser PSV Set Pressure
Buffer storage	kPag	3,800	Electrolyser PSV Set Pressure. Note: Hydrotest pressure to 7,650 kPag (1.5 x MAOP)

Table 5: Operating Pressures

Parameter	Value	Basis
Electrolyser	3,000 kPag	P&ID P2G-2099-DW-PD-005
Buffer storage	1,000 – 3,000 kPag	Datasheet P2G-2099-DS-JJ-002
Hydrogen generator and fuel cell	800 kPag	P&ID P2G-2099-DW-PD-006

2.7 Standards and Legislation

2.7.1 NSW Legislation

Compliance to NSW Acts and Regulations are mandatory for plant and equipment installed in the State of NSW. Compliance to all Australian Standards referenced in legislation is mandatory.

Key relevant legislation applicable to plant and equipment in NSW includes the following:

- Work Health and Safety Regulation 2017
- Gas and Electricity (Consumer Safety) Regulation 2018.

In addition to these regulations (and their associated Acts), the following NSW Safework Codes of Practice shall be incorporated into the scope of supply and include, but are not limited to the following:

- Managing Risks of Plant in the Workplace – Code of practice (July 2014)
- Managing Electrical Risks in the Workplace – Code of Practice (September 2016)
- Managing risks of hazardous chemicals in the workplace code of practice – Code of Practice (July 2014).

2.7.2 Australian, International and Hydrogen Specific Standards and Guidelines

Where applicable the codes listed in Table 6 shall apply or be used in part where relevant. The full list of applicable codes and standards is provided in project document P2G-2099-LS-QA-001. The hydrogen specific standards and guidelines shall be observed regarding hydrogen containing equipment where Australian Standards do not cover specific requirements.

Table 6: Standards and Guidelines

Australian Standard	Title
AS/NZS 1170.0	Structural Design Actions – General Principals
AS/NZS 1170.1	Structural Design Actions – Permanent, Imposed and Other actions
AS/NZS 1170.2	Structural Design Actions - Wind Actions
AS/NZS 1170.4	Structural Design Actions – Earthquake
AS 1596	The storage and handling of LP Gas
AS 1768	Lightning Protection
AS 2885.1 (1)	Pipelines – Gas and Liquid Petroleum - Design and Construction
AS 2885.3 (1)	Pipelines – Gas and Liquid Petroleum - Operation and Maintenance
AS/NZS 2885.5 (1)	Pipelines – Gas and Liquid Petroleum - Field Pressure Testing
AS/NZS 3000	SAA Wiring Rules
AS/NZS 3008	Electrical Installation – Selection of Cables - Cables for alternating voltages up to and including 0.6/1 kV
AS 3600	Concrete Structures
AS 4041	Pressure Piping
AS 4100	Steel Structures
AS/NZS 60079.10.1	Classification of areas – Explosive gas atmospheres
AS/NZS 60079 Series	Electrical equipment in hazardous area
NCC 2019	National Construction Code
International Standard	**Title**
ASME B31.12	Process Piping - Hydrogen
ASME B16.5	Pipe, Flanges and Flanged Fittings
ASME B16.21	Non-metallic Flat Gaskets for Pipe Flanges
ASME B1.20.1	Pipe Threads, General Purpose, Inch
ASME VIII	Boiler and Pressure Vessel
NFPA 2	Hydrogen Technologies Code
Hydrogen Plant	**Reference Standard and Title**
Electrolyser	• ISO 22734 Hydrogen generators using water electrolysis process -- Industrial, commercial, and residential applications • ISO 14687:2018 Hydrogen fuel quality – product specification
Gas Panel (and other exposed tubing)	• NFPA 2 Hydrogen Technologies Code • AIGA 033/14 Hydrogen Pipeline Systems (for pipeline pressures between 10bar and 210bar)
Buffer Store	• IGA 15/96 Gaseous Hydrogen Stations • ISO 19884 Gaseous Hydrogen - cylinders and tubes for stationary storage • ASME B31.12 Hydrogen Piping and Pipelines

Note (1) Although AS 2885 does not apply to hydrogen service, the general intent and operational considerations shall be observed in lieu of dedicated Australian hydrogen pipeline standards.

2.8 Security and Protection

The SCADA system shall be used to monitor the site security. All entry points including to the PLC and communication cabinets shall be monitored and an alarm raised when the panel doors are opened. This alarm will be annunciated on the SCADA system. Typical entry points:

- Site entrance
- Emergency access gate
- Gas / Fire detection
- Building entrance
- PLC / Communications Cabinet

2.9 Manning

The plant will not have a permanent operator presence and is designed to operate autonomously.

Operator attendance will be required to clear an ESD. The plant will be controllable remotely via SCADA.

2.10 Lightning Protection

Lightening protection for the site will be in accordance with AS 1768.

3 Safety Features

The inherent risks associated with high pressure gas facilities are managed in accordance with the principles of operational safety through design. The main philosophies that have been adopted to avoid potential high risk situations associated with the operation of this facility are to eliminate the potential risks through design and to ensure appropriate quality control during construction.

3.1 Detection of an Upset Condition

The operating philosophy for the facility, as detailed in the control philosophy (P2G-2099-RP-IE-001) is to employ remote telemetry to observe and monitor performance. The site will not have a permanent operator presence and is designed to operate autonomously.

In the event of equipment failure the system is designed to automatically isolate and allow only the natural gas network flow to continue uninterrupted. The telemetry system will provide data via SCADA, which in turn will alert the control room staff of the condition of the site prompting a response in line with the response sheet for the site. Operator attendance will be required to clear an ESD. The plant will be controllable remotely via SCADA.

3.2 Gas Leak Prevention and Protection

The facility has been designed and constructed in accordance with the requirements of Australian Standards, codes and practices. In general, leaks of natural gas or hydrogen from pipes and equipment are prevented through the following features:

- Minimising the number of flanges and threaded connections, with welded connections and hydrogen suitable compression fittings to be used wherever possible.
- Stringent requirements for material & fabrication inspection prior to fabrication of pipe.
- Non-destructive (x-ray or ultrasonic) testing of welds during construction.
- Hydrostatic testing of equipment prior to commissioning.
- Design and selection of soft components e.g. gaskets, Swagelok compression fittings, threads, valve internals will be selected in conjunction with vendors to ensure hydrogen compatibility.
- Creating a preventative maintenance and inspection program for all equipment and valves associated with the station.
- Leak inspection of above ground hydrogen piping systems (e.g. with helium or other suitable method) prior to commissioning with hydrogen.

Prevention of mechanical failure of above ground equipment due to external impact is achieved through the following:

- Defined access roads
- Access requirements considered when specifying the equipment layout
- Bollards are provided to protect above ground piping from vehicle impact.
- External facility fence to provide security for high risk assets via separation from the general public.

For external interference threats to the buried pipeline, the following safeguards will be in place:

- The buffer store pipeline will be installed within Jemena's new high security fence to provide exclusion from credible third party interference threats.
- The site is operated by Jemena – any work will be under direct supervision (incl. requirements to consult engineering prior to digging / trenching /placing load on site) and subject to work permits.
- Pipeline marker signs indicate the buried pipeline route.

- Company procedures. Jemena procedures require positive location of the pipeline prior to dig-up, and then restrict the use of mechanical equipment within 500 mm of the pipe wall.
- Marker tape above buried pipe provides pre-warning in case of digging.
- The pipe is expected to resist penetration based on design from;
  - Excavators up to 55 t in weight, fitted with general purpose teeth
  - Excavators up to 25 t in weight, fitted with tiger teeth. For excavators weighing 30 to 55 t using tiger teeth, it is expected that only one tooth will penetrate the pipe.
  - Dozer rippers up to 5 t weight, fitted with single point penetration teeth.

Corrosion prevention achieved for above ground equipment as follows:

- Hydrogen and natural gas are clean and dry gases with a low risk of causing internal corrosion.
- Facility piping is stainless steel, which is less susceptible than carbon steel to external corrosion.

Corrosion prevention achieved for the buried pipe as follows:

- Buried pipeline is coated with fusion bonded epoxy and STOPAQ joint coating and thick walled.
- Buried pipeline is provided with cathodic protection (with regular inspection and monitoring).

Prevention against degradation from hydrogen (e.g. hydrogen embrittlement) as follows;

- Facility piping is 316 stainless steel, which is less susceptible to hydrogen embrittlement.
- Buried pipe is designed with low design factor and relatively low-strength grade (X52) material to ensure low stress conditions to protecting against rupture due to hydrogen embrittlement.
- Assessment of the loss of fatigue life due to embrittlement has been completed, confirming that the fatigue risk is significantly beyond the operating profile for the pipeline.

Prevention of overpressure is managed as follows:

- Where a source of pressure is capable overpressuring downstream equipment, a pressure switch to initiate closure of an XSV in the event of a control valve failure, to isolate the source from downstream lower rated piping or equipment is included in the design. The switches are local, hardwired and act independently of the Programmable Logic Controller (PLC). A Layers of Protection Analysis assessment has been completed on overpressure instrumented functions (Ref 9).
- Buried pipeline will be designed to withstand considerable overpressure by being thick walled, welded & hydrotested well above required design limits.

3.3 Hydrogen Leak Detection

The following locations will be fitted with gaseous hydrogen detection systems:

Table 7: Hydrogen Leakage Sensors

Location	Requirement
Electrolyser	Leak detector located by supplier with high alarm back to Control Room and High-High to automatic local shutdown.
Gas Panel and Injection Panel	Leak detector located in the enclosure high point with alarm back to Control Room and alarm to indicate a leak.

Additionally the following actions were taken in the Balance of Plant HAZOP regarding leak detection:

- Include a short-term isolation function has been added to the design and will be included as a routine test in operating procedures. This isolates the system for 15 minutes and monitors pressure change during shut-in to detect a leak
- Any hydrogen leak detection will initiate a local beacon/siren. The siren will interlock with facility

gate and will alarms upon attempted entry.
- Include a pressure switch low low (PALL-06015) to shut down the electrolyser in the event of a significant downstream pressure loss.

3.4 Separation Distances

Equipment within the WSGGP will be generally arranged following a logical process gas flow. Pipe racks will be provided for routing process piping, providing plant services and electrical and instrumentation routes. Pipe racks will be located close to grade away from vehicle access routes.

The layout of the process equipment shall consider maintenance and access requirements and separation distance requirements to minimise risk of escalation of emergency events.

Utility systems will be co-located outside of hazardous areas wherever possible.

The control room is located within the control hut container which is located on the facility hardstand.

The layout shall consider requirements for the future electrolyser stack and balance of plant piping for the additional 100 Nm^3/h of hydrogen gas production.

An outcome of this report is to determine the required separation distance for equipment with potentially fatal offsite consequences and to ensure such consequences do not extend beyond the site boundary at grade in the vicinity of the general public or adjacent residents or land holders.

3.5 Control of Ignition Sources

Ignition sources are controlled through:

- Design of site and equipment as per Hazardous Area requirements
- Earthing of all equipment to an earth grid
- All electrical equipment having surge diverters installed for protection of the control system
- Adherence to the Permit to Work requirements (including Hot Work permit).
- Prohibiting smoking or naked flames allowed on site and specifying no spark ignition vehicles allowed in designated hazardous areas
- Delineated area with bollards and warning signs, as per Australian Standards requirements

Additionally, a HAZOP action was identified for Jemena to conduct a review to determine if any modifications to their existing ignition control management procedures are required such as antistatic/flame retardant clothing, non-sparking tooling specific to hydrogen and oxygen service.

3.6 Plant Isolation

Emergency shutdown of the facility can be triggered by the following (to be further assessed during detailed design):

- Electrolyser package
  - Gas detection
  - Fire detection
- Remote SCADA ESD push button
- Physical onsite ESD push button
- Greater Horsley Park facility ESD
- Automatic leak detection from high pressure storage compressor
- Emergency shutdown will result in all packages and systems reverting to their fail safe position.

There is no provision for automatic blowdown of the hydrogen storage pipeline due to the short length and limited inventory – pipeline blowdown is via a dedicated manual blowdown vent.

Refer to the WSGGT Control Philosophy, Ref 15.

3.7 Fire Detection and Suppression

The site shall be adequately equipped with fire detection (as per ISO 26142) and compliant to federal and state requirements, local planning conditions and Australian Standards as minimum.

It is assumed no fire suppression is required given the low inventory of fuel gas stored in instrument tubing above ground.

3.8 Fire Prevention – General

Fire extinguishers are provided at the WSGGP facility as required.

The existing Control Building and new Plant Building have been designed following the requirements under the Australian Building Code.

3.9 Prevention from Exposure to Harmful Material

There will be very limited amounts and types of potentially harmful material available at the facility. Nitrogen will be available for equipment purging. Nitrogen can displace oxygen and cause rapid suffocation. Jemena will manage nitrogen use using existing procedures and practices. Compressed natural gas and hydrogen are harmful if allowed to escape, due to their flammability. These risks are well understood and managed by the people performing the maintenance tasks, and procedures and work permit systems are in place. There are also requirements for PPE, such as the use of gloves, safety glasses etc. Further, a Permit to Work system applies on site.

3.10 Bush Fire Protection

The WSGGP facility will be gravelled and kept clear for several metres beyond the site perimeter.

In the event of a bush fire, the hydrogen plant will be remotely shutdown by control room operators.

3.11 Protection in Case of Loss of Services

Supply of hydrogen to customers is not critical; interruption to hydrogen supply will not impose a contractual loss as the facility is for demonstration purposes only.

Electrical power is supplied to the site from the Mains Power Grid. All critical instruments, safety systems, and control systems in the balance of plant will be powered by a DC UPS (Direct Current Uninterruptible Power Supply), powered directly from a battery bank (24V DC). The battery bank will be designed to supply power for critical instrumentation, control and equipment for up to 3 hours for balance of plant equipment. A 0.5 hour uninterruptible power supply (UPS) is used in electrolyser for control/communications and will return instruments to a safe condition so that monitoring of parameters can continue while site is shut down. Backup power will supply lighting of exit signs in enclosures.

Valves will be opened and shut using instrument air or natural gas. In case of loss of power gas to the actuator, the valves will be designed to fail safely (either open or close depending on their duty).

3.12 Prevention of Flooding on Site

Flooding in this area is regarded as a low risk scenario from a land use planning point of view.

The drainage system at the WSGGP will be considered in the detailed design, with suitable hardstand slope and drainage channels to avoid water ponding on site.

3.13 Road Transport Risks

The existing and proposed facilities will be unmanned and require only infrequent vehicular access. Increased site access will be required during facility maintenance activities, including heavy vehicles trips associated with site deliveries. Such activities occur infrequently and risk will be assessed and managed as required.

3.14 Safety Management Systems

Jemena have a commitment to workplace health and safety and have numerous policies and procedures to achieve a safe workplace. Their established safety management system will be applied to this new facility.

An incident reporting and response system is established, providing 24 hour coverage.

The WSGGP Plant will to comply with all codes and statutory requirements with respect to work conditions. Special precautions are observed as required by the site conditions, in particular, standards and requirement on the handling of pressurised, flammable gases. All personnel required to work with these substances are trained in their safe use and handling, and are provided with all the relevant safety equipment. Emergency procedures will be developed and personnel are trained to respond to emergencies. Response plans will be updated to include remote shutdown of hydrogen facility in the event of a fire at a neighbouring facility or in the adjacent bush.

The site will have operations manager with overall responsibility and who is supported by experienced personnel trained in the operation, maintenance and support of the facility.

A Permit to Work system (including Hot Work Permit for any work that could provide an ignition source) and control of modification systems will be in use on site to control work and to control plant and structure from substandard and potentially hazardous modifications. The existing hot work permitting system will be reviewed for hydrogen and oxygen service.

Protective systems are inspected and tested to ensure they are, and remain, in a good state of repair and function reliably when required to do so. This will include scheduled testing of shutdown valves, trips and alarms, and relief devices.

All persons on the premises will be provided with appropriate personal protective equipment suitable for use with the specific hazardous substances.

A first aid station will be provided comprising an appropriate first aid kit and first aid instructions, i.e. Material Safety Data Sheets (MSDS), for all substances kept or handled on the premises.

Refer Safety Management Manual GAS-999-OM-HSE-001 for additional details.

4 Pipeline Integrity & Impacts to Downstream Users

The potential impacts to the distribution network downstream of the injection point at the Horsley Park Trunk Receiving Station have been summarised in Document P2G-2099-RP-RM-004.

This includes the Sydney Secondary Mains distribution network, including the downstream medium and low pressure mains and the downstream industrial commercial and domestic users when:

- Hydrogen of up to 2% (by standard volume), the target injection percentage, is added to the natural gas mixture.
- Hydrogen of up to 10% (by standard volume) is temporarily released into the network. This scenario is only possible during failure of the hydrogen injection flow control valve and coincident low flow of natural into the Secondary Mains. A shutdown has been included in the design to isolate hydrogen injection in the event of low natural gas flow for a predetermined set point to limit volume to less than 10%.

The assessment includes analysis of the impacts of 2-10% hydrogen on the following:

- **Network materials**; including the carbon steel Secondary Mains and downstream polyethylene, nylon, cast iron, and carbon steel low pressure and medium pressure mains.
- **Gas composition & quality**; including assessment against the requirements and limits of AS 4564 and analysis of the change in properties introduced by the blend.
- **Safety**; including impact on gas build-up in buildings, radiation distance and odorisation.
- **Downstream user appliance operation**; including domestic, commercial and industrial cases.

Management of the impacts will be further assessed independently to this report in Jemena's Safety and Operating Plan (SAOP).

5 Study Methodology

5.1 Hazard Analysis Methodology

5.1.1 Introduction

The methodology for the PHA is well established in Australia. The assessment has been carried as per the DP&E's HIPAP No. 4 (Ref 1) and HIPAP No. 6 (Ref 2). These documents describe the methodology and the criteria to be used in PHAs, as required by the DP&E for major "potentially hazardous" development. There are five stages in risk assessment (as per Ref 2):

1. Hazard Identification:

   Review of possible accidents and impacts that may occur based on previous experience, industry research and judgements.

2. Consequences and Impact Analysis

   Define the characteristics of the identified possible accidents and the facility thresholds for each consequence type e.g. jet fire, flash fire, vapour cloud explosion.

3. Frequency Analysis

   Define the probability of the identified possible consequences

4. Risk Analysis

   Define the acceptable risk levels and compare against the determined location specific individual tolerable risk targets.

5. Review Mitigation Options

   Review options for mitigation or management where tolerable limits have been exceeded.

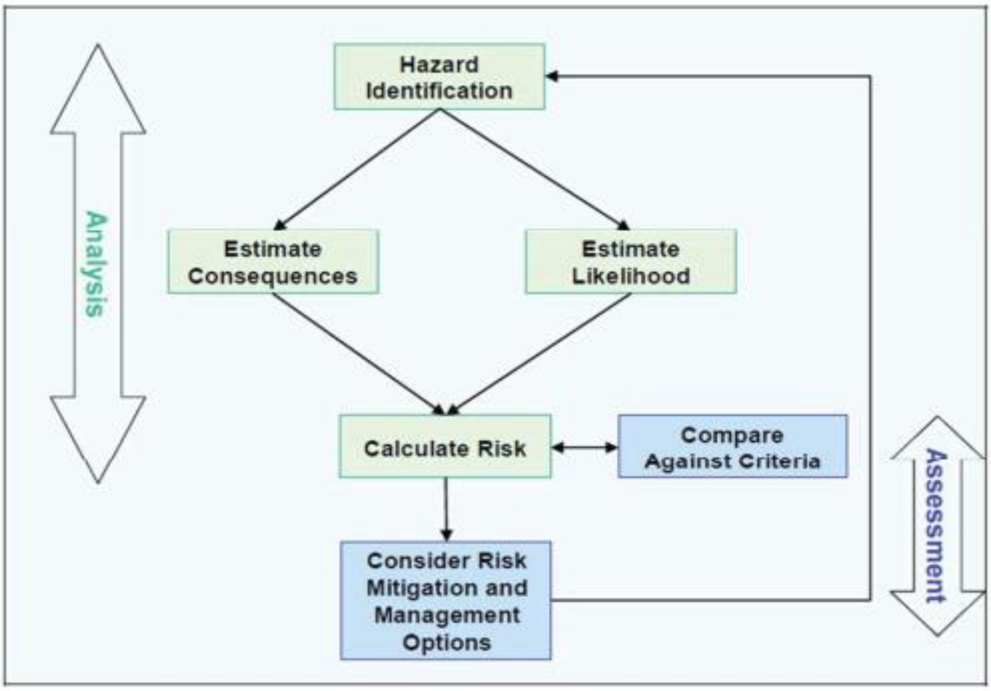


Figure 7: Hazard Analysis Methodology

6 Hazard Identification

6.1 Hazardous Materials

6.1.1 Hydrogen

Hydrogen is flammable over a very wide range of concentrations in air (4 – 75%) and is explosive over a wide range of concentrations (15 – 59%) at standard pressure and temperature. As a result, even small leaks of hydrogen have the potential to burn or result in an explosion. Where leaked hydrogen can accumulate in an enclosed environment, the risk of combustion and explosion is significantly increased. Hydrogen flames are very pale blue and are almost invisible in daylight due to the absence of soot.

The hydrogen molecule is smaller and lighter than that of all other gases, and therefore is highly buoyant in air and diffuses easily. Leaking hydrogen will rise and become diluted quickly, especially outdoors.

Prolonged exposure to hydrogen can affect some materials to compromise their facture and fatigue properties. In particular, carbon steel and other metals can experience hydrogen embrittlement. Hydrogen embrittlement is primarily exhibited by a reduced tolerance to defects, reduction in fracture toughness, loss of ductility and a reduction in fatigue life; this can be accommodated in design by ensuring that materials are defect-free, selecting materials that are more resistant to embrittlement (i.e. stainless steel) by keeping the stress in the material low, and by avoiding cyclic loading. Factors known to influence the rate and severity of hydrogen embrittlement include hydrogen concentration, pressure, the chemical composition of the equipment material, stress level, metal tensile strength, grain size and microstructure (Ref 7).

The storage quantity of hydrogen on site will be approximately 280 kg including the buffer storage and high pressure hydrogen storage.

Table 8: Properties of Hydrogen Gas

Property	Value
Molecular weight (g/mole)	2.02
Relative density of the gas (atmospheric temp. and pressure)	0.07
Heat of combustion (MJ/kg)	119.9
Flammable range (vol. % in air)	4 – 75%
Ratio of specific heats (Cp/Cv)	1.4
Flash point	Gas
Auto-Ignition Temperature	560 °C
UN Number	1971

6.1.2 Natural Gas

The natural gas to be present in the facility is composed predominantly of methane gas (>92 mole %) with the residual mainly ethane (approx. 4 mole %) and carbon dioxide (<2 mole %). The properties of natural gas are represented by methane and are presented in Table 9.

There is no storage of natural gas on site beyond the inventory in the adjacent Horsley Park facility piping and buried EGP transmission pipeline and distribution pipelines.

Table 9: Properties of Methane Gas

Property	Value
Molecular weight (g/mole)	16
Relative density of the gas (atmospheric temp. and pressure)	0.55
Heat of combustion (MJ/kg)	50
Flammable range (vol. % in air)	4.4 to 17
Ratio of specific heats (Cp/Cv)	1.31
Flash point	Gas
Auto-Ignition Temperature	595°C
UN Number	1049

6.1.3 Oxygen

Oxygen reacts with most materials. The higher the oxygen concentration and pressure in the atmosphere or in an oxygen system then:

a) the more vigorously a combustion reaction or fire takes place;
b) the lower the ignition temperature and ignition energy to get a combustion reaction started; and
c) the higher the flame temperature and destructive capability of the flame.

Some materials that do not burn in air, including some fire resistant materials, can burn vigorously in oxygen-enriched air or pure oxygen. Oxygen enrichment of the atmosphere can occur in the vicinity of oxygen vents. Areas near oxygen vents can be particularly hazardous.

In enriched oxygen atmospheres, a common combustible material that most directly affects safety of personnel is clothing. All clothing materials will burn fiercely in oxygen enriched atmosphere. The same applies to plastics and elastomers (Ref 8).

There is no storage of oxygen on site. Oxygen will only be present in the Electrolyser building where it is contained and vented to a safe location above the height of the electrolyser package.

Table 10: Properties of Oxygen Gas

Property	Value
Molecular weight (g/mole)	32
Relative density of the gas (atmospheric temp. and pressure)	1.11
Heat of combustion (MJ/kg)	N/A
Flammable range (vol. % in air)	N/A
Ratio of specific heats (Cp/Cv)	1.4
Flash point	N/A
Auto-Ignition Temperature	N/A

6.2 Hazard Identification

A Hazard Identification (HAZID) and Hazard and Operability (HAZOP) studies were completed on the Balance of Plant FEED on the 25th and 26th July and were attended by representatives from Jemena, GPA Engineering, ANT and Hydrogenics. A subsequent HAZOP to cover the design changes including addition of a hydrogen fuel cell for power generation and natural gas fuel supply source to the Microturbine coming from Jemena's 'back up trucks', until such time that it has been certified for operation using hydrogen as fuel, was conducted on 4th August 2020. This HAZOP also assessed a new design for Hydrogen compression package for filling cylinders. However this aspect of the design in not included for analysis in this report. A subsequent FHA will be prepared and submitted for this aspect of the design when it is required.

Minutes from these workshops can be seen in Appendix 1 and Appendix 2.

The objective of these reviews was to identify all significant hazards associated with a proposed activity with a view to eliminating or reducing hazards though the application of inherent safe design at an early stage of the project.

The methodology used in these reviews is as follows:

- In a facilitated session with subject matter experts, a set of predetermined guidewords is used to prompt the team to identify potential hazardous events
- The potential consequences of the events are then identified – safety, environmental and or financial
- The existing/proposed (in the design) safeguards are identified
- If the safeguards are considered inadequate, further actions are proposed to reduce the risk

Additionally, a layer of protection analysis (LOPA) was undertaken on the following three identified safety instrumented functions to determine if Safety Integrity Levels were required.

- High-High Injection Pressure PAHH-06006 closing XSV-06001.
- High-High gas fuelled generator Hydrogen Fuel Gas Pressure PAHH-03006 closing XSV-03001.
- High Hydrogen Injection protection of the downstream distribution network, detected by FAHH-06007 closing Hydrogen Injection Isolation Valve XSV-06001 via the PLC.

Of these functions, one was assigned a SIL 1 based on safety criteria (FAHH-06007). Details of the study can be found in SIL Study Report P2G-2099-RP-RM-001 (Ref 9). The purpose of this function is to prevent injection in excess of specifications into the natural gas network.

An AS2885 Safety Management Study (SMS) was conducted on the 9th September 2019 for the buffer storage pipeline (Ref 9), meeting the requirements of AS.NZS 2885.6. The SMS catalogued all identified threats to the pipeline and how those threats are to be controlled.

A HAZOP (Ref 11) was conducted by the vendor (Hydrogenics) for the Electrolyser Package on the 9th September 2019. Minutes from this workshop can be seen in Appendix 3.

Other Safety in Design Reviews conducted were:

- 60% Design Review held on 21st October 2019
- 90% Design Review held on 29th November 2019

A HAZOP for the fuel cell package is still planned for 16th September 2020 which will be undertaken by the fuel cell supplier.

The objective of all these reviews was to identify significant hazards associated with the design, with a view to eliminating or reducing hazards through the application of inherently safe design early enough in the process to minimise any impacts on cost and schedule.

The outputs of the hazard studies conducted to date have been summarised in a Hazard Identification Word Diagram which can be seen in Section 6.3.

6.3 Summary of Hazards Identified

The following Hazard Identification Word diagram has been prepared using inputs from the HAZID and HAZOP workshops and equipment vendors:

Table 11: HAZID Word Diagram

Facility Event	Cause/Comment	Possible Results/Consequences	Prevention/Detection Required
Release of flammable gas from pipes, equipment, valves, fittings, tubing	Corrosion (external or internal); flange of valve leak, failure in maintenance procedure	Loss of containment of hydrogen gas. Hydrogen is lighter than air and will disperse into the atmosphere. If ignition occurs there is potential for a fire.	Prevention of corrosion failure or failure due to embrittlement is achieved as follows: • Buried pipe is designed with low design factor and relatively low-strength grade (X52) material to ensure low stress conditions protecting against rupture due to hydrogen embrittlement. This pipe is also coated and has cathodic protection and will have an established integrity management plan. • There is a further action to review requirements relating to hydrogen-assisted fatigue crack growth (HA-FCG), relating to defect inspection, weld defect tolerances, and monitoring etc. • Facility piping is stainless steel, which is less susceptible than carbon steel to hydrogen embrittlement. It is also operating under low stress conditions which will prevent a rupture. • Design and selection of soft components e.g. gaskets, Swagelok, threads, valve internals will be done in conjunction with vendors to ensure hydrogen compatibility. • Hydrogen and Natural gas are clean dry hydrocarbons with a low risk of internal corrosion.
Release of flammable gas during commissioning	Design, material and or construction defects	Loss of containment of hydrogen gas. Hydrogen is lighter than air and will disperse well into the atmosphere. If ignition occurs there is potential for a fire.	All new equipment will be hydro tested. Prefabricated and site installed piping systems will be leak tested with air, nitrogen or helium. Jemena and subcontractor quality control procedures will be applied.

Facility Event	Cause/Comment	Possible Results/Consequences	Prevention/Detection Required
Release of flammable gas due to external impact – above ground equipment	Mechanical damage caused by external impact e.g. vehicle or dropped object	Loss of containment of hydrogen gas. Hydrogen is lighter than air and will disperse into the atmosphere. If ignition occurs there is potential for a fire.	Design will propose a layout which minimises vehicle traffic whilst considering access requirements for maintenance/production etc. A further layout review will be conducted to minimise the potential for vehicle impact. Bollards will be installed where required; specifically there will be a defined exclusion zone around the pipeline risers. Other exclusion zones will be defined and a light barrier installed to demark. The proposed layout will also be reviewed against existing buried services to determine optimum locations for vehicle access to the site. A specific vehicle turnaround access will be provided for water storage tank load-out. Laydown areas for construction will be allocated in development of the layout. Jemena lifting procedures will be applied for any heavy lifts, including requirement to isolate and depressure equipment during lifts if required.
Release of flammable gas due to external impact – buried pipe	Mechanical damage caused by external impact e.g. excavator, vehicle or dropped object	Loss of containment of hydrogen gas. Hydrogen is lighter than air and will disperse into the atmosphere. If ignition occurs there is potential for a fire.	The site is operated by Jemena – any work will be under direct supervision (incl. requirements to consult engineering prior to digging / trenching /placing load on site) and subject to work permits. The buried buffer store pipeline will be installed wholly within Jemena's high security fenceline. Pipeline marker signs indicate the buried pipeline route. Company procedures. Jemena procedures require positive location of the pipeline prior to dig-up, and then restrict the use of mechanical equipment within 500 mm of the pipe wall. Marker tape above buried pipe provides pre-warning in case of digging. The pipe is expected to resist penetration from -Excavators up to 55 t in weight, fitted with general purpose teeth -Excavators up to 25 t in weight, fitted with tiger teeth. For excavators weighing 30 to 55 t using tiger teeth, it is expected that only one tooth will penetrate the pipe.

Facility Event	Cause/Comment	Possible Results/Consequences	Prevention/Detection Required
Release of gas due to propagation from neighbouring plant incident	Bushfire, and knock-on effects from adjacent facilities (this plant is within radiation contour of adjacent facilities). Propagation damage from neighbouring facilities eg thermal radiation, projectiles	Damage to equipment, Hydrogen facility potentially harmed if a pipeline incident occurs, but will not cause escalation beyond the existing risk.	Hydrogen facility will be manually shutdown in the event of a neighbouring facility fire. Emergency response plans will be created/updated to include remote shutdown of hydrogen facility in the event of nearby fire.
Release of flammable gas due to overpressure	PLC error or failure, pressure control failure, operator error.	Loss of containment of hydrogen gas through flanges, fittings, connections, piping. If ignition occurs there is potential for a fire.	Prevention of overpressure is through basic process control and local hardwired trips, independent from the PLC, isolating pressure sources. Piping and equipment are designed with adequate wall thickness and are hydrotested.
Explosion/flash within piping	Human error. Air ingress following commissioning or maintenance.	Explosion/flash within piping	Strict use of nitrogen purging after maintenance to be enforced in hydrogen service, and included in all start-up/re-commissioning operating procedures. Competency based training module will be developed and made a compulsory requirement for hydrogen service operators. A register will be created for management of accredited personnel. Jemena will ensure regular field auditing of procedural activities occurs for the new facility. This will occur more intensively during initial operation.
Fire/Explosion/Incident within Electrolyser Building	Overpressure, corrosion, external impact	Jet fire/explosion within the building	The Electrolyser building is equipment with an exhaust fan which will ensure continuous purging flow through the electrolyser building enclosure. Detection of exhaust fan failure will initiate an ESD in Electrolyser building. Hydrogen gas detectors are also fitted in the building and will initiate an ESD if hydrogen is detected.

Facility Event	Cause/Comment	Possible Results/Consequences	Prevention/Detection Required
Oxygen enriched fire	Loss of containment of oxygen within or from electrolyser building	Loss of containment of oxygen gas through flanges, fittings, connections, piping.	All oxygen vents from the electrolyser are designed to be at a height promoting dispersion and are located at a safe distance from hydrogen vents. A procedure will be created for management of spare parts specific for hydrogen and oxygen service. A HAZID action was recorded for Jemena to contact existing hydrogen/oxygen industries (industrial gases) to further understand specific risks and risk management controls for this application.
Electrical flash/explosion	Arc flash may occur due to electrolyser current discharge. Considered a low risk in this application. Failure of battery on generator or the two UPS's	Personnel injury. Stored energy release if battery fails. Potential for fire/explosion.	The Electrolyser vendor will minimise potential for arc flash in the electrical design. There is a HAZID action to determine if arc flash detection is required and if so to include it in the design. GPA are also reviewing their design regarding arc flash requirements. Jemena and battery vendor management procedures to be applied for battery management. Preventative maintenance work orders to be created for battery inspection/testing.
Malicious damage; theft etc.	Intruders/ vandalism	Damage to equipment	Secure location, away from the roadside, on an existing industrial facility. Signposting will not draw unwanted attention to the facility. Facility will be fenced and locked with authorised personnel entry only signage. Jemena is carrying out an action to review designs from a site security perspective.
Third Party Impact	Aircraft crash / false landing. This site is in vicinity of training area with light aircraft.	Damage, loss of containment, fire.	General aircraft safety regulations make the event of a crash unlikely. The plant has a relatively small footprint making it unlikely to be hit in the event of a crash. Determine if the facility is directly under any new flight paths and potential consequences. Liaise with relevant authorities.

Facility Event	Cause/Comment	Possible Results/Consequences	Prevention/Detection Required
Microturbine Overpressure in turbine	Failure of upstream pressure regulators	Loss of containment of fuel gas. Both fuel sources are lighter than air and will disperse well into the atmosphere. If ignition occurs there is potential for a fire.	Trip on high pressure. Double solenoid isolation at the turbine Maximum pressure from Jemena Trucks is 800 kPag, and generator is rated for 1,000 kPag. The likelihood of exceeding full rating is low.
Microturbine compressor - Small fitting failure	Vibration or fatigue failure of small fittings.	Loss of containment of fuel gas. Both fuel sources are lighter than air and will disperse well into the atmosphere. If ignition occurs there is potential for a fire.	High vibration switches will shut down the microturbine. Small fittings to be designed with minimal weight/load stress and pipe supports. Jemena to implement a routine vibration monitoring program.
Fuel Cell Overpressure	Failure of upstream pressure regulators	Loss of containment of fuel gas. Both fuel sources are lighter than air and will disperse well into the atmosphere. If ignition occurs there is potential for a fire.	Active/monitor PCVs 03004/03012 PIT-03006 closes XSV-03002 on high high pressure, set at 1,000 kPag.

6.4 Scenarios for Consequence Modelling

A number of scenarios were identified in the HAZID and HAZOP studies that could lead to a loss of containment of flammable gasses. The scenarios chosen for consequence modelling are shown in Table 12. The logic for the selection of scenarios is described below:

All above ground pipework in the production and refuelling facilities is 25 mm NB and therefore any leaks are likely to be small. For frequent small releases (level 1) the EI Model (Ref 12) recommends using a hole size of 1mm. However, for conservatism and based on advice from the DPIE, a hole size of 10 mm has been assumed for this assessment. This hole size has been applied for 'pinhole' piping leaks and small flange leaks. A pinhole piping leak is unlikely to be as large as 10 mm due to the controls in place and the small diameter of the above ground equipment, so this is a conservative estimate. A 1 mm hole size was modelled for the refueller dispenser, in addition to the 10 and 15 mm cases.

All piping has been designed to operate in low stress conditions and hydrotested well in excess of the design pressure, therefore rupture or full bore/guillotine failure of piping is not considered credible. However, for conservatism, full bore releases have been modelled for all small bore above ground equipment. This also covers the potential scenario of tube connection pull-out from the compression fitting due to an impact (though this is unlikely with the protections measures, such as bollards, in place,).

Rupture of the buried hydrogen piping is not considered credible due to the low stress conditions and therefore has not been modelled. Similarly, a third party strike on the buried pipeline is not considered credible as it is within the facility boundary fence line and all excavations will be strictly controlled by Jemena. Excavation equipment capable of penetrating the pipeline will not be permitted to be used on the site.

There are two blind flanges (500 mm NB) present on the buried hydrogen storage pipeline risers in the facility. Gasket failures (segment and full) have been modelled. Hole sizes were calculated based on the method described in UK HSE Item FR 1.2.4 Flanges and Gaskets (Ref 13).

The scenarios for consequence modelling can be seen in Table 12 below.

Table 12: Scenarios for Consequence Modelling

Scenario	Location	Substance	Piping / Equipment Size	Causes	Hole Size	Potential Consequence
1 (a) 1(b)	Above ground hydrogen piping and equipment	Hydrogen	25 NB	Overpressure resulting in leak from a flange or valve, corrosion (internal or external); external impact.	10 mm (Flange Leak/Pinhole) 25 mm (full bore)	Potential jet fire or flash fire
2 (a) 2 (b)	Hydrogen piping and equipment within the electrolyser container	Hydrogen	25 NB	Overpressure resulting in leak from a flange or valve, corrosion (internal or external); external impact.	10 mm (Flange Leak/Pinhole) 25 mm (full bore)	Potential jet fire or flash fire, vapour cloud explosion.
3 (a) 3 (b) 3 (c) 3 (d)	Buried hydrogen piping and risers.	Hydrogen	500 NB	Corrosion (internal or external); Third party strike – (considered not credible at this site) Gasket Failure (overpressure, poor installation etc) Note: Rupture case not credible due to design and low stress conditions.	10 mm (Pinhole) 50 mm (excavator strike) 20 mm (Gasket Segment) 78 mm (Full Gasket)	Potential jet fire or flash fire
4 (a) 4 (b)	Above ground natural gas piping and equipment	Natural Gas	25 NB	Overpressure resulting in leak from a flange or valve, corrosion (internal or external); external impact.	10 mm (Flange Leak) 25 mm (full bore)	Potential jet fire or flash fire
5a 5b 5c	Electrolyser hydrogen vent/automatic blowdown Buffer Storage manual vent Underground piping (natural gas) manual vent	Hydrogen Hydrogen Natural Gas		Electrolyser will automatically vent hydrogen following an ESD The buffer storage pipe / underground natural gas piping can be manually blown down to atmosphere via a vent.	DN80 hydrogen vent, 7.4 m height DN50 manual vent, 3.9 m height DN25 manual vent, 4.0 m height	Potential jet fire or flash fire. Note all vents discharge above 1.8 m.
6 (a) 6 (b)	Above ground hydrogen piping and equipment (800 kPag) associated with the Fuel Cell	Hydrogen	25 NB	Overpressure resulting in leak from a flange or valve, corrosion (internal or external); external impact.	10 mm (Flange Leak/Pinhole) 25 mm (full bore)	Potential jet fire or flash fire
7 (a) 7 (b)	Above ground natural gas piping and equipment (800 kPag) associated with the Truck Fuel Supply to Microturbine	Natural Gas	25 NB	Overpressure resulting in leak from a flange or valve, corrosion (internal or external); external impact.	10 mm (Flange Leak/Pinhole) 25 mm (full bore)	Potential jet fire or flash fire

6.5 Credible Hazard Consequences

Due to the properties of natural gas and hydrogen being lighter than air, the most probable consequences have been determined to be as follows:

Jet Fire

A jet fire occurs when a flammable liquid or gas, under some degree of pressure, is ignited after release, resulting in the formation of a long, stable flame. Jet fires can be very intense and can impose high heat loads on nearby plant and equipment but are very directional in nature.

Flash Fire

A flash fire occurs when a cloud of flammable gas mixed with air is ignited. If the cloud is sufficiently large, it is also possible that the flame may accelerate to a sufficiently high velocity for a vapour cloud explosion (VCE) to occur. Though very brief, a flash fire can seriously injure or kill anyone within the burning cloud. Its effects are confined almost entirely to the area covered by the burning cloud. Incident propagation, sometimes called domino effects, can occur through ignition of materials or structures within the cloud.

Explosion

Explosions can occur through a variety of mechanisms, but in each case damage or injury is caused by a pressure wave which is created by rapid expansion of gases. The magnitude of the pressure wave is usually expressed in terms of blast overpressure. However, in order to properly predict the destructive capacity, it is necessary to consider the rate of increase/decrease in pressure as the wave passes. Explosions involving flammable gases are of particular concern in industrial facilities.

Explosions can occur if a mixture of flammable gas and air within the flammable range is ignited. The magnitude of overpressure developed is strongly influenced by factors such as:

- degree of confinement;
- the size of the cloud;
- degree of turbulence;
- the combustion properties of the gas; and
- the location of the ignition source relative to the cloud.

Explosions may also occur as a result of catastrophic rupture of a pressurised vessel, ignition of dust clouds, thermal decompositions, runaway reactions and detonation of high explosives such as TNT. Both blast waves and projectile fragments may result.

7 Consequence Analysis

A set of representative incident scenarios was determined, based on the current design of the WSGGT facility, applicable codes and standards, and engineering practice. These scenarios include a range of hazardous events that have some potential to occur in each area of the facility. In general, these events can be divided into the following categories:

- Moderate releases (punctures) caused by overpressure resulting in a leak from a flange / valve, corrosion (internal or external), flexible hose failure, vibration small fitting failure, etc., characterised by a hole of 10 mm equivalent diameter;
- External impact, characterised by a hole with a diameter equal to the pipe diameter or, for vessels and certain process equipment, a hole with a diameter equal to the diameter of the largest attached pipe;
- Third party strike to the buried hydrogen storage pipeline, characterised by a hole of 50 mm equivalent diameter;
- Gasket failure due to overpressure, poor installation, etc. For the 500 NB buffer storage risers, leaks have been characterised by a hole of 20 mm equivalent diameter for a gasket segment and a hole of 78 mm equivalent diameter for full gasket failure.

7.1 Modelling Software

Consequence analysis was undertaken using the DNV GL process hazard analysis software program Phast (version 8.1). DNV's Phast dispersion modelling software is capable also of modelling the effects of a gas cloud igniting resulting in flash fires, explosions, or jet fires. Based on the specific scenario, Phast can then predict radiation contours from fires and overpressure contours from explosions. The software is based on empirical models, as opposed to theoretical models, and are adjusted and calibrated based on information returned to DNV from partners who provide data following real-world events. The software has also been validated against other models such as:

- Skottene, M., Holm, A., 2008. H2 Release and Jet Dispersion - Validation of Phast and KFX, Report 2008-0073. DNV Research, Høvik, Norway.
- Witlox, H.W.M., et al., Modelling and validation of atmospheric expansion and near-field dispersion for pressurised vapour or two-phase releases, Journal of Loss Prevention in the Process Industries (2017), http://dx.doi.org/10.1016/j.jlp.2017.05.005

Evaluation Techniques

7.1.1 Leak Rates

Phast models the release behaviour for compressed gas releases from vessels and pipelines. Input data includes the type of release, location of release with respect to vessel geometry, pipe lengths etc. and initial conditions of the fluid (i.e. before release). The release rate is assumed to remain constant until isolation can be achieved - this is a conservative approach as in reality there will be pressure reduction due to the limited inventory and hence reduction in leak rate.

7.1.2 Duration

The results in Table 17 are based on continuous release rates. This is conservative as it is noted that in the final system design there will be emergency shutdown and isolation provision designed to detect leaks and isolate the inventory in as short a time as possible.

7.1.3 Dispersion Distances

A gas release will disperse in the atmosphere. A gas is flammable at concentrations between the upper flammable limit (UFL) and lower flammable limit (LFL). For the gases present in the WSGGP facility these limits are:

- Hydrogen: UFL = 75%. LFL = 4%.
- Natural gas: UFL = 15%. LFL = 4.4%.

Phast is used to estimate the distance to which a release of either hydrogen or natural gas will disperse to its LFL based on pressure, velocity and release rate.

7.1.4 Terrain Effects

Ground roughness effects the turbulent flow properties of wind, hence dispersion of a released material. Terrain effects are taken into account to some degree in dispersion modelling by use of a surface roughness length.

The roughness length used for all release scenarios is described as *Regular large obstacle coverage (suburb, forest)* in the modelling software. This corresponds to a surface roughness length of 1 m, appropriate to a plant located in a rural area, with some buildings, trees and fences in the vicinity, as well as some undulation of the surrounding land.

7.1.5 Weather Conditions

Consequence modelling was performed with the weather conditions presented in Table 13. Cases were determined based on weather data from the Australian Bureau of Meteorology (BOM) for the Horsley Park Equestrian Centre AWS for the years 1997-2019.

Table 13: Weather Conditions

Weather Parameter	Case 1	Case 2	Case 3	Case 4
Case Description	Typical Hot Summer Day	Typical Average Spring or Autumn Day	Typical Cold Winter Day	Typical Calm Autumn Day
Wind Speed (m/s)	5.2	3.8	3.0	0.5
Pasquil Stability	A/B	D	F	F
Atmospheric Temperature (°C)	36.7	18.2	2.5	18.3
Relative Humidity (%)	50	56	76	66
Solar Radiation Flux (kW/m^2)	1.2	0.99	0.68	0.93
Surface Temperature (°C)	36.7	18.2	2.5	18.3

Consequences for each weather condition were modelled with results reported for the worst case.

7.2 Heat Radiation and Explosion Overpressures

7.2.1 Modelling Techniques – Heat Radiation – Theory

The effect of impact of heat radiation on people from a jet fire is shown in the table below:

Table 14: Jet Fire Consequences

Radiant Heat Level kW/m²	Physical Effect (dependant on exposure duration)
1.2	Received from the sun at noon in summer
2.1	Minimum to cause pain after 1 minute
4.7	Will cause pain in 15-20 seconds and injury after 30 seconds' exposure (at least second degree burns will occur)
12.6	• Significant chance of fatality for extended exposure. High chance of injury • Causes the temperature of wood to rise to a point where it can be ignited by a naked flame after long exposure. • Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure
23	• Likely fatality for extended exposure and chance of fatality for instantaneous exposure • Spontaneous ignition of wood after long exposure • Unprotected steel will reach thermal stress temperatures which can cause failure • Pressure vessel needs to be relieved or failure would occur
53	• Cellulosic material will pilot ignite within one minute's exposure • Significant chance of fatality for people exposed instantaneously

The effect of impact of heat radiation on people from a flash fire is shown in the table below:

Table 15: Flash Fire Consequence

Criteria	Physical Effect (dependant on exposure duration)
Lower Flammability Limit	Potentially fatal from people in the ignited flammable cloud path. Assume 100% fatal in cloud area.

7.2.2 Modelling Techniques – Explosion Overpressures – Theory

The effect of impact of overpressure on facilities and people are shown in the table below:

Table 16: Overpressure Consequence

Overpressure kPag	Physical Effect
3.5	• 90% glass breakage • No fatality and very low probability of injury
7	• Damage to internal partitions and joinery but can be repaired • Probability of injury is 10%. No fatality
14	• House uninhabitable and badly cracked
21	• Reinforced structures distort • Storage tanks fail • 20% chance of fatality to a person in a building

Overpressure kPag	Physical Effect
35	• House uninhabitable • Wagons and plants items overturned • Threshold of eardrum damage • 50% chance of fatality for a person in a building and 1 5% chance of fatality for a person in the open
70	• Threshold of lung damage • 100% chance of fatality for a person in a building or in the open • Complete demolition of houses

In Phast, the Multi-Energy method is used to predict the overpressures from flammable gas explosions. The key feature of the Multi-Energy method is that the explosion is not primarily defined by the fuel air mixture but by the environment in which the vapour disperses.

Partial confinement is regarded as a major cause of blast in vapour cloud deflagrations. Blast of substantial strength is not expected to occur in open areas. A strong blast is generated only in places characterized by partial confinement while other large parts of the cloud burn out without contributing to the blast effects. The vapour cloud explosion is not regarded as an entity but is defined as a number of sub-explosions corresponding to various sources of blast in the vapour cloud, i.e. each confined part of the cloud is calculated as a separate vapour cloud explosion.

The initial strength of the blast is variable, depending on the degree of confinement and on the reactivity of the gas. The initial strength is represented as a scale of 1 to 10 where 1 represents slow deflagration and 10 represents detonation. For explosions in process plant environments the initial strength is thought to lie between 4 and 7 on the scale.

The Multi-Energy model selected for the electrolyser container was the uniform confined model, with an explosion strength of 10 and an explosion efficiency of 12.5%.

Phast can also perform explosion modelling for the parts of the vapour cloud that do not cover an area of strong confinement. The degree of confinement for the unconfined parts of the cloud must be set and is typically be around 1 (completely unconfined, e.g. open farmland) or 2 (slight confinement, e.g. fences, bunds, or hedges).

For the uncongested plant environment of the WSGGP facility, a user-defined Multi-Energy explosion model was used with the unconfined explosion strength set to 2 and an unconfined explosion efficiency of 100%.

7.2.3 Calculated Jet Fire Dimensions

Flame dimensions will vary depending on the wind weather conditions. Phast calculates the flame dimensions for each wind weather category and the worst case scenario is reported.

7.2.4 Calculated Blast Overpressure Dimensions

For a release of pressurised gas into an unconfined environment the chances of an explosion is extremely small (or of negligible risk).

A vapour cloud explosion is possible however if some degree of confinement is present.

7.3 Population Density

The population density in the area is very low, equivalent to the description of 'Farmland, scattered houses' with a density of 5 persons per hectare (Ref 3). There are a number of residential dwellings on the opposite side of Chandos Road from the facility (approximately 250 m away), but the area most likely to be affected by an incident - that which is adjacent to the facility - consists of vacant land within the Western Sydney Parklands Trust with future use allocated for market gardens and has no permanent residents.

7.4 Consequence Calculation results

Table 17 below summarises the heat radiation and overpressure effects for each of the scenarios modelled. The table indicates whether the specified impacts are expected to exceed the defined site boundaries. Full results overlayed on the site map with the proposed equipment layout can be seen in Appendix 5.

Table 17: Consequence Modelling Results – continuous release rates

Scenario	Release Rate kg/s	Jet Fire Distance m Note 5						Explosion Overpressure Distance m				Flash Fire Note 4 Distance m	Exceeds site?
		Injury Radiation (4.7 kW/m²)	Exceeds site?	Fatal Radiation (12.6 kW/m²)	Exceeds site?	Propagation Radiation (23 kW/m²)	Exceeds site?	7 kPag	Exceeds site?	14 kPag	Exceeds site?		
1a	0.16	8.0	N	7.5	N	7.5	N	n/a	-	n/a	-	13.5	N
1b	0.99	20.5	N	17.5	N	16.5	N	n/a	-	n/a	-	31.0	N
2a Note 1	0.16	7.5	N	6.5	N	5.5	N	19.5 Note 3	N	16.5 Note 3	N	-	-
2b Note 1	0.96	20.0 Note 2	N	17.0 Note 2	N	15.5 Note 2	N	47.0 Note 3	N	39.0 Note 3	N	25.5	N
3a	0.16	11.0	N	7.0	N	5.0	N	n/a	-	n/a	-	2.0	N
3b	3.83	48.5	Y	26.5	N	14.5	N	n/a	-	n/a	-	2.0	N
3c	0.61	20.5	N	12.0	N	7.5	N	n/a	-	n/a	-	3.0	N
3d	9.31	73.5	Y	39.5	N	21.5	N	n/a	-	n/a	-	2.0	N
4a	0.15	6.5	N	6.5	N	6.5	N	n/a	-	n/a	-	-	-
4b	0.94	15.5	N	13.5	N	13.0	N	n/a	-	n/a	-	-	-
5a	0.0025	n/a	-	n/a	-	n/a	-	n/a	-	n/a	-	-	-
5b	0.13	n/a	-	n/a	-	n/a	-	n/a	-	n/a	-	-	-
5c	0.087	n/a	-	n/a	-	n/a	-	n/a	-	n/a	-	-	-
6a	0.04	4.0	N	4.0	N	3.5	N	n/a	-	n/a	-	6.0	N
6b	0.25	10.0	N	9.0	N	9.0	N	n/a	-	n/a	-	16.5	N
7a	0.12	6.0	N	6.0	N	6.0	N	n/a	-	n/a	-	-	-
7b	0.73	14.0	N	12.0	N	11.5	N	n/a	-	n/a	-	-	-

Note 1. Modelled as open air.

Note 2. Container dimensions are 12.19 x 2.44 x 2.9 m (L x W x H) therefore these jet fires will impinge upon the container walls/roof.

Note 3. Explosion overpressure within the container will reach over 70 kPag. Blast assumed to destroy the shipping container it is housed in or lift explosion hatch/hatches. There will be some residual overpressure effects as shown in the table.

Note 4. Distance downwind to LFL at height of interest of 1.8 m (representing average human height). For maximum distance to LFL at any height, refer to raw data in 18667-CALC-002-r0 Appendix 2A.

Note 5. Distances shown are at height of interest of 1.8 m (representing average human height).

7.5 Major offsite Consequences

The scenarios with the greatest consequences are those which have the potential for offsite consequences. In this case, for the continuous release rates modelled, there were no flash fires or fatal radiation levels (*12.6 kW/m^2) for jet fires that extended beyond the site boundaries.

There was one scenario where a jet fire with potential radiation effects at the levels sufficient to cause an injury (4.7 kW/m^2) extended beyond the Jemena boundary fence. For the continuous release rates modelled this was:

- 3d – Full gasket failure of a 500 mm NB flange

An event tree frequency analysis for this scenarios has been conducted to be compared with defined tolerable risk targets, this is further described in Section 8.

Notes:

- Scenario 3B – an excavator strike on the buried buffer storage pipeline has potential injury consequences beyond the site boundary, however due to the controls in place this scenario is considered not credible.
- *Assuming that the heat radiation from a jet fire of 12.6 kW/m^2 will potentially result in an offsite fatality is a conservative approach as it would require extended exposure for a fatality to result as described in Table 14

8 Frequency Analysis

The frequency of an event is the number of occurrences of the event in a specific time period, typically one year. The event tree below shows the possible eventualities for this study for a gaseous hydrogen (GH) release

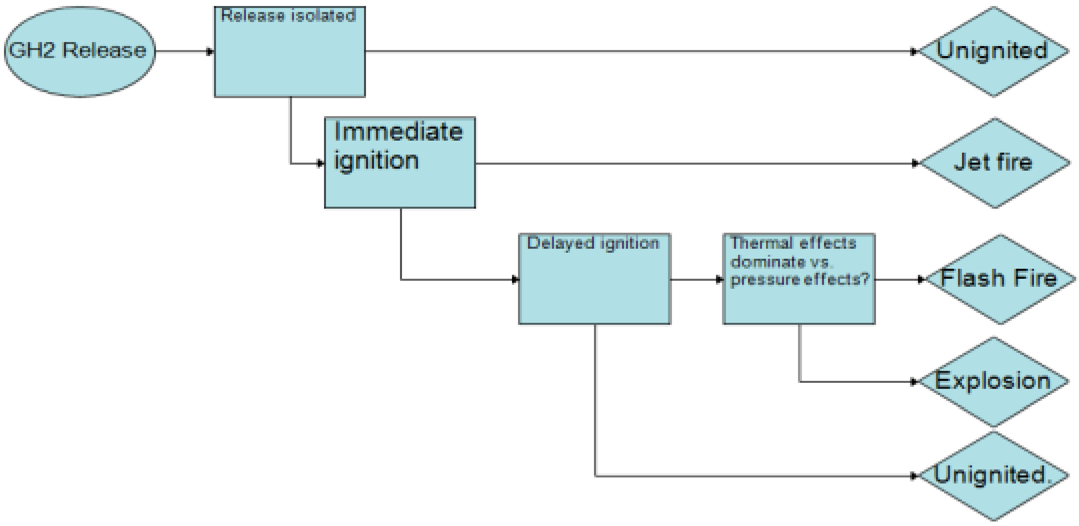


Figure 8: Event tree for gaseous hydrogen release

For any scenarios that have the potential for an offsite consequence, an event tree analysis has been conducted to determine the total individual fatality risk. The total individual risk for the site is the cumulative total of any offsite risks.

$$\text{Risk} = \sum p \times c$$

p = probability of occurrence

c = the consequences associated with each scenario

Assumptions:

Jet fires are directional and only those angled at human height are potentially fatal. For this assessment, only those angled at the site boundary can result in a potentially fatal offsite consequence. It has been assumed that 30% of jet fires could meet these criteria.

Modelling has indicated that due to the open air nature of the facilities and lack of congestion, an explosion is not a credible scenario.

An explosion may be possible within the confines of the electrolyser building only if the ventilation has and an undetected leak occurs resulting in an unignited hydrogen cloud accumulating before igniting resulting in a vapour cloud explosion. In the unlikely event of this occurring, modelling has indicated that the consequences will not extend beyond the site boundaries, and therefore has not been assessed in the frequency analysis.

An equipment parts count has been approximated based on preliminary drawings.

8.1 Failure Rates

The only scenario that required frequency determination, due to potential offsite consequences, was for the 500 NB flanges in place at the buffer storage risers. Failure data from UK HSE was utilised (Ref 13). There are no potential offsite consequences from a partial gasket failure.

Table 18: Leak Frequency Data from UK HSE – for comparison

Component	Release Size	Leak frequency
Flanges 500 NB	20 mm	5×10^{-6}

8.2 Ignition Probability

Ignition probabilities for hydrogen were sourced from data from HyRAM specific for hydrogen (refer to Ref 14).

Table 19: Default Ignition Properties in HyRAM

Hydrogen Release Rate kg/s	Immediate Ignition Probability	Delayed Ignition Probability
<0.125	0.008	0.004
0.125 – 6.25	0.063	0.027
>6.25	0.23	0.12

These were determined from the paper cited in Ref 18.

8.3 Likelihood of offsite effects

8.3.1 Potential Injuries

For the scenario of a jet fire with potential radiation effects at the levels sufficient to cause an injury (4.7 kW/m^2) that extended beyond the Jemena boundary fence, the estimated frequency of occurrence was:

Failure of 500 mm NB Gaskets (full)	7.6×10^{-10}

The probability of this event occurring is 7.6×10^{-10} which is well below the risk target of 50×10^{-6} listed in HIPAP 4. The event tree calculations can be seen in Appendix 4.

8.4 Risk Criteria

8.4.1 Individual Risk Criteria

The risk criterion to be assessed against is defined in HIPAP No. 4 Risk Criteria for Land Use and Planning (Ref 1) shown in Table 20 below.

Table 20: Fatality Risk Criteria

Risk in a million per year	Land Use
0.5	Hospitals, schools, child-care facilities, old age housing
1	Residential, hotels, motels, tourist resorts
5	Commercial developments including retail centres, offices and entertainment centres
10	Sporting complexes and active open space
50	Industrial

All of the offsite risk impacts are in the region on the eastern side that is owned by the Western Sydney Parklands Trust. The adjacent land is primarily used for market gardening and has no permanent residents and therefore is classified as 'active open space areas' which has a tolerable risk target of **1×10^{-5}.**

Propagation Risk

Heat radiation levels of 23 kW/m² and explosion overpressure levels of 14 kPag are considered sufficient to cause damage at neighbouring industrial operations to the extent where further potentially hazardous incidents can occur.

Incidents with these impacts shall not exceed a risk of 50 in a million a year.

Injury Risk

Heat radiation level of 4.7 kW/m² and explosions over 7 kPag are considered to cause injury to the public. Incidents with these impacts shall not exceed a risk of 50 in a million a year in residential and sensitive areas.

8.4.2 Societal Risk Criteria

Societal risk provides estimates of overall risk to the population. Societal risk takes into account whether an incident occurs in time and space with a population by taking into account the size of the population that would be affected by each incident. By integrating the risk by the local population density over spatial coordinates, the global risk for a given accident scenario is obtained. By adding up the several risk functions (one for each scenario), a global risk function is obtained. In order to estimate the number of people affected, the population density outside of the industrial site under review is determined. Therefore, two components are relevant, namely:

- The number of people exposed in an incident, and
- The frequency of exposing a particular number of people.

The Department of Planning have published a set of indicative societal risk criteria (HIPAP 4) as presented in tabular form in Table 21.

Table 21: Interim Criteria for Tolerable Societal Risk, NSW

Number of fatalities (N) [-]	Acceptable limit of N or more fatalities per year	Unacceptable limit of N or more fatalities per year
1	3×10^{-5}	3×10^{-3}
10	1×10^{-6}	1×10^{-4}
100	3×10^{-8}	3×10^{-6}
1000	1×10^{-9}	1×10^{-7}

9 Risk Results

Consequence Modelling has shown that there are no potentially fatal offsite events that can occur as a result of jet fires or flash fires. Similarly there are no heat radiation contours at 23 kW/m^2 necessary for propagation impact any of the neighbouring Jemena equipment.

9.1 Injury Risk Calculations

There was one scenario where a jet fire with potential radiation effects at the levels sufficient to cause an injury (4.7 kW/m^2) that extended beyond the Jemena boundary fence. For the continuous release rates modelled this was:

- 3d – Full gasket failure of a 500 mm NB flange

The probability of this event occurring is estimated at 7.6×10^{-10} is well below the tolerable risk target of 50×10^{-6} listed in HIPAP 4. The event tree calculations can be seen in Appendix 4.

10 Conclusion and Recommendations

There are no potentially fatal offsite individual risks presented by the design of the Western Sydney Green Gas Project Plant. Any risk of potential injury is well below the tolerable risk target for the surrounding land use. It should be noted that none of the credible consequence contours modelled are expected to impact the residential dwellings on the other side of Chandos Road approximately 250 m away from the new facility.

In conjunction with design safeguards listed in this report, Jemena will develop an integrity management plan involving inspection and maintenance of critical equipment as well as upgrading and implementing their safety management system for the site. This will be reflected in an update to the Safety Case GAS-999-PA-HSE-002 and the Asset Management System Manual, JEM-AM-MA-001.

11 References

Ref 1 Department of Planning and Environment. Hazardous Industry Planning Advisory Paper No. 4: Risk Criteria for Land Use Safety Planning. 2011.

Ref 2 Department of Planning and Environment. Hazardous Industry Planning Advisory Paper No. 6: Guidelines for Hazard Analysis. 2011.

Ref 3 Department of Planning and Environment. Assessment Guideline Multi Level Risk Assessment. 2011.

Ref 4 Jemena. WSGGP, Basis of Design. 2019. Rev 3. P2G-2099-DG-DN-001.

Ref 5 Australian/New Zealand Standard™ Gas distribution networks AS/NZS 4645.1:2018

Ref 6 Jemena - Detailed Design for Hydrogen Generation (Western Sydney Green Gas Trial) Downstream Impacts Report GPA Document 18667-S2909

Ref 7 Hydrogen Fuel Cell Engines and Related Technologies: Rev 0, December 2001 Module 1 Hydrogen Properties. https://www.energy.gov/sites/prod/files/2014/03/f12/fcm01r0.pdf

Ref 8 AIGA 005/10: Fire Hazards of Oxygen and Oxygen Enriched Atmospheres

Ref 9 WSGGT SIL Study Report P2G-2099-RP-RM-001

Ref 10 18667-REP-014 Safety Management Study Report

Ref 11 Hydrogenics P195947_Boundary Hazop_Rev.00

Ref 12 EI Model code of safe practice Part 15: Area classification for installations handling flammable fluids.

Ref 13 UK HSE Failure Rate and Event Data for use within Risk Assessments (28/06/2012)

Ref 14 HyRAM 1.1 Technical Reference Manual. KM Groth, ES Hecht, JT Reynolds, ML Blaylock, EE Carrier. Methodology for assessing the safety of Hydrogen Systems: SAND2017-2998. March 2017

Ref 15 WSGGP Control Philosophy P2G-2099-RP-IE-001

Ref 16 HyRAM 2.0: Brian D. Ehrhart, Cianan Sims, Ethan Hecht, Alice B. Muna, Katrina M. Groth, John T. Reynolds, Myra L. Blaylock, Erin Carrier, Isaac W. Ekoto, and Gregory W. Walkup. HyRAM (Hydrogen Risk Assessment Models), Version 2.0. Sandia National Laboratories (4/29/2019); software available at http://hyram.sandia.gov

Ref 17 "Analyses to support development of risk-informed separation distances for hydrogen codes and standards," Sandia National Laboratories, Albuquerque, NM, SAND2009-0874, March 2009 J. LaChance, W. Houf, B. Middleton, and L. Fluer,

Ref 18 A. V. Tchouvelev, "Risk assessment studies of hydrogen and hydrocarbon fuels, fuelling stations: Description and review," International Energy Agency Hydrogen Implementing Agreement Task 19, 2006

Ref 19 Failure Rate and Event Data for use within Risk Assessments (28/06/2012)

APPENDIX 1 BALANCE OF PLANT HAZID

Client	Jemena			Document Title	Document Subtitle	Document No.
Client	-	GPA	18667	HAZOP Minutes		18667-REP-008
Project	Western Sydney Green Gas Trial					

HAZOP Minutes - Overview

Node		Problem Description			Safeguards and Controls		Action			
ID	System / Plant	Guideword	Cause	Consequence	Existing Proposed Safeguards	New Proposed Safeguards	Priority	Responsible	Complete Yes/No	Comments / Notes
H-1	Hydrogen Systems	CHEMICAL ENERGY	Corrosion - internal or external Underground pipeline is carbon steel pipe, which is susceptible to hydrogen embrittlement.	Release of Hydrogen to atmosphere, ignition occurs instantaneously or delayed resulting in a jet or flash fire. Property damage and potential fatality/s	Buried pipe is designed with low design factor and relatively low-strength grade (X52) material to ensure low stress conditions protecting against rupture due to H2 embrittlement. This pipe is also coated and has cathodic protection. Facility piping is stainless steel, which is less susceptible than carbon steel to H2 embrittlement, and is also operating under low stress conditions which will prevent a rupture. As part of the quality management plan, defect testing of the piping and equipment will occur post manufacture. Exhaust fans and H2 gas detectors initiating an ESD in Electrolyser building. Operator clothing will be antistatic and flame retardant.	To further control ignition sources, determine whether non-sparking tooling is required for all maintenance work. Provide training and equipment per specifications. HAZOP action O-4 Review requirements relating to hydrogen-assisted fatigue crack growth (HA-FCG), relating to defect inspection, weld defect tolerances, and monitoring etc.	2	AW		
H-2	Buried Steel	ELECTRICAL ENERGY	Stray currents	Compromised cathodic protection leading to corrosion - including of existing assets.		Consider cross-bonding to existing buried assets. HAZOP action 1-25.				
H-3	Electrolyser	CHEMICAL ENERGY	Mole sieve material passing through into filters - on the electrolyser package.	Loss of performance	Maintenance procedures and operations monitoring.					
H-4	SS Piping	CHEMICAL ENERGY	Dissimilar metals.	Galvanic corrosion.		Include isolation joints in the design.	1	NK		
H-5	Buried Steel	CHEMICAL ENERGY	CP Interference	-	The potential for CP Interference will be mitigate in the CP design. Submission of the new design to the Electrolysis committee is required for approval.					
H-6	Steel	HARM TO PLANT	Hydrogen effects on steel	Embrittlement and fatigue crack growth.	To be susceptible, a combination of three factors is required: presence of (and diffusion of) hydrogen, susceptible material, and stress. The design of piping will be 'no rupture' to ensure that any potential fatigue cracks will not propagate due to the low stress conditions. Material susceptibility is being managed by material selection (compatible with hydrogen), post manufacture defect testing such as hydotest and radiography.					
H-7	Buried Steel	CHEMICAL ENERGY	Soil corrosion - potential for acid sulphate soils.	Corrosion of piping.	Coating and CP of buried pipe.	Procedure for handling of piping and equipment during construction to be created to avoid soil contact. Training of construction personnel is requirements.	2	AW		
H-8	Electrolyser	ELECTRICAL ENERGY	Vents - sparking due to flaps/moving components and velocity.	Ignition of hydrogen when venting.		Design of all vents to be non-sparking.	1	AP		
H-9	Pipeline	ELECTRICAL ENERGY	Vents - sparking due to flaps/moving components and velocity.			Design of all vents to be non-sparking. Use a sock.	1	NK		
H-10	Electrolyser	THERMAL ENERGY	Failure of electrolyser chilling systems- max temp 80°C.	Potential burns to personnel touching pipe.	Electrolyser package will trip on high discharge temperature.					

Client	Jemena			Document Title	Document Subtitle	Document No.
Client	-	GPA	18667	HAZOP Minutes		18667-REP-008
Project	Western Sydney Green Gas Trial					

HAZOP Minutes - Overview

Node		Problem Description			Safeguards and Controls		Action			
ID	System / Plant	Guideword	Cause	Consequence	Existing Proposed Safeguards	New Proposed Safeguards	Priority	Responsible	Complete Yes/No	Comments / Notes
H-11	Electrolyser	THERMAL ENERGY	No low temperature issues. Considered Joule-Thompson, and chiller system harm to personnel (it operates to min. 5°C)							
H-12	Generator	THERMAL ENERGY	Hot components, and exhaust temperatures. Potential for hydrogen attack (on steel components).	Personnel injury, corrosion.	Controlled by design. Cladding will be installed to protect operators. Internal materials are designed to prevent hydrogen attack. Vent stack has air shrouded combustion.					
H-13	Whole site	RADIANT ENERGY	Fire from adjacent facility, or bushfire.	Hydrogen facility potentially damaged if a neighbouring natural gas pipeline incident occurs, but it unlikely to cause an escalation that is beyond the existing risk. There is bushland adjacent to the facility but only 2 trees on site.	In the event of a bush fire or incident at a neighbouring facility, the hydrogen plant will be remotely shutdown.					
H-14	Whole site	ELECTRICAL ENERGY	Battery on generator, and two UPS'.	Stored energy release if battery fails. Potential for fire/explosion.	Jemena and battery vendor management procedures to be applied for battery management.	Preventative maintenance work orders to be created for inspection/testing.	3	AW		
H-15	Electrolyser	ELECTRICAL ENERGY	Electrolyser current discharge.	Arc flash may occur resulting in personnel injury. Considered a low risk in this application.	Low risk. Reviewing design. Arc flash detection? Bus bars may be heavy.	ANT to minimise potential for arc flash in the electrical design. Determine if arc flash detection is required and include in the design.	1	AP		
H-16	Transformer	ELECTRICAL ENERGY	Supplied pad-mount from the grid by electricity supplier.							
H-17	Whole site	ELECTRICAL ENERGY	Ignition of releases.	Fire if loss of containment occurs.	A hazardous area study will be completed. The equipment will hazardous area designed and rated as per report requirements. The existing Jemena permit system will be reviewed for the new application and applied in operation. Equipment will be procured with IecEx compliance suitable for hydrogen. - (International Electro technical Commission System for Certification to Standards Relating to Equipment for Use in Explosive Atmospheres (IECEx System))					
H-18	Whole site	ELECTRICAL ENERGY	Static risks - ignition source for explosive environment. Numerous visitors expected to the site, including media.	Fire if loss of containment occurs.	Anti-static clothing a requirement for anyone entering the site. Mobile phones and other devices that may be potential ignition sources to be managed by Jemena's reviewed permitting system. for this site. No-go / exclusion zones to be marked out e.g. electrolyser building.	Induction process to be created for workers / visitors. Hydrogen gas detectors a requirement for personnel.	3	AW		
H-19	Whole site	ELECTRICAL ENERGY	Mowers, vehicles	Fire if loss of containment occurs.	Jemena's permit to work system Reference XXX	Define exclusion zone around pipeline riser using bollards.	1	SH		

Client	Jemena			Document Title	Document Subtitle	Document No.
Client	-	GPA	18667	HAZOP Minutes		18667-REP-008
Project	Western Sydney Green Gas Trial					

HAZOP Minutes - Overview

Node		Problem Description			Safeguards and Controls		Action			
ID	System / Plant	Guideword	Cause	Consequence	Existing Proposed Safeguards	New Proposed Safeguards	Priority	Responsible	Complete Yes/No	Comments / Notes
H-20	Whole site	CHEMICAL ENERGY	Small leaks.	Loss of product, potential fire. May go undetected.	Hydrogen detectors are located in in the electrolyser building. Detection will trip the electrolyser (confirm). Jemena personnel will be required to wear H2 detectors when entering the site, exclusion zones will be created for areas with a higher potential for leaks of venting. HAZOP action 1-19 Balance of plant design to include use of hoods with gas detectors in locations with multiple fittings and valves. E.g.. gas panel, injection panel, pipeline end connections.	Create leak response procedure for hydrogen leak detection. Add short-term isolation function, which shuts in system for 15 minutes and monitors pressure change during shut-in to detect leak. Include as routine test in operating procedures.	3 1	AW SD		
H-21	Whole site	CHEMICAL ENERGY	Large leaks	Fire	Video cameras reporting to remote control room are a part of the design. Remote shut-down of the facility is available. An ESD button will be available at the entrance gate.	Determine requirements for an infrared camera to be installed on site. Provide Infrared cameras for personnel entering the site. Leak detection to initiate a local beacon/siren. Make siren interlock with gate (so only alarms if someone is there).	3 1	AW SD		
H-22	Whole site	KINETIC ENERGY	Impact from vehicle	Loss of containment.	Design will propose a layout to minimise vehicle traffic considering access requirements for maintenance/production etc.	Conduct further layout review to minimise potential for vehicle impact. Consider all access requirements. Install bollards where required.	1	NK		
H-23	Whole site	NOISE ENERGY	Noise	Residential disturbances/complaints.	A noise study will be conducted in the design phase.					
H-24	Electrolyser	GRAVITATIONAL ENERGY	Working on top of electrolyser package	Fall from height	Jemena working at heights procedures will be applied.	Consider moving maintainable components to the side. Confirm roof railings are provided.	1	AP		
H-25	Whole site	GRAVITATIONAL ENERGY	Soil settlement	Stress on fittings causing leaks.	Tubing flexibility, civil design to consider local conditions.					
H-26	Electrolyser	NATURAL ENERGY	Hailstones	Damage to the cooling fans on the electrolyser roof.		Hydrogenics to advise on requirements for protection from hail damage.	1	AP		
H-27	Electrolyser	NATURAL ENERGY	Lightning	Electrolyser damage.		ANT/Hydrogenics to advise on required protection mechanisms against lightning damaging the electrolyser package.	1	AP		
H-28	Oxygen System	CHEMICAL ENERGY	Oxygen loss of containment.	Oxygen enriched fire in the electrolyser building, from pipework or around vents	Continuous purging flow through the enclosure with exhaust fans.	Hydrogenics to provide input from package HAZOP on management of oxygen risks. Is O2 building analyser included in the package? Confirm SIL rating of exhaust fan failure detection as well as H2 and O2 detection in the building. HAZOP action 3-12 Action for Hydrogenics to identify all feeds to drains. If gas breakthrough can occur in O2 or H2 scrubbers connected to drains, a SIL study will be required on the Low level instrumented functions.	1	AP		

GPA ENGINEERING

Client	Jemena			Document Title	Document Subtitle	Document No.
Client	-	GPA	18667	HAZOP Minutes		18667-REP-008
Project	Western Sydney Green Gas Trial					

HAZOP Minutes - Overview

Node		Problem Description			Safeguards and Controls		Action			
ID	System / Plant	Guideword	Cause	Consequence	Existing Proposed Safeguards	New Proposed Safeguards	Priority	Responsible	Complete Yes/No	Comments / Notes
H-29	Whole site	CONTROLS AND CONTROLLERS	Human error - maintenance activities.	Hydrogen and oxygen services are new to Jemena. Will require some additional training ad new practices.	HAZOP action 1-23 Develop competency based training module for the new facility. Make competency based training a requirement for hydrogen service operators . Create register for management of accredited personnel.	Jemena to contact existing hydrogen/oxygen industries (industrial gases) to further understand specific risks and risk management. Create procedure for management of spare parts specific for hydrogen and oxygen service. Ensure field auditing of procedural activities occurs for the new facility. More intensively during initial operation.	3	AW		
H-30	Whole site	THIRD PARTY HAZARDS	Malicious damage; theft etc. (this has happened before at this location)	Damage	Secure location, away from the roadside, on an existing industrial facility. Signposting will not draw unwanted attention to the facility. Facility will be fenced and locked with authorised personnel entry only signage.					
H-31	Whole site	CHEMICAL ENERGY	Air ingress during commissioning, start up after maintenance	Explosion within piping	HAZOP action 1-22 Strict use of nitrogen purging after maintenance to be enforced in hydrogen service, and included in all start-up/re-commissioning operating procedures. HAZOP action 1-23 Develop competency based training module for the new facility. Make competency based training a requirement for hydrogen service operators . Create register for management of accredited personnel.					
H-32	Whole site	KINETIC ENERGY	Distortion of soft components in hydrogen service e.g. gaskets, swagelock, treads, valve internals	Loss of containment.	Design and liaison with material vendors. Leak detection					
H-33	Whole site	THIRD PARTY HAZARDS	Aircraft crash / false landing. This site is in vicinity of training area with light aircraft.	Damage, loss of containment, fire.	General aircraft safety regulations make the event of a crash unlikely. The plant has a relatively small footprint making it unlikely to be hit in the event of a crash.					
H-34	Whole site	HARM TO HUMANS / BIOLOGY	Cooling water system - legionnaires?		Cooling uses refrigerant, no cooling tower (Hydrogenics to confirm) .					
H-35	Whole site	HARM TO ENVIRONMENT	Prospect reservoir - 1km away. Drains to creek. Only potential effluent is Brine.	Contamination of water ways		Water treatment and disposal options to be reviewed and specified. Consider EPA regulations and minimising harm to the environment.	1	SH		
H-36	Whole site	HARM TO ENVIRONMENT	NG venting through instrument gas system.	negligible contribution						
H-37	Whole site	HARM TO PUBLIC / COMMUNITY	Potential push-back from the consumer community on increased hydrogen in the product.		Jemena public affairs to develop engagement program with the local community and broader consumers.					
H-38	Whole site	HARM TO ADJACENT PROPERTY	Harm to aircraft flying overhead due to released flammable gas cloud during venting of storage pipeline.	Aircraft disturbance		Determine if the facility is directly under any flight paths and potential consequences. Lease with relevant authorities.	2	AW		

GPA ENGINEERING

Client	Jemena			Document Title	Document Subtitle	Document No.
Client	-	GPA	18667	HAZOP Minutes		18667-REP-008
Project	Western Sydney Green Gas Trial					

HAZOP Minutes - Overview

Node		Problem Description			Safeguards and Controls		Action			
ID	**System / Plant**	**Guideword**	**Cause**	**Consequence**	**Existing Proposed Safeguards**	**New Proposed Safeguards**	**Priority**	**Responsible**	**Complete Yes/No**	**Comments / Notes**
H-39	**Whole site**	DOWNSTREAM / UPSTREAM EFFECTS	Electrical generation - synchronisation system	Generator supplies to the grid	Design is compatible with grid supply.					

APPENDIX 2 BALANCE OF PLANT HAZOP

Supplier Document Cover Sheet

GPA ENGINEERING		
	Supplier PO/Contract No:	**4600005082**
	Supplier Item Description:	Engineering Services
	Equipment/Tag No:	n/a

Project Name:	Western Sydney Green Gas Trial (WSGGT)		
Supplier Document Title:	Western Sydney Green Gas Trial HAZOP minutes		
Supplier Document No:	18667-REP-008	**Supplier Rev No:**	1
		Jemena Rev No:	***To be completed by Jemena Document Controller***
Jemena Document No:	P2G-2099-MM-HZ-001	**Total No of Pages (**incl cover page)	33

Document Revision History:

Rev	Issue Date	Key Reason for Issue (as above table)	Approved By/ Signature	Company Name	Notes (if not applicable N/A)
0	12/08/2019	Issued for Use	Luke Jureidini	GPA Engineering	
1	13/08/2020	Issued for Use	Luke Jureidini	GPA Engineering	

Key Reason for Issue:

IFR- Issued for Review	**IFI**- Issued for Information	**IFU**- Issued for Use
IFP- Issued for Purchase	**IFC**- Issued for Construction	**AB**- As Built

GPA ENGINEERING	Document Title				Document No.	
	HAZOP Minutes				P2G-2099-MM-HZ-001	
Client Name	Jemena			Date	04/08/2020	By	MJL
Client Project No.	P2G-2099	GPA Project No.	18667	Rev	1	Chkd	FPL
Project Name	Western Sydney Green Gas Project					QA	LTJ

HAZOP Details - Session 2

Facilitator	Francois Lambrechts
Scribe	Astrid Bealing
Workshop Date	4th August 2020
Workshop Location	Online via Teams
HAZOP Sponsor	Jemena
HAZOP Stage	Detailed Design

HAZOP Participants - Session 2

Name	Initials	Role / Position	Company	AM	PM
Astrid Bealing	AB	Senior Process Engineer	GPA Engineering	X	X
Cameron Ryan	CR	Senior Mechatronics Engineer	GPA Engineering	X	X
Jason Dini	JD	Senior Electrical Engineer	GPA Engineering	X	X
Josh Wickham	JW	Project Manager	GPA Engineering	X	X
Nick Kastelein	NK	Senior Mechanical Engineer	GPA Engineering	X	X
Alistair Wardrope	AW	Technical Lead - Renewable Gases	Jemena	X	X
Andrew MacKay	AM	Prn. Process Engineer	Jemena	X	
Norman Sim	NS	Prn. Mechanical Engineer	Jemena	X	X
Paul Dixon	PD	E&I Technical Officer	Jemena	X	X
Nathan Tickle	NT	Mechanical Technical Offier	Jemena	X	X
Rahul Dorairaj	RD	H&S Advisor	Jemena	X	
Craig Dugan	CD	Chief Executive Officer	Optimal	X	
Mathew Moore	MM		Optimal	X	
Chris Rouse	CRo	Engineering	Coregas	X	X
Wodek Jakubik	WJ	Innovation Manager	Coregas	X	X
Donald Guan	DG	Application Engineer	Ballard	X	

Background

Update: Produced hydrogen gas will either be injected into the existing natural gas distribution network for sale as blended natural gas/hydrogen, used to generate electricity using a gas fuelled generator package and fuel cell or to fill transportable hydrogen cylinders. Initially, however, the gas fuelled generator package will run on natural gas supplied from one of Jemena's "back up" gas trucks until such time that it has been certified for operation using hydrogen as fuel.

The plant includes the following equipment, packages and utilities **additional** to that shown in the overview for Session 1:

- Fuel cell using hydrogen
- Hydrogen compression package for filling cylinders.

The plant will be designed with the following provisions for expansion:

- Electrolyser package, balance of plant piping and natural gas distribution network injection system designed for an additional 500 kW electrolyser stack and associated additional 100 Nm^3/h of hydrogen gas.
- Electrolyser electrical supply designed to be powered via a proposed solar farm adjacent the facility.
- Connection to a proposed future hydrogen refuelling station package from the compression package.

The electrolyser package, including associated cooling and water treatment system, the gas fuelled generator package, fuel cell and hydrogen compression package will be vendor designed packages that will interface with the plant.

A HAZOP (Session 1) has already been conducted on the balance of plant equipment, including the waste water disposal system, hydrogen storage pipeline, natural gas network injection package, and gas panel package, and the plant interfaces to mains water and natural gas distribution network. This HAZOP (Session 2) will cover new balance of plant equipment that has been designed to accommodate new vendor packages being introduced to the project. These new vendor packages are:

- A hydrogen fuel cell
- A hydrogen compression package to fill transportable cylinders.

Detailed P&IDs of the electrolyser package, fuel cell, micro turbine and compressor package (TBC) will be available for reference during the workshop but are excluded from the scope. The HAZOP will consider the interface between these P&IDs and the balance of plant P&IDs prepared by GPA.

Client	Jemena			Document Title	Document Subtitle	Document No.
Client	P2G-2099	GPA	18667	HAZOP Minutes	Node Definitions	P2G-2099-MM-HZ-
Project	Western Sydney Green Gas Project					

Node Definitions

Node	Session	Description	Drawings:	Plant & Equipment:	Instrumentation:	Line Numbers:
1	**S1**	Electrolyser outlet, hydrogen storage pipeline and bypass	P2G-2099-DW-PD-005, P2G-2099-DW-PD-006, P2G-2099-DW-PD-004	EYX-H01001, FG-H03001, FG-H02001	PIT-06015, XSV-06001, PIT-03016, XSV-03001	HG-H01001-SH3D-25, HG-02001-SH3D-25, HG-02001-CH5D-500, G-H02003-SH3D-25
2	**S1**	Electrolyser Package Water Supply	P2G-2099-DW-PD-005	EYX-H01001		PW-H01001-C1TD-50
3	**S1**	Waste Water Disposal System	P2G-2099-DW-PD-005	T-H01002, P-H01001, T-H01001	LSHH-01005, LIT-01004, PI-01001, LIT-01002, LSHH-01003	n/a
4	**S1**	Electrolyser Vents	P2G-2099-DW-PD-005	EYX-H01001		n/a (oxygen vent and hydrogen vent)
5	**S1**	Natural Gas Distribution Network Injection Run	P2G-2099-DW-PD-004	FG-H02001	XSV-06001, PI-06002, FV-06003, PIT-06005, PIT-06006, TIT-06007	HG-06001-SH3D-25
6	**S1**	Natural Gas Distribution Network Withdrawal Run HAZOP NOTE: During the workshop Node 6 and Node 8 were considered simultaneously and recorded against Node 6.	P2G-2099-DW-PD-004, P2G-2099-DW-PD-006	FG-H02001, FG-H03001	XSV-06011, PIT-06008, XSV-03003	G-H02003-SH3D-25, G-H02001-PE HOLD-50, G-H02001-SH3D-25
7	**S1**	Gas Fuelled Generator Package Hydrogen Pressure Regulation Run	P2G-2099-DW-PD-006, P2G-2099-DW-PD-003	GX-H09001	XSV-03001, PI-03003, PCV-03017, PI-03018, PCV-03019, PIT-03006, UT-03007, TE-03007	HG-H09001-SH3D-25, G-H09003-SH3D-25
8	**S1**	Gas Fuelled Generator Package Natural Gas Pressure Regulation Run HAZOP NOTE: During the workshop Node 6 and Node 8 were considered simultaneously and recorded against Node 6.	P2G-2099-DW-PD-005	GX-H09001	XSV-03003, PI-03009, PCV-03020, PI-03021, PCV-03022, PIT-03012, UT-03013, TE-03013	G-H09001-SH3D-25, G-H09003-SH3D-25
8	**S2**	**Hydrogen Fuel Cell Supply Line (review)** **Node 8 will be reviewed during HAZOP Session 2. This node has been repurposed to regulate hydrogen to the target pressure for both the micro turbine and fuel cell.**	**P2G-2099-DW-PD-006, P2G-2099-DW-PD-003**	**GX-H08001**	**XSV-03002, F-03011, PI-03003, PCV-03004, PI-03005, PCV-03012, PIT-03006, UT-03007, TE-03007**	**HG-H03004-SH3D-25, HG-H09001-SH3D-25, HG-H08001-SH3D-25**
9	**S1**	Natural Gas Distribution Network Instrument Gas Offtake	P2G-2099-DW-PD-004	F-HOLD	PCV-06014, PI-06013, PSV-06012	n/a

Node Definitions

Node	Session	Description	Drawings:	Plant & Equipment:	Instrumentation:	Line Numbers:
10	**S1**	Instrument Air Package (HOLD) and Instrument Air Header HAZOP NOTE: During the workshop it was agreed that instrument air be supplied from the electrolyser package instrument air system rather than a separate balance of plant instrument air compressor. Therefore no review of this node was required.	P2G-2099-DW-PD-002, P2G-2099-DW-PD-003, P2G-2099-DW-PD-005	CX-H1001 (HOLD)	PIT-10001 (HOLD)	IA-H10002-CT1D-25, IA-10001-CT1D-25
10	**S2**	**Instrument Air Balance of Plant**	**P2G-2099-DW-PD-005, P2G-2099-DW-PD-006, P2G-2099-DW-PD-003, P2G-2099-DW-PD-007, P2G-2099-DW-PD-008**	**EYX-H01001**	**PCV-03014, PI-03016, PSV-03015**	**IA-H10007-SH3D-15, IA-H03003-SH3D-15, IA-H03005-SH3D-15, IAH07002-SH3D-15, IA-H09004,SH3D-15**
12	**S2**	**Micro turbine natural gas supply line**	**P2G-2099-DW-PD-007, P2G-2099-DW-PD-003**	**n/a**	**n/a**	**G-H09003-SH3D-25, G/HG-H09002-SH3D-25**
13	**S2**	**Hydrogen Compressor package supply line**	**P2G-2099-DW-PD-006, P2G-2099-DW-PD-007**	**n/a**	**XV-03008, F-03010, PI-03009**	**HG-H03006-SH3D-25, HG-H07001-SH3D-25**
14	**S2**	**Hydrogen Compressor discharge line**	**P2G-2099-DW-PD-007**	**n/a**	**PIT-XXXX, XSV-07001, PIT-XXXX**	**HG-H07003-SHXD-25**
15	**S2**	**Electrolyser Nitrogen supply line**	**P2G-2099-DW-PD-007, P2G-2099-DW-PD-005**	**n/a**	**PCV-XXXX, PI-XXXX, PSV-XXXX**	**N-H01010-SHXD-25**

Client	Jemena			Document Title	Document Subtitle	Document No.
Client	P2G-2099	GPA	18667	HAZOP Minutes	Overview	P2G-2099-MM-HZ-001
Project	Western Sydney Green Gas Project					

HAZOP Minutes - Overview

		Problem Description			Safeguards and Controls		Action			
ID	Session	Guideword	Cause	Consequence	Existing safeguard	Action required	Priority	Responsible	Complete Yes/No	Close-out Comments and References
O-1	S1	TOXICITY	Nitrogen leak within electrolyser enclosure.	Nitrogen is an asphyxiant. There is potential to create low oxygen atmosphere.	Continuous ventilation of the enclosure. Ventilation flow meter will stop unit if the ventilation is not working. Nitrogen bottles are located outside the container. Personnel use of low-oxygen gas detectors.	Develop procedures for entering enclosure when the system is shut-down. Consider use of low-oxygen alarm on atmosphere in the electrolyser container.	1 1	AW AW		JEMENA ACTION
O-2	S1	SERVICES REQUIRED	Low light inside enclosure on power failure.	Slip, trip or fall.	Night work not required.	Egress lighting from enclosure supplied from UPS to be provided.	1	AP		Electrical Equipment Room specified to include emergency exit lighting - refer P2G-2099-SP-EL-004. Electrolyser containers proposed to include points for battery-backup Exit lighting as per ANT Variation Request JEM-002A. Exit lighting to be installed by construction contractor.
O-3	S1	SERVICES REQUIRED	Only instrument air users in current balance of plant scope are two small actuated shutoff valves.	Including a balance of plant air compressor may be an unnecessary expense		Facility instrument air to tie into electrolyser instrument air system.	1	AP / SH	YES	Refer P&ID DW-PD-005. Note that air consumption has not been confirmed, so supplementary compression may be required in future, but instrument air tie-in to electrolyser has been provided.
O-4	S1	MATERIALS OF CONSTRUCTION	Underground pipeline is CS pipe, which is susceptible to hydrogen embrittlement.	Loss of containment.	Carbon steel pipeline designed with low design factor and relatively low-strength grade (X52) material to ensure low stress conditions protecting against rupture due to H2 embrittlement. Facility piping is stainless steel, which is less susceptible than carbon steel to H2 embrittlement, and is also operating under low stress conditions which will prevent a rupture.	Review requirements relating to hydrogen-assisted fatigue crack growth (HA-FCG), relating to defect inspection, weld defect tolerances, and monitoring etc.	1	NK	YES	Refer safety management study report, P2G-2099-RP-RM-001, and fatigue crack growth modelling calculation, P2G-2099-CA-PL-001, which utilised the ASME model for HA-FCG.
O-5	S1	MATERIALS OF CONSTRUCTION	Buried piping.		Use of coating and cathodic protection	Determine requirements for cathodic protection (sacrificial anode or cross-bonding to existing lines, TBC)	1	NK	YES	The pipeline will be protected using sacrificial anode cathodic protection. Refer also the Safety Management Study, P2G-2099-RP-RM-001, which provides detail of corrosion control.
O-6	S1	MATERIALS OF CONSTRUCTION	Degradation of soft materials e.g. Swagelok fittings, gaskets, instrumentation from exposure to hydrogen.	Loss of containment.		Confirm compatibility of soft components in hydrogen service (hot-tap O-rings, insulation joints, instrument seals etc.)	1	NK / SD	YES	All tubing components are confirmed by supplier as suitable for hydrogen service. The requirement that soft components be compatible with hydrogen has been included in the project construction SOW and IFT datasheets.
O-7	S1	COMMISSIONING	Contaminated pipeline.	Unable to achieve specified hydrogen purity (particularly for future scope items - fuel cells - where high purity is required)	Initial lower-spec hydrogen can be directed into the natural gas network (due to lower purity requirement).	Prepare commissioning plan for quality, with focus on pipeline cleanliness and dryness.	1	NK		HOLD - commissioning plan to be prepared. High-level requirements are included in the DRAFT construction SOW.

HAZOP Minutes - Overview

		Problem Description			Safeguards and Controls		Action			
ID	**Session**	**Guideword**	**Cause**	**Consequence**	**Existing safeguard**	**Action required**	**Priority**	**Responsible**	**Complete Yes/No**	**Close-out Comments and References**
O-8	**S1**	BREAKDOWN	Loss of power.	Site communications turn off and cannot identify the condition / status of the station. Note that hydrogen supply is not critical; interruption to hydrogen supply is not a contractual loss of supply problem. Demonstration plant only.	0.5 hour uninterruptible power supply (UPS) used in electrolyser for control/communications and will return instruments to a safe condition so that monitoring of parameters can continue while site is shut down.	Install UPS for balance of plant with 2 to 3 h backup time. Include backup power supply to lighting of exit signs in enclosures.	1 1	SD AP		UPS with minimum 2hr battery backup specified - Refer P2G-2099-DS-EL-005. Circuit provided for egress lighting from UPS distribution.
O-9	**S1**	STARTUP / SHUTDOWN	Start-up and shutdown are critical. One of the critical concerns is purging of piping; managing potential for air ingress during maintenance.	Explosion in piping/equipment.		Create competency based training for operators/maintainers and include risks of air ingress during start-up/shutdown. Create start-up and shutdown procedures and include air freeing/nitrogen purging of equipment prior to start-up.	3	AW		JEMENA ACTION
O-10	**S1**	EFFLUENT	Effluent includes Reject water from water treatment plant, Hydrogen and oxygen gasses.	Environmental pollution	Environmental approval plan required to be submitted and approved for the operation.	HAZOP action 3.1: design pre-filtration system to reduce waste water production rate from RO system from 30% to target 1% Sizing basis for on-site water inventory is 5m3 currently. Preferred sizing basis is the duration between load-out and size of load-out truck (e.g. 18 m3). Finalise sizing requirements for input into Environmental Impact Statement. Look at options to reduce water consumption and waste; on-site use optional.	1	SH	YES	Water options study concluded that pre-filtration is not required and waste water generated can be used onsite for irrigation. On-site storage capacity is based on irrigation usage rather than load-out. Refer water options report, P2G-2099-RP-EV-002.
O-11	**S1**	NOISE / VIBRATION	Pumps, vents etc.	Neighbourhood disturbances.	Noise study planned for the site.					
O-12	**S1**	FIRE / EXPLOSION	Hydrogen, oxygen, bushfire, and knock-on effects from adjacent facilities (this plant is within radiation contour of adjacent facilities).	Hydrogen facility potentially harmed if a pipeline incident occurs, but will not cause escalation beyond the existing risk.	Consequence modelling and risk assessment to be completed. Note: no gas or fire detection currently provided in the facility. HAZOP action	Determine if fire detection is required for the site e.g. fusible loops as a result of risk assessment.	1	SH	YES	Fusible loops are not effective for detecting jet fires, which are directional, and so have not been used. Fire detection will not be provided at the facility.
O-13	**S1**	FIRE / EXPLOSION	Loss of containment within electrolyser enclosure.	Fire within enclosure.	Hydrogen detector in the electrolyser enclosure, with control functionality to increase the fan speed for ventilation on low levels of H2 and shutdown on high levels.	Shutdown balance of plant when electrolyser shuts down on safety function (e.g. high hydrogen). Determine if fire detection is required within the electrolyser enclosure.	1 1	SD AP		Cam to close out item Dan K to close out item

HAZOP Minutes - Overview

ID	Session	Guideword	Cause	Consequence	Existing safeguard	Action required	Priority	Responsible	Complete Yes/No	Close-out Comments and References
		Problem Description			Safeguards and Controls		Action			
O-14	**S1**	SAFETY EQUIPMENT	Loss of containment.	Operator approaches plant without knowing there's a leak, potentially introducing an ignition source.	Hydrogen detectors installed in the electrolyser building and planned for the BOP gas panel. Operators to wear personal hydrogen detectors. Control of ignition sources on the site though Jemena's existing management procedures such as hot work permits, antistatic clothing etc. Competency based training for operators.	Install an alarm/beacon at the site entrance gate to alarm on hydrogen detection so that operators do not approach faulted equipment. Determine if any modifications to Jemena's ignition control management procedures are required such as hot work permit system, antistatic clothing requirements, non-sparking tooling.	1 2	SD AW		Cam to close out item Jemena to close out item
O-15	**S1**	QUALITY AND CONSISTENCY	*Leak due to material defect or human error during construction or maintenance.*	Loss of containment.	Jemena's Existing test and tag systems. Commissioning procedures					
O-16	**S1**	OUTPUT – RELIABILITY AND BOTTLENECKS	*Demonstration plant only. Provision for future rate increase is included.*							
O-17	**S1**	EFFICIENCY	*No Causes identified.*							
O-18	**S1**	SIMPLICITY	*No Causes identified.*							
O-19	**S1**	MOBILE EQUIPMENT / PLANT MOVEMENT	Buried services supplying Eastern Gas Pipeline (EGP) site are located in the area of the vehicle turnaround.	Access to buried equipment restricted by new development.		Review layout against buried services. Determine optimum locations for vehicle access to the site. Jemena to provide buried services drawing. Provide vehicle turnaround access for water storage tank load-out. Provide for laydown requirements for construction in development of layout.	1 1 1	AW / NK NK NK	YES	Vehicle turn-around has been designed with consideration of existing buried services. Vehicle route will cross existing services, but new foundations will be clear of existing services. Refer plot plan P2G-2099-DW-CV-001. Water storage load-out is no longer required. Laydown areas are available at rear of facility; construction contractor to finalise layout and construction sequence. Refer construction specification P2G-2099-SW-CN-001.
O-20	**S1**	MOBILE EQUIPMENT / PLANT MOVEMENT	construction traffic	Compromise to existing operations	Construction phase - access to the EGP site required to be maintained during construction.	Include in commissioning plan access plans, laydown areas etc. so as not to disrupt access to existing facilities.	2	MR		HOLD - commissioning plan to be prepared. High-level requirements are included in the DRAFT construction SOW.
O-21	**S1**	PROCESS PLANT NORMAL / ABNORMAL MAINTENANCE	Presence of oxygen causes high flammability of materials.	Unexpected ignition/fire	Specific oxygen-service grease provided by Hydrogenics.	Competency-based training to be reviewed for operators for equipment in oxygen service. Jemena to create management plan for consumables and critical spares - in oxygen and hydrogen service.	1 1	AW AW		JEMENA ACTION
O-22	**S1**	PROCESS PLANT PROCESS FUNCTIONALITY		Value in keeping spares separate to natural gas equipment.		Determine suitable location for spares. Review potential to store spares in site control hut, or existing facility sheds - separate room?	1	AW		JEMENA ACTION

HAZOP Minutes - Overview

		Problem Description			Safeguards and Controls		Action			
ID	**Session**	**Guideword**	**Cause**	**Consequence**	**Existing safeguard**	**Action required**	**Priority**	**Responsible**	**Complete Yes/No**	**Close-out Comments and References**
O-23	**S1**	ERGONOMICS	Electrolyser has a number of filter packages and nitrogen bottles that need to be changed out routinely.			Ensure ease of access and manual handling requirements are accommodated.	1	NK	YES	Ease of access and manual handling has been considered at each design review. Refer minutes of 90% design review, P2G-2099-MM-PM-053.
O-24	**S1**	GUARDING				Demarcate boundary of hazardous area for pipeline flanges (e.g. with Bollards).	1	NK	YES	Hazardous area boundary is 3m from flanges, refer HA classification report: P2G-2099-CA-HA-001. Area demarcated with chin-linked bollards: P2G-2099-CA-HA-001.
O-25	**S1**	WARNINGS	*Unauthorised access to site*	introduction of ignition sources.	Fencing and signage will be provided.					
O-26	**S1**	VULNERABILITY	*Unauthorised access to site* *Demonstration plant has government & media interest.*	introduction of ignition sources.	Access to be managed through permit system.					
O-27	**S1**	3RD PARTY INTERFERENCE	*Unauthorised access to site* *Demonstration plant has government & media interest.*	Theft, plant damage, introduction of ignition sources.	Site security includes line of sight detectors, gate alarms, CCTV (recently upgraded) etc. A separate security assessment will be completed for the site.	Complete site security review	2	AW		JEMENA ACTION
O-28	**S1**	GUARDING	ELECTRICAL: Electrical supply. Electrical equipment is high current.	Jemena technicians for the site are not familiar with electrolyser electrical equipment. Is there potential that stray currents will compromise CP function?		Confirm electrical maintenance requirements w. Hydrogenics/ANT. Determine if additional training is required for electricians. Confirm potential for stray currents to compromise CP system.	1 2 1	AP AW NK		Training in basic electrolyser maintenance will be provided to Jemena personnel as part of the contract with provider, ANT. For all major issues, ANT/hydrogenics will be contracted to complete repairs and maintenance. - Safety management study (P2G-2099-RP-RM-001) considered fault current and other CP electrical effects. No sources of CP interference have been identified.
O-29	**S1**	NATURAL EVENTS	Heavy rains	flooding	Site located at high point. There is a stormwater gully between facility and fence.					
O-30	**S1**	NATURAL EVENTS	Bushfire	Plant damage	A bushfire assessment will be completed for the Environmental Impact Statement EIS					
O-31	**S1**	NATURAL EVENTS	Wind	Debris, hail, branches coming down…		Operators to monitor trees to control risk of branches falling off.	3	AW		JEMENA ACTION
O-32	**S1**	NATURAL EVENTS	Lightning	Plant damage		Lightning review in accordance with AS 1768. Hydrogenics to advise of any lightning protection requirements	1 1	SD AP		Lightning risk assessment P2G-2099-RP-EL-003 completed and issued. It is proposed to earth the process container vents and install lightning rods.
O-33	**S2**	TOXICITY	No new issues identified.							
O-34	**S2**	SERVICES REQUIRED	No new issues identified.							
O-35	**S2**	MATERIALS OF CONSTRUCTION	No new issues identified.							
O-36	**S2**	COMMISSIONING	A number of different packages and equipment need to be commissioned by different parties.	Lack of coordination could lead to delays, incidents and accidents.		Integrated coordination procedure for start up of various packages required.	3	AW		
O-37	**S2**	BREAKDOWN	No new issues identified.							

HAZOP Minutes - Overview

		Problem Description			Safeguards and Controls		Action			
ID	**Session**	**Guideword**	**Cause**	**Consequence**	**Existing safeguard**	**Action required**	**Priority**	**Responsible**	**Complete Yes/No**	**Close-out Comments and References**
O-38	S2	STARTUP / SHUTDOWN	No new issues identified.							
O-39	S2	EFFLUENT	Potential pooling of water locally around the fuel cell bund if the drain from the exhaust is not plumbed to the facility drainage line.	Water pooling in bund or on hardstand around the fuel cell.	Design is not finalised so no safeguards in place.	Confirm expected flow rate quantity from fuel cell and determine whether the waste water line for the fuel cell needs to be connected to the facility vent. If yes, then assess impact to HAZOP.	1	ML		
O-40	S2	NOISE / VIBRATION	Pulsation from compressor leading to failure of tubing.	Loss of containment.	No safeguards identified.	Confirm with vendor what pulsation control/resonance frequencies of the compressor are present and confirm whether a pulsation study/vibration analysis is required on the BOP pipework.	1	ML		
O-41	S2	FIRE / EXPLOSION	Fire at injection panel - unable to isolate instrument gas supply at injection panel.	Fire continues to be fuelled by the natural gas network.	Manual isolation valves at pipeline riser - although may not be accessible in the event of a fire.	A design change request and risk assessment to address the inability to safely isolate the secondary mains is required.	1	TR		
O-42	S2	SAFETY EQUIPMENT	Fire at new packages.	Damage to equipment/injury to operations personnel.	It is unknwon what fire safety equipment will be supplied with the new pacakges or if the vendors believe they will be required.	Confirm what safety equipment is required for the new equipment packages (e.g., fire extinguishers).	1	ML		
O-43	S2	QUALITY AND CONSISTENCY	No new issues identified.							
O-44	S2	OUTPUT – RELIABILITY AND BOTTLENECKS	No new issues identified.							
O-45	S2	EFFICIENCY	No new issues identified.							
O-46	S2	SIMPLICITY	Control complexity as a result of adding fuel cell, microturbine (and potentially) solar array.	Electrical fault as multiple generators are not working together properly. Decouple site from grid due to generation on site resulting in shutdown.	Automatic isolation from grid in the event of unstable generation is included in the design and the safe state.	Microgrid control philosphy to be drafted. Microgrid controller to be incorporated.	1	CR		
O-47	S2	MOBILE EQUIPMENT / PLANT MOVEMENT	Insufficient access for forklift to drive to cylinder cage.	Cylinders cannot be replaced due to insufficient access.	Space for cylinder cage and subsequent access has been allowed for (but may be insufficient).	Review the footprint of the cylinder cage and compressor pacakges once they are included in the 3D model to confirm adequate space has been allowed for forklifts.	1	ML		
O-48	S2	PROCESS PLANT NORMAL / ABNORMAL MAINTENANCE	No new issues identified.							
O-49	S2	PROCESS PLANT PROCESS FUNCTIONALITY	No new issues identified.							
O-50	S2	ERGONOMICS	No new issues identified.							
O-51	S2	GUARDING	No new issues identified.							
O-52	S2	WARNINGS	Inadequate warning signs shown on new package items.	Hazards unknown to operators (e.g. high voltage residual electricty in DC fuel cell bus after shutdown).	No safeguards identified.	Confirm what warning signs will be provided with new packages and which signs are to be added (if not provided, but also in addition to provided signs).	2	ML		
O-53	S2	VULNERABILITY	No new issues identified.							
O-54	S2	3RD PARTY INTERFERENCE	Additional packages will involve additional vehicles requiring access. Vehicles colliding with plant.	Damage to vehicles and plant.	Some traffic bollards have been provided throughout the facility.	Review additional bollard protection/ other traffic management protection requirements with the new pacakges.	1	ML		
O-55	S2	NATURAL EVENTS	No new issues identified.							

Client	Jemena			Document Title	Document Subtitle	Document No.
Client	P2G-2099	GPA	18667	HAZOP Minutes	Nodes	P2G-2099-MM-HZ-001
Project	Western Sydney Green Gas Project					

HAZOP Minutes - Nodes

ID	Session	Guideword	Cause	Consequence	Existing safeguard	Action required	Priority	Responsible	Complete Yes/No	Close-out Comments and References
		Problem Description			Safeguards and Controls	Action				
1-1	S1	HIGH FLOW / LEVEL	High amperage into the electrolyser package.	Design sized for maximum hydrogen production.	Current control and current meters which trigger shut-down of the electrolyser. Stack cannot physically generate more than 200 Nm3/h.					
1-2	S1	HIGH FLOW / LEVEL	Downstream rupture / leak occurs.	Loss of containment of H2 and production continues to atmosphere. Gas pressure decreases as the buffer store inventory depletes.	Back-pressure regulator on electrolyser stack prevents low discharge pressure.	Add trip to PALL-06015 to shut down the electrolyser in the event of rupture (consider pressure rate-of-change trip). Confirm back-pressure regulator on electrolyser stack prevents low discharge pressure.	1 1	SD		Pipeline low-pressure and rate of change trip have been added. Refer P2G-2099-DW-PD-008, tag number PIT-02001 (new). Back-pressure regulator ??? Clarification issued to ANT
1-3	S1	LOW FLOW / LEVEL	Closed or partially closed manual valve (such as H03003 or other downstream valves).	Loss of production. High pressure in the electrolyser and continuous hydrogen venting from the vent stack.	Electrolyser controls current in response to discharge pressure. High downstream pressure would reduce electrolyser settings to minimum turn-down, manual vent will relieve pressure, and finally an electrolyser PSV will relieve hydrogen to protect the electrolyser.					
1-4	S1	NO FLOW / EMPTY	See low flow							
1-5	S1	NO FLOW / EMPTY	Downstream end of pipeline is not flowing in some operating conditions, such as if the valve line-up on the gas panel means that the buffer storage is bypassed.	The downstream end of the pipeline will be a "dead leg".	Pipeline is dry and clean and hence internal corrosion risk is not expected even in zero flow conditions.					
1-6	S1	REVERSE FLOW	Backflow from secondary mains during empty/low pressure conditions of the buffer store.	Natural gas contamination into the hydrogen piping. Hydrogen purity is compromised, which will do damage to any customers using fuel cells or other sensitive technology.	PALL-06015 to XSV-06001 will inhibit injection system from opening if the pressure is less than 1,050 kPag (the MAOP of the secondary mains). Check valve on natural gas injection line.	Jemena's preference is for anti-feedback of NG into H2 is a primary method plus two additional layers of protection. Primary Protection in this case would be from PALL-06015 which closes XSV-06001. Check valve is a layer of protection. Consider second check valve (different type) or closing FV-06003 on PALL-06015 (although not independent to closing XSV-06001) as a second layer of protection. Specify soft seats check valves with zero leak.	1	NK	YES	PIT-02001 now also closes the flow valve, FV-06003. Refer P&ID P2G-2099-DW-PD-004.
1-7	S1	REVERSE FLOW	Rupture / leak or venting of the electrolyser package.	The buffer store is emptied via the electrolyser package.		Add a check valve adjacent H03003.	1	SH	YES	Check valve added on electrolyser outlet, refer drg. P2G-2099-DW-PD-005, (grid reference D8).

HAZOP Minutes - Nodes

		Problem Description			Safeguards and Controls		Action			
1-8	**S1**	HIGH PRESSURE	Locked in gas warms up after being shut in.	The pressure increases, ultimately exceeding the pressure design conditions.	The pipeline will not reach more than 3,500 kPag due to high pressure electrolyser shut-down trips. The piping is designed for 3,800 kPag and hence can handle any thermal pressure increase during shut-in conditions. Pipeline is buried, and hence not subject to short-term heating.	Increase pipeline design pressure from 3,800 kPag to full class 300, and hydrotest to that pressure. DRAFTING NOTE: Correct set-points on PIT-06015	1	NK	YES	The pipeline hydrotest pressure was increased to maximum for class 300 (1.5 x 5.1MPag). However, the design pressure of the pipeline remains at 3,800 kPag. Refer safety management study, P2G-2099-RP-RM-001, and the construction specification, P2G-2099-SW-CN-001.
1-9	**S1**	LOW PRESSURE	Consumption of gas in the buffer store depletes the inventory, e.g. because multiple users take the gas simultaneously.	The buffer store pressure reduces below the minimum pressure for the gas turbine, which is 540 kPag. This will initiate a trip for the gas turbine.	PALL-03016 interlocked to XSV-03001 will prevent use of gas turbine if the inlet pressure to the turbine is below 540 kPag.					
1-10	**S1**	HIGH TEMPERATURE	Electrolyser supplies high temperature hydrogen at discharge due to incorrect operation of the dryer in its recharge cycle.	The pipeline downstream is designed to a maximum of 65°C; potential damage to coatings of other soft components if the temperature is exceeded. Also harm to personnel if they contact piping at high temperatures.	Electrolyser high temperature alarm on each dryer, trip on discharge vessels. TTZ 1160 is a temperature switch set at 80°C, the gas sent to the vent stack will never exceed this temperature, not even during regeneration, this is because heat exchanger X-1156 is present. Length of buried pipeline will allow for cooling to occur.	Determine maximum allowable temperature for the piping. Set electrolyser's high temperature trip to shut down the electrolyser if temperatures exceed maximum allowable for downstream piping.	1	NK / AP		Clarification issued to ANT
1-11	**S1**	LOW TEMPERATURE	Low temperatures may occur after rapid depressurisation of the system. The minimum temperature would occur after depressurisation at minimum ambient temperature.	No significant consequence.	Pipeline minimum design temperature is -10°C, and minimum ambient is -6°C. Thermal mass of steel will prevent low steel temperatures.					
1-12	**S1**	IMPURITIES	Failure / reduction of performance of upstream deoxy / drier systems in the electrolyser skid.	Impure hydrogen is sent to the gas panel, which will damage fuel cells that use the gas.	The electrolyser package has a gas analyser which will vent off-specification gas and control logic to reduce impurities. Set points: O2 = 2ppm, Dew point = -75°C.					
1-13	**S1**	IMPURITIES	Residual debris, water remains in pipeline after the hydrotest.	Required hydrogen purity cannot be achieved. Product off spec, potential damage to fuel cell users.		Prepare a commissioning procedure involving cleaning, drying and purging to achieve required purity.	2	NK		HOLD - Commissioning procedure not written, but high-level requirements have been included in the construction SOW. Refer also O-7

HAZOP Minutes - Nodes

			Problem Description			Safeguards and Controls		Action			
1-14	S1	IMPURITIES	Residual debris, water remains in pipeline after the hydrotest.	Required hydrogen purity cannot be achieved. Product off spec, potential damage to fuel cell users.		Determine need for filtration to be installed downstream near users. To be used as a post commissioning check before selling product.	1	SH	YES	This issue was considered in the design review. Refer minuted discussion from the 90% design review in P2G-2099-MM-PM-053(0), *"Filtration for post-commissioning was discussed. The velocities aren't high and no additional filters are required during commissioning. To remove particulates during normal operation a filter is included on each of the piping runs on the gas panel."*
1-15	S1	CHANGE IN COMPOSITION	*No issues identified*								
1-16	S1	CHANGE IN CONCENTRATION	*No issues identified*								
1-17	S1	REACTIONS	Use of incompatible materials, that fail in hydrogen service.	Failure of materials.	Pipeline designed to "no rupture" and use of low design factor (guidance per ASME B31.12).	Confirm that hot tap and all soft component fittings have hydrogen-compatible materials.	1	JEMENA		JEMENA ACTION
1-18	S1	REACTIONS	Use of incompatible materials, that fail in hydrogen service.	Failure of materials.	Pipeline designed to "no rupture" and use of low design factor (guidance per ASME B31.12).	Sparing philosophy to ensure that natural gas service components are not used in hydrogen system when incompatible.	2	AW		JEMENA ACTION
1-19	S1	TESTING	Hydrogen leaks from fittings.	Flammable mixture forms around fitting.	Personal gas detection, permit to work procedures.	Design to include use of hoods with gas detectors in locations with multiple fittings and valves. E.g. gas panel, injection panel, pipeline end connections. Add short-term isolation function, which shuts in system for 15 minutes and monitors pressure change during shut-in to detect leak. Include as routine test in operating procedures.	1 1	SH SD		Hoods have been added to the design of the gas panels, which include hydrogen detectors. Refer P&IDs: P2G-2099-DW-PD-004 and P2G-2099-DW-PD-006. Hoods are not used at the pipeline risers, which are away from the rest of the facility, adjacent a vent and generate a hazardous area with bollards. Cam / Jason to close out
1-20	S1	TESTING	Regular functioning testing of the gas Pressure Reducing Station PRS results in pressure pulses in the gas line.	Reverse flow into hydrogen system.		PRS testing procedure to be updated to include manual isolation and lock-out of the hydrogen injection line during testing of PRS. Provide manual lockout valve to isolate hydrogen.	1	AW NK		JEMENA ACTION Manual isolation valves provided above-ground at secondary main offtakes. Refer P2G-2099-DW-PD-004.

		Problem Description			Safeguards and Controls		Action			
1-21	**S1**	OPERABILITY / MAINTAINABILITY	Pipeline blowdown for maintenance	Ignition of released hydrogen due to expansion/velocity.		Design venting procedure. E.g. limit velocity, nitrogen dilution at vent, flow control valve, or calculate radiation distance and provide exclusion zone. Include requirements in the shutdown procedure. Also consider noise attenuation as part of blow down system design and consider cross bonding and earthing across all components. Ensure pipework is clearly labelled i.e. H2, CH4, O2 & H2O.	1	SH	YES	Radiation distance was calculated and an RO sized to limit the maximum vent rate to avoid danger to the operator (calculation P2G-2099-CA-PI-003). At 90% design review (P2G-2099-MM-PM-053), it was also decided to include an actuated control valve to allow remote operation and control of the flow-rate. Noise attenuation was considered in noise study and at design reviews and was rejected. This is a non-routine activity and the flow-rate has been limited by inclusion of an RO. Note operators will have control to reduce vent rate also if noise becomes excessive. Vents have been earthed locally, refer earthing drawing P2G-2099-DW-EL-051. Clear labelling of all lines is required in the construction SOW, P2G-2099-SW-CN-001.
1-22	**S1**	OPERABILITY / MAINTAINABILITY	Air ingress after maintenance. Including from incorrectly connected instrument air tubing.	Flammable mixture forms in pipe and ignites. Localised release of hydrogen		Strict use of nitrogen purging after maintenance to be enforced in hydrogen service, and included in all start-up/re-commissioning operating procedures.	3	AW		JEMENA ACTION
1-23	**S1**	OPERABILITY / MAINTAINABILITY	Air ingress after maintenance. Including from instrument air.	Flammable mixture forms in pipe and ignites.		Develop competency based training module for the new facility. Make competency based training a requirement for hydrogen service operators . Create register for management of accredited personnel.	1	AW		JEMENA ACTION
1-24	**S1**	OPERABILITY / MAINTAINABILITY	Potential for a high leak rate at connections, especially large-bore flanged connections.	Loss of containment of product. Wastage of inventory.		Review potential alternatives for mechanical connections on large diameter joins, which may have high leak-rate.	1	NK	YES	Connection types were reviewed. It was concluded that pigability was more important. Mechanical connections have been minimised by using welding but DN500 pipeline flanges have been retained. Refer also safety management study documentation of this issue: P2G-2099-RP-RM-001.
1-25	**S1**	ELECTRICAL	Cathodic protection current on buried pipeline.	Current discharges through the above-ground piping making CP ineffective.	*None identified.*	Consider cross-bonding to existing buried assets. DRAFTING NOTE: mark up connections from pipeline to tubing as isolation joints with surge diverters.	1	NK	YES	Cross-bonding was considered and rejected (JAM-RESTECHQ-000014). The piping will be provided with cathodic protection using a sacrificial anode CP system.
1-26	**S1**	ELECTRICAL	Electrolyser has 200V DC stack. Design for potentials and touch potentials is mitigated by earthing on the electrolyser package.	Discharge through the piping could damage soft components or shock personnel/operators and may cause corrosion over time.	Earthing system design of electrolyser package.	Review putting isolation joints at electrolyser connections to isolate electrically.	1	NK	YES	Per 18667-LIS-003_X Clarification No. 66: Electrical discharge through piping does not require consideration, no insulation gasket is required at the hydrogen nozzle. All piping is to be earthed.
1-27	**S1**	INSTRUMENTS	*No issues identified*							

HAZOP Minutes - Nodes

		Problem Description			Safeguards and Controls		Action			
2-1	**S1**	HIGH FLOW / LEVEL	Downstream rupture.	Continuous flow from the water main. Water accumulates at the leak site, e.g. the utility area in the electrolyser container.	Site water can be isolated at the custody transfer from Sydney water.					
2-2	**S1**	LOW FLOW / LEVEL	Filter blockage.		Filter monitoring and change-out requirements to be specified in water treatment package.					
2-3	**S1**	NO FLOW / EMPTY	Closed valve upstream of electrolyser.	Electrolyser shuts down on low water.	Package trips; about 20 minutes at maximum production between detection and electrolyser shut-down.					
2-4	**S1**	REVERSE FLOW	*No issues identified*							
2-5	**S1**	HIGH PRESSURE	High supply pressure from water mains.	Design pressure for water inlet is exceeded.	High pressure trip on electrolyser inlet line.	Confirm what water network pressure is, and determine the maximum inlet pressure to the electrolyser. Design pressure regulator if required.	1	AW		Daniel to close out
2-6	**S1**	LOW PRESSURE	*No issues identified*							
2-7	**S1**	HIGH TEMPERATURE	*No issues identified*							
2-8	**S1**	LOW TEMPERATURE	Low ambient temperatures.	Below freezing. Potential blockage of pipe while not running overnight.	No history of this occurring in this location. Unlikely and short-term.					
2-9	**S1**	IMPURITIES	*No issues identified*							
2-10	**S1**	CHANGE IN COMPOSITION	*No issues identified*							
2-11	**S1**	CHANGE IN CONCENTRATION	*No issues identified*							
2-12	**S1**	REACTIONS	*No issues identified*							
2-13	**S1**	TESTING	*No issues identified*							
2-14	**S1**	OPERABILITY / MAINTAINABILITY	Material of supply line.			Change to Polyethylene pipe.	1	NK	YES	Polyethylene has been specified, refer drawing P2G-2099-DW-PD-001.
2-15	**S1**	ELECTRICAL	*No issues identified*							
2-16	**S1**	INSTRUMENTS	*No issues identified*							
3-1	**S1**	HIGH FLOW / LEVEL	RO plant malfunction or reduced function (e.g. off-specification water is rejected by water purity or safety function and dumps load of water into reject water system. (Design flow rate is less than 500 L/d) OR - Long duration between load-out of storage tank and hence it accumulates inventory until full.	Tanks are full, initiating overflow and leading to shut-down of electrolyser and loss of production.	LSHH 01004/5 on sump trigger shut-down of electrolyser. LSHH01002/3 on storage tank shut-down pump.	DRAFTING NOTE: Pump on/off wrong way around. High level on storage tank to shut down pump, rather than electrolyser. Conduct review to minimise wastewater production. Design pre-filtration system to reduce waste water production rate from RO system from 30% to target 1% Determine sizing of tanks.	1	SH	N/A	NULL - this node has changed since the HAZOP.
3-2	**S1**	LOW FLOW / LEVEL								
3-3	**S1**	NO FLOW / EMPTY								
3-4	**S1**	REVERSE FLOW	Open DN20 ball valve.	Siphon out tank volume through outlets.		Prevent siphon through inlet by removing internal fill tube.	1	SH	N/A	NULL - this node has changed since the HAZOP.
3-5	**S1**	HIGH PRESSURE	Blocked discharge on pump due to closed valves.			Determine over-pressure requirements on pump to suit pump type; fully-rate piping if possible.	1	SH	N/A	NULL - this node has changed since the HAZOP.
3-6	**S1**	LOW PRESSURE	Low sump level.	Vapour at pump suction / cavitation.		Determine NPSH potential. Size sump so that there is sufficient time for pump to self-prime if required.	1	SH	N/A	NULL - this node has changed since the HAZOP.
3-7	**S1**	HIGH TEMPERATURE								
3-8	**S1**	LOW TEMPERATURE								

HAZOP Minutes - Nodes

		Problem Description			Safeguards and Controls		Action			
3-9	**S1**	IMPURITIES	Debris accumulates in sump or storage tank, such as leaves, dirt or snakes.	Blockage accumulates over time, most likely of sump pump suction line.	Sump and tank have cover (but are still atmospheric).					
3-10	**S1**	CHANGE IN COMPOSITION								
3-11	**S1**	CHANGE IN CONCENTRATION								
3-12	**S1**	REACTIONS	Enriched oxygen or hydrogen environment forms in drain due to gas break-through.	Fire/explosion potential.		Confirm that gas break-through is not feasible from oxygen or hydrogen streams in electrolyser. Action for Hydrogenics to identify all feeds to drains. If gas breakthrough can occur in O2 or H2 scrubbers connected to drains, a SIL study will be required on the Low level instrumented functions.	1	AP	YES	Per 18667-LIS-003_X Clarification No. 67: Breakthrough is not possible since tanks that are open to atmosphere provide a separation between the water line and the process equipment.
3-13	**S1**	TESTING	Requirement to test the level indicators and switches.	Access to tank internals may be required.		Confirm access requirements to get into sump and tank for clean-out, and access to instruments for testing/calibration.	1	NK	N/A	NULL - this node has changed since the HAZOP.
3-14	**S1**	OPERABILITY / MAINTAINABILITY	Connection of suck truck to load-out.	Truck will bring their own hose.		Remove unnecessary hose from storage tank discharge.	1	SH	N/A	NULL - this node has changed since the HAZOP.
3-15	**S1**	ELECTRICAL	*No issues identified*							
3-16	**S1**	INSTRUMENTS	*No issues identified*							
4-1	**S1**	HIGH FLOW / LEVEL	All O2 and all H2 in vents are directed into just two vents. These are 5m apart, and also separated in height by ~1m.	H2 can ignite in the vent when doing deliberate venting (larger volume vented), which does not have significant consequences apart from making noise--receptors are only sensitive to noise at night, generally. A noise study is being completed.		Include ignition noise in noise study.	1	BOS	YES	Noise study completed by Marshall Day Acoustics includes assessment of maximum noise level events (venting of hydrogen, oxygen, and pipeline blowdown). The predicted noise level for these maximum noise level events and the frequency of occurrence are such that no further mitigation action is required. See EIS Appendix I [P2G-2099-RP-EV-001]
4-2	**S1**	LOW FLOW / LEVEL	Proximity of trees to O2 vent.	Potential for fire.		Consequence modelling for oxygen vents to be conducted. Results to include offset requirements to nearby foliage.	1	SH	YES	Trees are well outside the oxygen vent hazardous zone. The trees are on the other side of the control hut. Refer layout P2G-2099-DW-PI-003.
4-3	**S1**	NO FLOW / EMPTY	*No issues identified*							
4-4	**S1**	REVERSE FLOW	*No issues identified*							
4-5	**S1**	HIGH PRESSURE	*No issues identified*							
4-6	**S1**	LOW PRESSURE	*No issues identified*							
4-7	**S1**	HIGH TEMPERATURE	*No issues identified*							
4-8	**S1**	LOW TEMPERATURE	*No issues identified*							
4-9	**S1**	IMPURITIES	*No issues identified*							
4-10	**S1**	CHANGE IN COMPOSITION	*No issues identified*							
4-11	**S1**	CHANGE IN CONCENTRATION	*No issues identified*							
4-12	**S1**	REACTIONS	*No issues identified*							
4-13	**S1**	TESTING	*No issues identified*							
4-14	**S1**	OPERABILITY / MAINTAINABILITY	*No issues identified*							
4-15	**S1**	ELECTRICAL	*No issues identified*							

HAZOP Minutes - Nodes

		Problem Description			Safeguards and Controls		Action			
4-16	**S1**	INSTRUMENTS	*No issues identified*							
5-1	**S1**	HIGH FLOW / LEVEL	Incorrect reading of natural gas flow at the pressure reduction station metering upstream.	Higher hydrogen flows, resulting in high concentrations of hydrogen in the pipeline stream (higher than the upper limit agreed with the technical regulator).	Specified maximum blend percentage is very low so that no expected impact on appliances. Hydrogen disperses very well in natural gas.	Conduct a LOPA/SIL study to determine integrity requirements for flow metering to prevent over injection of H2 into the gas mains. Remove both existing natural gas flow meters and calibrate to within 1% on Jemena meter calibration rig. Put on a PM program.	1 3	SH MR		Refer SIL study report, P2G-2099-RP-RM-001. JEMENA ACTION
5-2	**S1**	HIGH FLOW / LEVEL	During PRS testing there is no gas flow. If there is no gas customer demand and a gas flow instrument error, hydrogen could continue to be injected.	Slug of hydrogen could accumulate in the secondary gas main. Potential for consumer burner flame-out.	Limited hydrogen inventory can be injected in the line due to physical constraints of design. Hydrogen disperses well in natural gas. Gas demand is usually high.	Add low natural gas flow shut-off of hydrogen injection, so that there is a minimum NG flow required to be injecting. Prepare a LOPA for the potential consumer flame-out scenario, determine if any SIL rated instrumentation is required to prevent too much hydrogen injection.	1	SH	YES	Refer low-flow interlock on drawing P2G-2099-DW-PD-004 (grid reference A12). Refer SIL study report, P2G-2099-RP-RM-001.
5-3	**S1**	LOW FLOW / LEVEL	*No consequences identified.*							
5-4	**S1**	NO FLOW / EMPTY								
5-5	**S1**	REVERSE FLOW	*Already covered - ref. node 1*			Close FV-06003 on PALL-06015. Increase low pressure set-point to 1,050 + 10%. Add interlock so that XSV is opened before the FV.	1	SD	YES	Refer P&ID drawing P2G-0299-DW-PD-004; PAL-02001 now closes FV-06003 (tags renumbered). Refer P&ID P2g-2099-DW-PD-008, showing PAL set point of 1,150 kPag. Refer Note 3 on P&ID P2G-2099-DW-PD-004. Other evidence? - Cam to close out

HAZOP Minutes - Nodes

		Problem Description			Safeguards and Controls		Action			
5-6	**S1**	HIGH PRESSURE	Hydrogen pressure is up to 3,000 kPag operating pressure (and 3,800 kPag design).	Hydrogen supply can overpressure the natural gas line.	PAHH-06005 closes FV-06002, and PAHH-06006 closes XSV-06001.	Review overpressure control equipment, with consideration to integrity level achieved and Jemena's existing requirements for JGN.	1	SH	YES	Jemena standard requirements per GAS-999-DG-FA-001 (Section 2.1.6) requires two independent levels of over-pressure protection. PIT-06005 is part of a flow-control loop (so does not strictly count as over-pressure protection), and PIT-06006 and XSV-06001 together constitute an independent layer of protection. There is realistically no chance of overpressure because there is limited inventory upstream which is insignificant to the volume of the downstream system. The overpressure case was considered by the LOPA report within the SIL assessment (refer P2G-2099-RP-RM-001).
5-7	**S1**	HIGH PRESSURE	Slow leak across FV.	Over-pressure downstream tubing.		Move pressure spec. break to downstream manual valve.	1	SH	YES	Refer P2G-2099-DW-PD-004; the spec. break is off the panel where there is a change of material.
5-8	**S1**	LOW PRESSURE	Low inventory	Low injection flow rate	Sizing basis for FV at low-inventory pressures.					
5-9	**S1**	HIGH TEMPERATURE								
5-10	**S1**	LOW TEMPERATURE								
5-11	**S1**	IMPURITIES								
5-12	**S1**	CHANGE IN COMPOSITION								
5-13	**S1**	CHANGE IN CONCENTRATION								
5-14	**S1**	REACTIONS								
5-15	**S1**	TESTING								
5-16	**S1**	OPERABILITY / MAINTAINABILITY	preparation for maintenance			Add vent downstream of panel for double-block-and-bleed.	1	SH	YES	Refer P&ID drawing P2G-0299-DW-PD-004, showing double-block and bleed isolations, in addition to the hot-tap operation isolation, which is buried.
5-17	**S1**	ELECTRICAL	Corrosion			Add isolation joint to secondary main tie-in	1	NK	YES	Refer P&ID drawing P2G-0299-DW-PD-004, showing flange isolation kits on each secondary main tie-in.
5-18	**S1**	INSTRUMENTS	Use of instrument gas.	Complaints from neighbours due to odorant from continuous venting of control valves.	Low flowrate from instruments unlikely to reach neighbouring dwelling.					
6-1	**S1**	HIGH FLOW / LEVEL	Line rupture / leak. (Note Nodes 6 and 8 combined)	Loss of containment. Generator out of operation.	Quality and integrity management.	DRAFTING NOTE: Change PCVs to fail open.	1	SH	YES	Refer drawing P2G-0299-DW-PD-004.
6-2	**S1**	LOW FLOW / LEVEL	Pressure drop through second regulator may reduce discharge pressure below 700 kPag. (Sensor line currently between the two regulators)	Low flow conditions due to excessive pressure reduction across regulator arrangement.	Regulators to be designed for active-monitor arrangement to achieve 700 kPag min downstream.	DRAFTING NOTE: Active and Monitor labelled wrong way around.	1	SH	YES	Refer drawing P2G-0299-DW-PD-004.
6-3	**S1**	NO FLOW / EMPTY	Expected future operation to take line out of service but leave gassed up.	Dead legs.	Use of SS and PE.					
6-4	**S1**	REVERSE FLOW	Future tie-in of hydrogen.	Potential for hydrogen/NG mixing in line.	The generator will be fuelled by hydrogen or natural gas not blends. P&ID note added: Positive isolation will be provided in future case. The drawings will be updated with an MOC to show positive isolation of the gas line once hydrogen fuel is available.					

HAZOP Minutes - Nodes

		Problem Description			Safeguards and Controls		Action			
6-5	**S1**	HIGH PRESSURE	Regulator failure.	Overpressure of the inlet to the generator.	Active-monitor arrangement; regulators fail closed. Maximum pressure from upstream is 1,050 kPag (10% above transient is possible), and generator is actually rated for 1,000 kPag. The likelihood of exceeding full rating is low.	Check with manufacturer to test and re-rate/certify to 1050kPa	1	SH		Dan / Sam to discuss
6-6	**S1**	LOW PRESSURE	Reduced operating pressure in the secondary main.	Generator inlet pressure too low.	Generator will trip at low supply pressure.					
6-7	**S1**	HIGH TEMPERATURE	*No issues identified*							
6-8	**S1**	LOW TEMPERATURE	*No issues identified*							
6-9	**S1**	IMPURITIES	Nitrogen purging.	Nitrogen flow back into NG network.	Check valve at offtake.					
6-10	**S1**	CHANGE IN COMPOSITION	*No issues identified*							
6-11	**S1**	CHANGE IN CONCENTRATION	*No issues identified*							
6-12	**S1**	REACTIONS	*No issues identified*							
6-13	**S1**	TESTING	*No issues identified*			Critical function testing of ESD valves will be required. Create PMs	3	AW		JEMENA ACTION
6-14	**S1**	OPERABILITY / MAINTAINABILITY	*No issues identified*			DRAFTING NOTE: Add bleed to secondary main offtake to form double-block-and-bleed, and upstream of turbine.	1	SH	YES	Refer P&ID drawing P2G-0299-DW-PD-004, showing double-block and bleed isolations, in addition to the hot-tap operation isolation, which is buried.
6-15	**S1**	ELECTRICAL	*No issues identified*							
6-16	**S1**	INSTRUMENTS	Flow metering does not require temperature correction.	Opportunity to simplify.	Temp data is available from the outlet of PRS if correction is required.	Remove temperature element.	1	SH	YES	Not applicable after implementation of design change, refer design change request DCR-001.
8-1	**S2**	HIGH FLOW / LEVEL	Leak from downstream valve left open or fitting not tightened properly following maintenance.	Uncontrolled release of hydrogen leading to potential explosion.	Panel gas monitor QAH-03013 warning of hydrogen detection.	Jemena to ensure that operator training includes raising awareness of the risks associated with leaving valves open, or not closing them properly, on hydrogen systems. Jemena also to ensure that Jemena procedures for leak testing of flanges be reviewed to ensure they are appropriate for hydrogen service, given the small molecule, and risk of leaks.	3	AW		
8-2	**S2**	HIGH FLOW / LEVEL	Failure of PCV.	Damage to filter due to excessive flow/pressure drop. Potential overpressure on some piping components.	Double PCV-03004/03012 (active/monitor). PIT-03006 closes XSV-03002 on high high pressure, set at 1,000 kPag. Line and equipment designed for flow to two consumers: microturbine and fuel cell (i.e., designed for flow that is higher than just flow to fuel cell).	Confirm failure action of PCVs, i.e., both open, both closed, or one open and one closed. (Review decision following potential changes due to close out of action 8-4.) If agreement is that both fail open, confirm filter pressure drop will not lead to damage, and downstream piping components can handle resultant pressure.	1	GPA		
8-3	**S2**	LOW FLOW / LEVEL	Refer to previous note in Session 1 (Item 6-2).							

HAZOP Minutes - Nodes

		Problem Description			Safeguards and Controls		Action			
8-4	**S2**	LOW FLOW / LEVEL	Blocked filter F-03011 on gas panel. Blocked filter in fuel cell package. Blocked orifice in FE-0007. PCV not operating properly. Low instrument air pressure causing partial closure of XSV, restricting flow.	Permanent damage to fuel cell, potentially leading to fire (worse case) and hydrogen release.	Fuel cell has low pressure protection but no low flow protection. Unlikely that filters will block after commissioning and the team does not want to add online DP monitoring. Low instrument air pressure was not considered a major cause of restriction, as XSV will shut, albeit slowly.	Confirm PCV active/monitor order. Also consider one stage, two stage pressure cut and sensing lines. (Jemena used to seeing monitor upstream of active.) Confirm lower flow rate limit of hydrogen to fuel cell.	1 1	GPA DG		
8-5	**S2**	NO FLOW / EMPTY	Refer to previous note in Session 1 (Item 6-3).	Refer to previous note in Session 1 (Item 6-3).	For maintenance purposes panel will be taken out of service and lines depressurised.	When developing operating procedures, appropriate procedures for purging and re-commissioning to be included in operating procedures.	2	AW		
8-6	**S2**	REVERSE FLOW	In the event of stack failure in the fuel cell it is theoretically possible to have flow of air back to the turbine.	Flame out at turbine.	Requires multiple independent failures: - Stack membrane failure - Fuel cell low hydrogen pressure - No flow of hydrogen from upstream. Not deemed credible by the team. Air would be under low pressure.	No action required.				
8-7	**S2**	HIGH PRESSURE	Refer to previous note in Session 1 (Item 6-5).	Refer to previous note in Session 1 (Item 6-5).	Note addition of PIT-03006 with high pressure shutdown of XSV. PCV may not fail close.	Due to addition of high pressure trip, no further action required.				
8-8	**S2**	LOW PRESSURE	No new issues raised.							
8-9	**S2**	HIGH TEMPERATURE	No new issues raised.							
8-10	**S2**	LOW TEMPERATURE	No new issues raised.							
8-11	**S2**	IMPURITIES	Iron oxide dust from buffer store.	Contamination of stack within fuel cell.	F-03011 with 5 micron mesh. Additional filter within fuel cell package.	Confirm maximum allowable load of impurities and requirement of filter (size and type).	1	DG		
8-12	**S2**	IMPURITIES	Nitrogen left in the system following purging operations, or bleeding in through passing valve/fitting.	Reduction in purity of hydrogen to fuel cell.	Operating procedures.	Operating procedures to address activities and risks during start-up, shutdown, nitrogen purging, isolation, and venting. Procedures also to consider including integrity check of piping using local hydrogen detection (hand held devices would be required).	3	AW		
8-13	**S2**	CHANGE IN COMPOSITION	No new issues raised.							
8-14	**S2**	CHANGE IN CONCENTRATION	No new issues raised.							
8-15	**S2**	REACTIONS	No new issues raised.							
8-16	**S2**	TESTING	No new issues raised.		NOTE: Microturbine is a Type B appliance with predetermined associated testing and procedures. Optimal will apply for Type B certification of fuel cell.					
8-17	**S2**	OPERABILITY / MAINTAINABILITY	Lack of signed electrical isolation points for safe isolation.	Electrocution and personnel injury/death.	None identified.	Add appropriate weatherproof signage at the required locations to warn of risk of electrocution and to identify appropriate isolation locations.	2	AW		
8-18	**S2**	ELECTRICAL	Electrical package information not available to GPA/Jemena.	Uncertainty in the design with potential for something to be missed.	Internal HAZOPs will be held by Optimal with invites to GPA and Jemena representatives.	No further action required.				

HAZOP Minutes - Nodes

		Problem Description			Safeguards and Controls		Action			
8-19	**S2**	INSTRUMENTS	No remote pressure indication between PCV-03004 and 03012.	If the PCV arrangement and operation is changed, intermediate pressure monitoring may be required, else the protection system may not function properly, leading to overpressure events missed.	None identified.	When reviewing the arrangement of the PCVs (see action 8-4), review overpressure protection is adequate and instruments added/changed, if required.	1	GPA		
9-1	**S1**	HIGH FLOW / LEVEL	PSV-06012 remains open.	Continuous venting. This PSV is instrumentation type; due to continuous acting, they can release frequently. Neighbourhood complaints due to odorant.	Operator rounds	Maximise difference between PCV and PSV set-points to minimise potential for unintended PSV opening. Identify re-seating pressure for PSV from manufacturer, search for PSV with lower re-seat pressure	1	SH		Vendor has advised (see response to 18667-S6916) PCV set pressure of 580 kPag and PSV set pressure of 700 kPag – PSV set pressure is 20% greater than PCV set pressure which is considered acceptable.
9-2	**S1**	LOW FLOW / LEVEL	Blocked filter.	Low flow resulting in actuated valves closing.	Routine maintenance. Bypass around filter to continue IG services during change-out.					
9-3	**S1**	NO FLOW / EMPTY	Closure of upstream manual isolation valves (e.g. future case of not using the natural gas supply any more)	Instrument gas cut off, and hence fail closed of injection valves.	No consequence of loss of injection.					
9-4	**S1**	REVERSE FLOW	*No issues identified*							
9-5	**S1**	HIGH PRESSURE	PCV-06014 stops closing properly due to particulates accumulating in the seals.	Potential overpressure downstream.	PSV-06012 protects from over-pressure. Gas is sales gas. Filter installed upstream.	DRAFTING NOTE: Mark fail state of PCV Confirm need for PSV, as IG components may be fully rated.	1	SH	YES	Actuator design pressure is 790 kPag for XSV-06001/XSV-06011 therefore PSV is required for overpressure protection. PSV set pressure of 700 kPag as per vendor advice (ref. email 18667-R5610).
9-6	**S1**	HIGH PRESSURE	Transient high pressure due to operational checks upstream.		PSV-06012 protect from over-pressure.					
9-7	**S1**	LOW PRESSURE	Low supply pressure of network.	Lose IG supply, and valves fail closed.	No consequence of loss of injection.					
9-8	**S1**	HIGH TEMPERATURE	*No issues identified*							
9-9	**S1**	LOW TEMPERATURE	*No issues identified*							
9-10	**S1**	IMPURITIES	*No issues identified*							
9-11	**S1**	CHANGE IN COMPOSITION	*No issues identified*							
9-12	**S1**	CHANGE IN CONCENTRATION	*No issues identified*							
9-13	**S1**	REACTIONS	*No issues identified*							
9-14	**S1**	TESTING	*No issues identified*							
9-15	**S1**	OPERABILITY / MAINTAINABILITY	-			Change bypass and isolation needle valves for ball valve.	1	SH	YES	Refer drawing P2G-0299-DW-PD-004.
9-16	**S1**	ELECTRICAL	*No issues identified*							

HAZOP Minutes - Nodes

		Problem Description			Safeguards and Controls		Action			
9-17	**S1**	INSTRUMENTS	Upstream connection has ball and needle.	Simplify.		Change to just a ball valve. Change vents to ball valve w. ventable plug for all natural gas service lines.	1	SH	YES	Refer drawing P2G-0299-DW-PD-004.
7-1	**S1**	HIGH FLOW / LEVEL		(note: micro turbine has not been run in the field off H2 before; control philosophy maybe to control to downstream exhaust temperature)		DRAFTING NOTE: Change PCVs to fail open. The control system of the micro-turbine may react differently when the fuel is changed from Natural Gas over to Hydrogen (different burn and product characteristics) therefore the vendor needs to confirm that a high flow scenario cannot occur, where the fuel control valve demands more fuel than the turbine requires .	1	SH	YES	Refer drg. P2G-2099-DW-PD-006.
7-2	**S1**	LOW FLOW / LEVEL	Blocked filter.	Low flow, restricted supply to generator and reduced output.	Unlikely due to cleanliness requirements of service.	DRAFTING NOTE: Change name of active and monitor.	1	SH	YES	Refer drg. P2G-2099-DW-PD-006.
7-3	**S1**	NO FLOW / EMPTY	*No issues identified*							
7-4	**S1**	REVERSE FLOW	Purge nitrogen migrates back to storage pipeline.	Off-specification H2.		Start-up procedures to ensure purging pressure is below the hydrogen storage pressure.	1	AW		JEMENA ACTION
7-5	**S1**	REVERSE FLOW	-			DRAFTING NOTE: Remove check valve.	1	SH	YES	Action no longer relevant after design change, documented in design change request DCR-001.
7-6	**S1**	HIGH PRESSURE	Blocked discharge OR PCVs fail open.	Overpressure of the inlet to the generator.	Active monitor pressure regulation arrangement (PCV 03017, 03019) and PAHH-03006 controlling XSV-03001.	DRAFTING NOTE: Electrical signal should come off PAHH, not PI block. Move design pressure change to downstream manual valve. LOPA assessment required for pressure protection function.	1	SH	YES	Electrical signal take off updated. Design pressure change moved to downstream manual valve. LOPA assessment completed (SIF 3 in P2G-2099-RP-RM-001), SIL not required.
7-7	**S1**	LOW PRESSURE	*No issues identified*							
7-8	**S1**	HIGH TEMPERATURE	*No issues identified*							
7-9	**S1**	LOW TEMPERATURE	*No issues identified*							
7-10	**S1**	IMPURITIES	*No issues identified*							
7-11	**S1**	CHANGE IN COMPOSITION	*No issues identified*							
7-12	**S1**	CHANGE IN CONCENTRATION	*No issues identified*							
7-13	**S1**	REACTIONS	*No issues identified*							
7-14	**S1**	TESTING	*No issues identified*							

HAZOP Minutes - Nodes

		Problem Description			Safeguards and Controls		Action			
7-15	**S1**	OPERABILITY / MAINTAINABILITY	*No issues identified*			Provide connections and layout for future expansion adding second generator.	1	NK	YES	Generator supply line is isolatable. Tubing run to future generator can be implemented easily, no specific offtake is provided. Refer drg. P2G-2099-DW-PD-003.
7-16	**S1**	ELECTRICAL	*No issues identified*							
7-17	**S1**	INSTRUMENTS	*No issues identified*			DRAFTING NOTE: Remove thermowell reference, retain 'TE'.	1	SH	YES	Refer P2G-2099-DW-PD-006.
10-1	**S1**	HIGH FLOW / LEVEL	Supplied from electrolyser package. IA / IG. No longer required.							
10-2	**S1**	LOW FLOW / LEVEL								
10-3	**S1**	NO FLOW / EMPTY								
10-4	**S1**	REVERSE FLOW								
10-5	**S1**	HIGH PRESSURE								
10-6	**S1**	LOW PRESSURE								
10-7	**S1**	HIGH TEMPERATURE								
10-8	**S1**	LOW TEMPERATURE								
10-9	**S1**	IMPURITIES								
10-10	**S1**	CHANGE IN COMPOSITION								
10-11	**S1**	CHANGE IN CONCENTRATION								
10-12	**S1**	REACTIONS								
10-13	**S1**	TESTING								
10-14	**S1**	OPERABILITY / MAINTAINABILITY								
10-15	**S1**	ELECTRICAL								
10-16	**S1**	INSTRUMENTS								
10-17	**S2**	HIGH FLOW / LEVEL	Regulator failure.	Increased pressure in system.	PSV at accumulator set at 1000 kPag (within electrolyser package) - see action 10.21, however. PSV-03015 at gas panel package set at 700 kPag.	No further action required.				
10-18	**S2**	LOW FLOW / LEVEL	Regulator failure.	All valves will close on loss of instrument air pressure (fail closed valves). No failures of equipment expected purely due to closed valves; however, could lead to uncontrolled shutdown of the facility with unexpected and unpredictable consequences.	Fail closed position of all valves considered the plant fail safe mode.	Add a low pressure alarm on instrument air system (either a new instrument, or reusing an existing instrument within ANT package) and discuss with Jemena the required response to this alarm. During assessment, review the interaction with the injection system, which has a separate instrument gas supply and may, therefore, remain on line while the rest of the facility shuts down.	1	GPA DK		
10-19	**S2**	NO FLOW / EMPTY	As above for low flow.							
10-20	**S2**	REVERSE FLOW	Instrument air only supplies instruments and not the process. No downstream source of pressure and therefore no reverse flow possible.							
10-21	**S2**	HIGH PRESSURE	Failure of air compressor discharge overpressure protection.	If PSV on accumulator not sized for compressor discharge flow, high pressure can damage instruments downstream, particularly valve actuators	None identified (although it is expected that the compressor will have a discharge PSV, but set pressure is unknown).	ANT to confirm overpressure protection provided (e.g., PSV on compressor discharge), as well as buffer tank PSV sizing basis.	1	ANT DK		
10-22	**S2**	LOW PRESSURE	As above for low flow.							
10-23	**S2**	HIGH TEMPERATURE	Air compressor has after cooler and dryer. Failure of these.	High air temperature could damage some instruments	None identified.	Confirm maximum temperature of air from instrument air package within electrolyser and confirm over temperature protection provided.	1	ANT DK		

HAZOP Minutes - Nodes

		Problem Description			Safeguards and Controls		Action			
10-24	S2	LOW TEMPERATURE	No issues identified.							
10-25	S2	IMPURITIES	Dryer failure.	Wet instrument air, potential failure of actuators.	F-0200 in electrolyser package.	Confirm what protection exists against moisture transfer to downstream system.	1	ANT DK		
10-26	S2	CHANGE IN COMPOSITION	No issues identified.							
10-27	S2	CHANGE IN CONCENTRATION	No issues identified.							
10-28	S2	REACTIONS	No issues identified.							
10-29	S2	TESTING	No issues identified.							
10-30	S2	OPERABILITY / MAINTAINABILITY	No issues identified.							
10-31	S2	ELECTRICAL	Loss of electrical supply.	IA buffer tank no longer topped up as compressor will stop.	Does not affect instrument signals which are on UPS. Plant philosophy is to fail safe, which is the plant status if all valves close on loss of air supply.	No action required.				
10-32	S2	INSTRUMENTS	Mechanical regulating valve on buffer tank outlet set up incorrectly (appears to be controlling upstream pressure - expect it should be downstream pressure).	Starve system of instrument air.	None identified.	Confirm set pressure of air regulator (within electrolyser package) and function (upstream or downstream pressure regulation).	1	ANT DK		
12-1	S2	HIGH FLOW / LEVEL	Regulator failure.	Pressure build-up at turbine as it will only consume as much gas as is required for power output.	Trip on high pressure. Double solenoid isolation at turbine.	Confirm rating of all piping/equipment components downstream of CNG supply appropriate for system maximum pressure. If not, ensure over pressure protection provided.	1	AW		
12-2	S2	LOW FLOW / LEVEL	Hose rupture/breakaway.	Loss of containment. Potential for fire and equipment damage, personnel injury. Flameout of turbine itself not a serious consequence.	None identified.	Confirm details of pressure regulation, overpressure protection and isolation on the truck. These need to be upstream of the hose. Confirm details relative to standard Jemena hook up arrangement. Review need for additional overpressure protection and also breakaway protection.	1	AW		
12-3	S2	LOW FLOW / LEVEL	Regulator failure.	Flameout of turbine, no serious consequence.		No action required.				
12-4	S2	NO FLOW / EMPTY	Gas supply depleted (empty cylinders).	Turbine will shut down on low pressure, no adverse consequences expected.		No action required.				
12-5	S2	REVERSE FLOW	Future connection of hydrogen will not be simultaneous with CNG connection, so no reverse flow possible from hydrogen supply.	Potential for flow of hydrogen into natural gas and onto turbine or natural gas into hydrogen and onto fuel cell - potential damage of fuel cell		No action required. Confirm vent sizing..				
12-6	S2	HIGH PRESSURE	Regulator failure.	Loss of containment with potential for fire.	None identified.	Update P&ID with details of pressure regulation, pressure indication, and overpressure protection. Update micro turbine P&ID to show details including regulation, overpressure protection, etc.	1 1	GPA AB CD		

		Problem Description			Safeguards and Controls		Action			
12-7	**S2**	HIGH PRESSURE	Incorrect procedure/installation of gas cylinder pack connection to piping.	Loss of containment with potential for fire.	None identified.	Appropriate signage on line to indicate required pressure and service. Consider special fitting for connection to ensure correct truck connection.	1	AW		
12-8	**S2**	LOW PRESSURE	Regulator failure.	Flame out at turbine. Refer to low flow (Item 12-3).		No action required.				
12-9	**S2**	HIGH TEMPERATURE	No issues identified.							
12-10	**S2**	LOW TEMPERATURE	Expansion of gas across regulator.	Minimum temperature requirement of 0 °C for micro turbine. Liquid in line, damage to turbine, loss of performance.	None identified.	Confirm minimum temperature of all components downstream of CNG supply. Consider addition of liquid knock-out. Check length of piping required for temperature recovery. Add temperature indication upstream of connection to turbine. Consider appropriate measures to ensure damage to the turbine is avoided.	1 1	GPA AB CD		
12-11	**S2**	IMPURITIES	Natural gas comes from known sources and will be free of impurities and of known composition. Future plan to mix natural gas and hydrogen; current details unknown.	Turbine can accept maximum 17% hydrogen. Incorrect operation/ damage of the turbine if hydrogen concentration too high.		No action required at this stage. Future activity and scope.				
12-12	**S2**	CHANGE IN COMPOSITION	See above (Item 12-11).							
12-13	**S2**	CHANGE IN COMPOSITION	Accidental connection of nitrogen to CNG supply or vice versa.	Nitrogen to turbine causes flameout, which is not unsafe. CNG to electrolyser package can result in package damage.	Colour coded labels for gas supply already specified. Fittings for the different gas cylinders are not interchangeable so gas cannot be connected to the wrong supply.	No further action required.				
12-14	**S2**	CHANGE IN CONCENTRATION	No issues identified.							
12-15	**S2**	REACTIONS	No issues identified.							
12-16	**S2**	TESTING	No earthing connection for truck at loading point.	Risk of explosion due to ignition of gas (in case of a leak) from static discharge.	None identified.	Show earthing connection to CNG truck on P&ID. Confirm truck electrical connection equipment and procedure for connecting gas.	1 1	GPA AB CD		
12-17	**S2**	OPERABILITY / MAINTAINABILITY	Connection to CNG truck pressurised once supply is open.	Cannot remove the connection without causing gas release, and potential for injury.	None identified.	Add appropriate vent and second isolation valve at truck connection to allow coupling and uncoupling.	1	GPA AB		
12-18	**S2**	OPERABILITY / MAINTAINABILITY	Ground slopes towards loading point behind truck. Truck handbrake not applied.	Truck rolls towards loading point causing damage to equipment and potentially loss of containment.	None identified.	Add bump stop unless site can be graded such that slope is removed.	1	GPA ML		
12-19	**S2**	OPERABILITY / MAINTAINABILITY	Existing trucks and known operation in new facility with, potentially, special and different requirements.	Unfamiliarity leading to human error and unpredictable consequences/injury/facility damage.	None identified.	Review the impact of any actions in this HAZOP relative to existing Jemena procedures related to CNG trucks.	1	AW		
12-20	**S2**	ELECTRICAL	Note: Operation is not intended during a lightning storm.		HAZOP of turbine package will be conducted.	No action required.				
12-21	**S2**	INSTRUMENTS	No issues identified.							

HAZOP Minutes - Nodes

		Problem Description			Safeguards and Controls		Action			
13-1	**S2**	HIGH FLOW / LEVEL	Higher flow than expected, caused by transient changes/start-up/shutdown.	Higher pressure drop leading to lower suction pressure at the compressor.	None identified.	Confirm flow vs pressure differentials across piping and compare with compressor operating range.	1	AB		
13-2	**S2**	LOW FLOW / LEVEL	Blocked filter. Blocked flow element. Low instrument air pressure closing shutdown valve.	Refer to compressor HAZOP, no consequence.		No further action required.				
13-3	**S2**	NO FLOW / EMPTY	No issues identified.							
13-4	**S2**	REVERSE FLOW	Compressor failure.	Discharge side pressure is much higher than suction due to connection to cylinders, leading to high pressure hydrogen flowing back into buffer storage. Failure of the piping upstream of the compressor, loss of containment leaing to potential for fire/explosion.	Check valve between compressor and cylinder filling. Pressure detection on compressor suction which closes suction XSV. (Relief valve on compressor suction.)	Confirm chances of reverse flow within compression package. Suction PSV set pressure and capacity to be confirmed to enable accepting PSV as safeguard.	1	WJ		
13-5	**S2**	HIGH PRESSURE	No issues identified. All components upstream of compressor rated for maximum upstream pressure.							
13-6	**S2**	LOW PRESSURE	Compressor runs either when it should have stopped or is not meant to run. Draws down pressure in the buffer store. Risk of drawing gas from Secondary Main network back into the buffer store.	Contamination of hydrogen store; negative commercial impact with customer(s).	Layers of protection: - Check valve on injection panel - low pressure alarm on the buffer store at 1150 kPag.	Confirm low pressure cut off for compressor package. Should be set at 1150 kPag or above. Confirm compressor minimum low pressure aligns with design and alarms.	1	WJ		
13-7	**S2**	HIGH TEMPERATURE	No issues identified.							
13-8	**S2**	LOW TEMPERATURE	No issues identified.							
13-9	**S2**	IMPURITIES	Iron oxide dust from buffer store.	No consequence to compressor however contamination of product gas.	Filters on both suction and discharge of compressor.	Add sample points upstream and downstream of compressor. Isolation with 1/4" NPT fitting (sample equipment to be provied by others when needed).	1	GPA AB		
13-10	**S2**	IMPURITIES	Nitrogen left in the system after purging or bleeding in from passing valve or fitting.	No consequence to compressor; however, contamination of product gas.	Operating procedures.	No further action required.				
13-11	**S2**	CHANGE IN COMPOSITION	No issues identified.							
13-12	**S2**	CHANGE IN CONCENTRATION	No issues identified.							
13-13	**S2**	REACTIONS	No issues identified.							
13-14	**S2**	TESTING	No issues identified.							
13-15	**S2**	OPERABILITY / MAINTAINABILITY	Filter maintenance requires line to be purged before putting back in service.	Air in line if not purged properly, leading to flammable mixture in compressor with potential for explosion.	Operating procedures.	Coordination procedure required for doing regular maintenance on items outside of compressor package. Procedure to amalgamate balance of plant and compressor requirements.	3	AW		
13-16	**S2**	ELECTRICAL	Inadequate certification and proof of correct equipment supply.	Potential for ignition sources, failure to receive certification by Australian authorities, production impact on loss of power in the event of substandard fittings, cabling, power supply equipment. Inability to handle surges damaging sensitive equipment.	None identified.	HA certification rating to be IECex. IEC compliance to be as per AS electrical standards compliance. Loss of power to PLC impact to be confirmed. Confirm the need for surge protection on new scope nodes.	1 1 1	WJ AW GPA JD		
13-17	**S2**	INSTRUMENTS	No issues identified.							

HAZOP Minutes - Nodes

		Problem Description			Safeguards and Controls		Action			
14-1	**S2**	HIGH FLOW / LEVEL	Compressor is fixed speed and cannot produce more flow than design.			No action required.				
14-2	**S2**	LOW FLOW / LEVEL	No issues identified.							
14-3	**S2**	NO FLOW / EMPTY	No issues identified.							
14-4	**S2**	REVERSE FLOW	Covered in Item 13-4.							
14-5	**S2**	HIGH PRESSURE	Failure of the compressor controls.	Overpressure of downstream components and loss of containment leading to gas release and potential for fire. Maximum compressor outlet pressure of 689 barg. Burst disc on tube trailer ruptures, leading to uncontrolled release of tube trailer contents, whcih can be a large volume. Potential for large fire/explosion.	Compressor discharge PSV protects against overpressure downstream. Burst disc is weak point, but also offers protection against catastrophic overpressure failure.	Confirm pressure rating of compressor discharge piping to cylinder filling package. 300 barg min requirement. Confirm compressor discharge PSV set pressure. Set to protect the lowest rated pressure in the downstream system. Review control philosophy for outlet of compressor, i.e., number of transmitters and their locations, and shutdown result (i.e., what happens?).	1 1 1	GPA ML WJ WJ		
14-6	**S2**	LOW PRESSURE	Compressor malfunction.	No filling of cylinders.		No action required.				
14-7	**S2**	HIGH TEMPERATURE	Failure of compressor discharge cooler.	Hot gas damages cylinders (seals, etc), leading to potential loss of containment. Personnel safety (burns).	High temperature trip - details to be confirmed.	Confirm maximum discharge temperature from the compressor. Appropriate signage to be added on compressor discharge piping to warn against hot surface temperatures.	1 1	WJ AW		
14-8	**S2**	LOW TEMPERATURE	No issues identified.							
14-9	**S2**	IMPURITIES	Refer to Items 13-9 and 13-10.							
14-10	**S2**	CHANGE IN COMPOSITION	No issues identified.							
14-11	**S2**	CHANGE IN CONCENTRATION	No issues identified.							
14-12	**S2**	REACTIONS	No issues identified.							
14-13	**S2**	TESTING	No issues identified.							
14-14	**S2**	OPERABILITY / MAINTAINABILITY	Inadequate isolation (incorrect type) under pressure instruments in high pressure systems.	Unnecessary depressurisation of piping to gain access to instruments. No ability to do online maintenance.	None identified.	Provide appropriate isolation for service.	1	GPA AB		
14-15	**S2**	OPERABILITY / MAINTAINABILITY	Once hose connected to truck and pressurised, cannot remove without gas release under high pressure.	Loss of containment, personnel injury from fire/explosion or hose whip.	None identified.	Add 1/2" plug (isolation) valve on truck side of flexi hose.	1	GPA AB		
14-16	**S2**	OPERABILITY / MAINTAINABILITY	Operations for cylinder filling by third party outside high security fence.	Difficulty carrying out tasks without proper lighting if after hours, potential clashes or miscommunication between Jemena and third party operations leading to incidents.	None identified.	Confirm requirement for local lighting at cylinder filling area. Confirm interaction between compressor package, cylinder filling package and balance of plant with respect to ESD shutdowns. Appropriate signage needs to be confirmed and provided.	1	AW		
14-17	**S2**	OPERABILITY / MAINTAINABILITY	Operations for cylinder filling by third party outside high security fence with inappropriate surface preparation for cylinder trucks/trailers.	Trucks have insufficient clearance to manouvre, impact with fences/lighting poles, tipping of trailers, all potentially leading to personnel injury and equipment damage.	None identified.	Concrete slab required for landing legs of trailers to prevent sinking into the ground and tipping trailer. Consideration required for positioning of trailers relative to hose location and potential parallel operation (two fill locations).	1	GPA ML		
14-18	**S2**	ELECTRICAL	No issues identified.							

HAZOP Minutes - Nodes

		Problem Description			Safeguards and Controls		Action			
14-19	S2	INSTRUMENTS	Operations for cylinder filling by third party outside high security fence and insufficient communications or information between packages/parties.	Miscommunication leading to incidents.	None identified.	Confirm comms philosophy between packages and how this relates to operation of the facility both by Jemena and clients. Requires preparation of a coordination procedure for third party operations, including inductions, safety requirements, operating procedures, etc.	3	AW		
15-1	S2	HIGH FLOW / LEVEL	Regulator failure	Potential component failure downstream of regulator leading to nitrogen release with potential to cause asphyxiation within the closed space of the electrolyser container.	Container is ventilated. Personnel entering the container will have gas detectors. Nitrogen PSV/PRV inside package.	Confirm with ANT what protections are provided against nitrogen line failure. Jemena to ensure that gas detectors for operators include low oxygen warning.	1 3	DK ANT AW		
15-2	S2	LOW FLOW / LEVEL	All users inside electrolyser package open simultaneously, or component failure, or vent open, unexpectly leading to higher consumption of nitrogen than designed.	Early depletion of the nitrogen supply leading to inadequate purging leading to off spec hydrogen. (several other consequences may occur; only one example listed here).	Flow switches (x2) - FIZS0125 / 0126	Confirm with ANT action resulting from flow switch activation.	1	AW		
15-3	S2	NO FLOW / EMPTY	Refer to Action 12-2	Pressurised hose breakaway leading to whipping leading to injury (if a flexible hose is required to connect the nitrogen bottles to the balance of plant piping).		See action 12-2 and confirm whether a hose will be used or not	2	AW		
15-4	S2	REVERSE FLOW	Relief of hydrogen from PSVs in hydrogen purification system at 38 barg causing reverse flow into the nitrogen supply system.	Hydrogen release at the nitrogen cylinders - most likely through PSV, but can alos be through open vents, or fittings if leaking.	NRV in nitrogen supply line within the electrolyser package. Nitrogen supply line would have to be at very low pressure to cause reverse flow of hydrogen. Open valve or failure at the cylinders would be required for a release.	Not deemed credible. No further action required.				
15-5	S2	REVERSE FLOW	Hydrogen flow through the nitrogen network within the elecrolyser.	Hydrogen into lines that normally contain oxygen - potential for flammable mixtures that could result in fire.		Item covered within ANT HAZOP of electrolyser package. No further action required.				
15-6	S2	HIGH PRESSURE	Nitrogen bottles supply pressure higher than expected and designed for.	Failure of downstream piping and fitting components and exceeding PSV capacity.	AS 2473.3 Type 50 connection type at cylinder cage preventing connection of higher pressure bottles.	Confirm details of nitrogen supply (bottle pressure and whether regulation and relief is going to be included on the bottles) and pipe specification. Also refer action 12-7	1	AW		
15-7	S2	LOW PRESSURE	No issues identified	As per 15-2						
15-8	S2	HIGH TEMPERATURE	No issue identified							
15-9	S2	LOW TEMPERATURE	Expansion of gas across regulator.	Gas cools to low temperature; however, consequences inside package are unknown. Vendor has stated a minimum nitrogen temperature of -40 °C is required.	Ambient temperature recovery after regulator.	Calculate lowest temperature possible on cold day following gas expansion through regulator, and check against the required limit. If colder than limit, check heat recovery possible from ambient heating.	1	AB		
15-10	S2	IMPURITIES	No issues identified based on assumption that supplied gas will not contain impurities. Refer Safeguard and action.	Impurities could result in inadequate purging.	Assumption - nitrogen will be supplied by reputable suppliers. Electrolyser vendor has stated nitrogen purity needs to be 99.996%.	Jemena to ensure nitrogen purity meets electrolyser specification of 99.996%.	2	AW		

HAZOP Minutes - Nodes

		Problem Description			Safeguards and Controls		Action			
15-11	**S2**	CHANGE IN COMPOSITION	Refer action 12-13.		Refer to action 12-7 relating to signage.					
15-12	**S2**	CHANGE IN CONCENTRATION	No new issues raised.							
15-13	**S2**	REACTIONS	No issues identified.							
15-14	**S2**	TESTING	Lack of appropriate purge/test point(s).	Inadequate purging due to lack of suitable purge/test point in/near the electrolyser package where the purged gas can be tested for oxygen.	No safeguards identified.	Confirm whether purge/test points are required and at which locations.	1	DK		
15-15	**S2**	OPERABILITY / MAINTAINABILITY	Only one purge valve currently in design at the upstream end. No other spare connections (utility points) for other potential uses along the line.	Limited ability to depressurise other lines and use nitrogen elsewhere on site.	No safeguards identified.	Add purge valves and nitrogen access points at suitable locations.	1	ML		
15-16	**S2**	ELECTRICAL	No issues identified.							
15-17	**S2**	INSTRUMENTS	No issues identified.							

Client	Jemena			Document Title	Document Subtitle	Document No.
Client	P2G-2099	GPA	18667	HAZOP Minutes	HAZID	P2G-2099-MM-HZ-001
Project	Western Sydney Green Gas Project					

GPA ENGINEERING

HAZID Minutes

Node			Problem Description			Safeguards and Controls		Action			
ID	**Session**	**System / Plant**	**Guideword**	**Cause**	**Consequence**	**Existing Proposed Safeguards**	**New Proposed Safeguards**	**Priority**	**Responsible**	**Complete Yes/No**	**Comments / Notes**
H-1	**S1**	**Hydrogen Systems**	CHEMICAL ENERGY	Corrosion - internal or external Underground pipeline is carbon steel pipe, which is susceptible to hydrogen embrittlement.	Release of Hydrogen to atmosphere, ignition occurs instantaneously or delayed resulting in a jet or flash fire. Property damage and potential fatality/s	Buried pipe is designed with low design factor and relatively low-strength grade (X52) material to ensure low stress conditions protecting against rupture due to H2 embrittlement. This pipe is also coated and has cathodic protection. Facility piping is stainless steel, which is less susceptible than carbon steel to H2 embrittlement, and is also operating under low stress conditions which will prevent a rupture. As part of the quality management plan, defect testing of the piping and equipment will occur post manufacture. Exhaust fans and H2 gas detectors initiating an ESD in Electrolyser building. Ignition control: To be managed by Jemena's permit to work system, operator clothing will be antistatic and flame retardant.	HAZOP action O-4 Review requirements relating to hydrogen-assisted fatigue crack growth (HA-FCG), relating to defect inspection, weld defect tolerances, and monitoring etc.	2	AW	YES	Refer action O-4.
H-2	**S1**	**Buried Steel**	ELECTRICAL ENERGY	Stray currents	Compromised cathodic protection leading to corrosion - including of existing assets.		Consider cross-bonding to existing buried assets. HAZOP action 1-25.	1	NK	YES	Refer action 1-25
H-3	**S1**	**Electrolyser**	CHEMICAL ENERGY	Mol sieve material passing through into filters - on the electrolyser package.	Loss of performance	Maintenance procedures and operations monitoring.					
H-4	**S1**	**SS Piping**	CHEMICAL ENERGY	Dissimilar metals.	Galvanic corrosion.		Include isolation joints in the design.	1	NK	YES	Refer drawing P2G-2099-DW-PD-004 and -008.
H-5	**S1**	**Buried Steel**	CHEMICAL ENERGY	CP Interference	-		The potential for CP Interference will be mitigated in the CP design. CP design to address other buried structures CP interferences. Submission of the new design to the Electrolysis committee may required for approval TBC.	1	MR		HOLD - NK to resolve
H-6	**S1**	**Steel**	HARM TO PLANT	Hydrogen effects on steel	Embrittlement and fatigue crack growth.	To be susceptible, a combination of three factors is required: presence of (and diffusion of) hydrogen, susceptible material, and stress. The design of piping will be 'no rupture' to ensure that any potential fatigue cracks will not propagate due to the low stress conditions. Material susceptibility is being managed by material selection (compatible with hydrogen), post manufacture defect testing such as hydrotest and radiography.					

HAZID Minutes

Node			Problem Description			Safeguards and Controls		Action			
ID	**Session**	**System / Plant**	**Guideword**	**Cause**	**Consequence**	**Existing Proposed Safeguards**	**New Proposed Safeguards**	**Priority**	**Responsible**	**Complete Yes/No**	**Comments / Notes**
H-7	**S1**	**Buried Steel**	CHEMICAL ENERGY	Soil corrosion - potential for acid sulphate soils.	Corrosion of piping.	Coating and CP of buried pipe.	Procedure for handling of piping and equipment during construction to be created to avoid soil contact. Training of construction personnel is a requirement.	2	DK	YES	Construction SOW, P2G-2099-SW-CN-001 Section 4.4.1 includes requirement to keep pipe clean and undamaged.
H-8	**S1**	**Electrolyser**	ELECTRICAL ENERGY	Vents - sparking due to flaps/moving components and velocity.	Ignition of hydrogen when venting.		Design of all vents to be non-sparking.	1	AP	YES	Needle valves are used for all hydrogen bleeds, to limit flow rate. Toroidal ring also used on main hydrogen vent which is earthed. Flow rate can be controlled on main vent also. Together these provide every practical mitigation of ignition potential. Refer Isometric P2G-2099-DW-ISO-015.
H-9	**S1**	**Pipeline**	ELECTRICAL ENERGY	Vents - sparking due to flaps/moving components and velocity.			Design of all vents to be non-sparking. Use a sock.	1	NK	YES	Vents will be earthed and fitted with vent 'socks' to prevent rain ingress. Refer Isometric P2G-2099-DW-ISO-015 for earth lugs and rain cap protection.
H-10	**S1**	**Electrolyser**	THERMAL ENERGY	Failure of electrolyser chilling systems- max temp 80°C.	Potential burns to personnel touching pipe.	Electrolyser package will trip on high discharge temperature. TTZ 1160 is a temperature switch set at 80°C, the gas sent to the vent stack will never exceed this temperature, not even during regeneration, this is because heat exchanger X-1156 is present.					
H-11	**S1**	**Electrolyser**	THERMAL ENERGY	No low temperature issues. Considered Joule-Thompson, and chiller system harm to personnel (it operates to min. 5°C)							
H-12	**S1**	**Generator**	THERMAL ENERGY	Hot components, and exhaust temperatures. Potential for hydrogen attack (on steel components).	Personnel injury, corrosion.	Controlled by design. Cladding will be installed to protect operators. Internal materials are designed to prevent hydrogen attack. Vent stack has air shrouded combustion.					
H-13	**S1**	**Whole site**	RADIANT ENERGY	Fire from adjacent facility, or bushfire.	Hydrogen facility potentially damaged if a neighbouring natural gas pipeline incident occurs, but it unlikely to cause an escalation that is beyond the existing risk. There is bushland adjacent to the facility but only 2 trees on site.	In the event of a bush fire or incident at a neighbouring facility, the hydrogen plant will be remotely shutdown.	Response plans to be created/updated to include remote shutdown of hydrogen facility in the event of nearby fire.	1	AW		JEMENA ACTION
H-14	**S1**	**Whole site**	ELECTRICAL ENERGY	Battery on generator, and two UPS'.	Stored energy release if battery fails. Potential for fire/explosion.	Jemena and battery vendor management procedures to be applied for battery management.	Preventative maintenance work orders to be created for inspection/testing.	3	AW		JEMENA ACTION
H-15	**S1**	**Electrolyser**	ELECTRICAL ENERGY	Electrolyser current discharge.	Arc flash may occur resulting in personnel injury. Considered a low risk in this application.	Low risk. Reviewing design. Arc flash detection? Bus bars may be heavy.	ANT to minimise potential for arc flash in the electrical design. Determine if arc flash detection is required and include in the design. GPA also to review design regarding arc flash requirements.	1 1	AP JD		Following up with ANT MCC specification includes arc flash detection. Refer P2G-2099-DS-EL-006.

HAZID Minutes

Node			Problem Description			Safeguards and Controls		Action			
ID	**Session**	**System / Plant**	**Guideword**	**Cause**	**Consequence**	**Existing Proposed Safeguards**	**New Proposed Safeguards**	**Priority**	**Responsible**	**Complete Yes/No**	**Comments / Notes**
H-16	**S1**	**Transformer**	ELECTRICAL ENERGY	Supplied pad-mount from the grid by electricity supplier.							
H-17	**S1**	**Whole site**	ELECTRICAL ENERGY	Ignition of releases.	Fire if loss of containment occurs.	A hazardous area study will be completed. The equipment will be hazardous area designed and rated as per report requirements. The existing Jemena permit system will be reviewed for the new application and applied in operation. Equipment will be procured with IECEx compliance suitable for hydrogen. - (International Electro technical Commission System for Certification to Standards Relating to Equipment for Use in Explosive Atmospheres (IECEx System))	Review and update if required existing Jemena permit system for application in hydrogen operation. To further control ignition sources, determine whether non-sparking tooling is required for all maintenance work. Provide training and equipment per specifications.	1	AW		JEMENA ACTION
H-18	**S1**	**Whole site**	ELECTRICAL ENERGY	Static risks - ignition source for explosive environment. Numerous visitors expected to the site, including media.	Fire if loss of containment occurs.	Anti-static clothing a requirement for anyone entering the site. Mobile phones and other devices that may be potential ignition sources to be managed by Jemena's reviewed permitting system. for this site. No-go / exclusion zones to be marked out e.g. electrolyser	Induction process to be created for workers / visitors. Hydrogen gas detectors a requirement for personnel.	3	AW		JEMENA ACTION
H-19	**S1**	**Whole site**	ELECTRICAL ENERGY	Mowers, vehicles	Fire if loss of containment occurs.	Jemena's permit to work system Reference XXX	Define exclusion zone around pipeline riser using bollards. Define all exclusion zones and install a light barrier.	1	SH	YES	Exclusion zone is demarcated with chain-link bollards. Refer plot plan, drg. P2G-2099-DW-CV-001.
H-20	**S1**	**Whole site**	CHEMICAL ENERGY	Small leaks.	Loss of product, potential fire. May go undetected.	Hydrogen detectors are located in in the electrolyser building. Detection will trip the electrolyser (confirm). Jemena personnel will be required to wear H2 detectors when entering the site, exclusion zones will be created for areas with a higher potential for leaks of venting. HAZOP action 1-19 Balance of plant design to include use of hoods with gas detectors in locations with multiple fittings and valves. E.g.. gas panel, injection panel, pipeline end connections.	Create leak response procedure for hydrogen leak detection. Add short-term isolation function, which shuts in system for 15 minutes and monitors pressure change during shut-in to detect leak. Include as routine test in operating procedures.	3 1	AW SD		JEMENA ACTION Cam to close out
H-21	**S1**	**Whole site**	CHEMICAL ENERGY	Large leaks	Fire	Video cameras reporting to remote control room are a part of the design. Remote shut-down of the facility is available. An ESD button will be available at the entrance gate.	Determine requirements for an infrared camera to be installed on site. Provide Infrared cameras for personnel entering the site. Leak detection to initiate a local beacon/siren. Make siren interlock with gate (so only alarms if someone is there).	3 1	AW SD		JEMENA ACTION Cam to close out item 3

HAZID Minutes

Node			Problem Description			Safeguards and Controls		Action			
ID	**Session**	**System / Plant**	**Guideword**	**Cause**	**Consequence**	**Existing Proposed Safeguards**	**New Proposed Safeguards**	**Priority**	**Responsible**	**Complete Yes/No**	**Comments / Notes**
H-22	**S1**	**Whole site**	KINETIC ENERGY	Impact from vehicle	Loss of containment.	Design will propose a layout to minimise vehicle traffic considering access requirements for maintenance/production etc.	Conduct further layout review to minimise potential for vehicle impact. Consider all access requirements. Install bollards where required.	1	NK	YES	Vehicle access was considered at each design review, resulting in bollard installation. Refer layout drawings.
H-23	**S1**	**Whole site**	NOISE ENERGY	Noise	Residential disturbances/complaints.	A noise study will be conducted in the design phase.					
H-24	**S1**	**Electrolyser**	GRAVITATIONAL ENERGY	Working on top of electrolyser package	Fall from height	Jemena working at heights procedures will be applied.	Consider moving maintainable components to the side. Confirm roof railings are provided.	1	AP	YES	Elevated equipment (chiller unit) has been removed from the roof so that access is not required.
H-25	**S1**	**Whole site**	GRAVITATIONAL ENERGY	Soil settlement	Stress on fittings causing leaks.	Tubing flexibility, civil design to consider local conditions.					
H-26	**S1**	**Electrolyser**	NATURAL ENERGY	Hailstones	Damage to the cooling fans on the electrolyser roof.		Hydrogenics to advise on requirements for protection from hail damage.	1	AP		Most of the package is in a shipping container and is expected to be relatively durable. The interconnecting pipework and cooling fans could be impacted by heavy hail but consequences are expected to be minimal. Design is considered acceptable.
H-27	**S1**	**Electrolyser**	NATURAL ENERGY	Lightning	Electrolyser damage.		ANT/Hydrogenics to advise on required protection mechanisms against lightning damaging the electrolyser package.	1	AP		It is proposed by GPA to earth the vents of the electrolyser process container and to include 2 x lightning rods.
H-28	**S1**	**Oxygen System**	CHEMICAL ENERGY	Oxygen loss of containment.	Oxygen enriched fire in the electrolyser building, from pipework or around vents	Continuous purging flow through the enclosure with exhaust fans.	Hydrogenics to provide input from package HAZOP on management of oxygen risks. Is O2 building analyser included in the package? Confirm SIL rating of exhaust fan failure detection as well as H2 and O2 detection in the building. HAZOP action 3-12 Action for Hydrogenics to identify all feeds to drains. If gas breakthrough can occur in O2 or H2 scrubbers connected to drains, a SIL study will be required on the Low level instrumented functions.	1	AP	YES	Per 18667-LIS-003 Clarification No. 68: There is an oxygen analyser in hydrogen ATZ 1520 (SIL 1) to monitor the gas quality on P&ID ANA-1. The ventilation system is guarded by a differential pressure transmitter PDTZ 1311 (SIL 1 level) on P&ID GGS-1

HAZID Minutes

Node			Problem Description			Safeguards and Controls		Action			
ID	**Session**	**System / Plant**	**Guideword**	**Cause**	**Consequence**	**Existing Proposed Safeguards**	**New Proposed Safeguards**	**Priority**	**Responsible**	**Complete Yes/No**	**Comments / Notes**
H-29	**S1**	**Whole site**	CONTROLS AND CONTROLLERS	Human error - maintenance activities.	Hydrogen and oxygen services are new to Jemena. Will require some additional training ad new practices.	HAZOP action 1-23 Develop competency based training module for the new facility. Make competency based training a requirement for hydrogen service operators . Create register for management of accredited personnel.	Jemena to contact existing hydrogen/oxygen industries (industrial gases) to further understand specific risks and risk management. Create procedure for management of spare parts specific for hydrogen and oxygen service. Ensure field auditing of procedural activities occurs for the new facility. More intensively during initial operation.	3	AW		JEMENA ACTION
H-30	**S1**	**Whole site**	THIRD PARTY HAZARDS	Malicious damage; theft etc. (this has happened before at this location)	Damage	Secure location, away from the roadside, on an existing industrial facility. Signposting will not draw unwanted attention to the facility. Facility will be fenced and locked with authorised personnel entry only signage. Jemena is carrying out an action to review designs from a site security perspective.					
H-31	**S1**	**Whole site**	CHEMICAL ENERGY	Air ingress during commissioning, start up after maintenance	Explosion within piping	HAZOP action 1-22 Strict use of nitrogen purging after maintenance to be enforced in hydrogen service, and included in all start-up/re-commissioning operating procedures. HAZOP action 1-23 Develop competency based training module for the new facility. Make competency based training a requirement for hydrogen service operators . Create register for management of accredited personnel.					
H-32	**S1**	**Whole site**	KINETIC ENERGY	Distortion of soft components in hydrogen service e.g. gaskets, Swagelok, treads, valve internals	Loss of containment.	Design and liaison with material vendors. Leak detection					
H-33	**S1**	**Whole site**	THIRD PARTY HAZARDS	Aircraft crash / false landing. This site is in vicinity of training area with light aircraft	Damage, loss of containment, fire.	General aircraft safety regulations make the event of a crash unlikely. The plant has a relatively small footprint making it unlikely to be hit in the event of a crash.					
H-34	**S1**	**Whole site**	HARM TO HUMANS / BIOLOGY	Cooling water system - legionnaires?		Cooling uses refrigerant, no cooling tower (Hydrogenics to confirm) .					
H-35	**S1**	**Whole site**	HARM TO ENVIRONMENT	Prospect reservoir - 1km away. Drains to creek. Only potential effluent is Brine.	Contamination of water ways		Water treatment and disposal options to be reviewed and specified. Consider EPA regulations and minimising harm to the environment.	1	SH	YES	Refer water treatment options report, P2G-2099-RP-EV-002 and environmental impact statement (EIS)
H-36	**S1**	**Whole site**	HARM TO ENVIRONMENT	NG venting through instrument gas system.	negligible contribution						
H-37	**S1**	**Whole site**	HARM TO PUBLIC / COMMUNITY	Potential push-back from the consumer community on increased hydrogen in the product.		Jemena public affairs to develop engagement program with the local community and broader consumers.					

HAZID Minutes

Node			Problem Description			Safeguards and Controls		Action			
ID	**Session**	**System / Plant**	**Guideword**	**Cause**	**Consequence**	**Existing Proposed Safeguards**	**New Proposed Safeguards**	**Priority**	**Responsible**	**Complete Yes/No**	**Comments / Notes**
H-38	**S1**	**Whole site**	HARM TO ADJACENT PROPERTY	Harm to aircraft flying overhead due to released flammable gas cloud during venting of storage pipeline.	Aircraft disturbance		Determine if the facility is directly under any new flight paths and potential consequences. Liaise with relevant authorities.	2	AW		JEMENA ACTION
H-39	**S1**	**Whole site**	DOWNSTREAM / UPSTREAM EFFECTS	Electrical generation - synchronisation system	Generator supplies to the grid	Design is compatible with grid supply.					

APPENDIX 3 ELECTROLYSER HAZOP

HYDROGENICS
SHIFT POWER | ENERGIZE YOUR WORLD

Project: P195947 JEMENA
HAZOP: Hydrogen Plant
Date: 9/09/2019

BOUNDARY HAZOP

Rev.	Date	By	Description
00	9/09/2019	RDA	Create project specific document derived from HYGS standard file

Project: P195947 JEMENA
HAZOP: Hydrogen Plant
Date: 9/09/2019

Source document: HYG-JEM-PRO-F02_PFD_Rev.00

Node No.	Description	Remarks	Drawing Reference
1.1	Electrolyser H2 vent		HYG-JEM-PRO-F03
1.2	Electrolyser outlet		HYG-JEM-PRO-F03
2.1	Electrolyser O2 vent		HYG-JEM-PRO-F03
3.2	N_2 to PEM		HYG-JEM-PRO-F03
4.1	AC power MV in		HYG-JEM-ELE-E01
5.1	Tap Water IN		HYG-JEM-PRO-F03
5.2	Drain Water Out		HYG-JEM-PRO-F03

HAZOP Worksheet

Node 1.1
Description: Electrolyser H2 vent
Drawings: HYG-JEM-PRO-F03

Deviation / Guideword	#	Causes	Consequences			Frequency		Class	Safeguards			Recommendations / actions	Who
		description		description	rank	Description	rank		description	Risk reduction	SIL		
High Flow	1.1.1	Producing more than 200Nm3/hr hydrogen while venting to atmosphere		Hazardous area zone 1 balloon increases around vent stack	N/A	Failure of the DC current measurement	3	N/A	Design conditions consider hazardous area zoning of up to 15,000Nm3/hr.	100	N/A	N/A	N/A
Low Flow	1.1.2	Blockage (partial) of vent stack		System unable to vent or relief pressure, safety relief valves don't work propperly	B	Freezing of condensate	3	II	Vent stack designed to avoid blockage (no water pockets), heat tracing provided when ambient temperatures < -20°C	100	N/A	N/A	N/A
Reverse Flow	1.1.3	Electrolyser at atmospheric pressure in cooling cycle will end up with under pressure within the system.		Vacuum drawn and air ingress into system creating an explosive mixture.	B	Any de-pressurising shut down situation.	5	I	- Design pressure of system is 38barg meaning equipment can contain an explosion. Max explosion pressure 17.0barg. - If system pressure drops below 0.2barg then safety system prevents the production of hydrogen. This system also checks that the purge was successful. - Nitrogen purge of system once pressure drops below 0.2barg which purges Oxygen out of system. Minimum amount of N2 required to be passed through the system before re-start.	100 10 100	 1 2	N/A	N/A
High Pressure	1.1.4	Blockage of vent - Ice build up.		Rupture of vent stack	N/A	N/A	N/A	N/A	Vent stack is designed to 38barg which is design pressure of system. Stack will not rupture.	N/A	N/A	N/A	N/A
Low Pressure	1.1.5	No low pressure case possible.		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Temperature	1.1.6	Failure of cooling system in electrolyser		Vent stack over temperature. Degradation of stack.	N/A	N/A	N/A	N/A	Temperature switch on electrolysis cell. If high temperature sensed then production stops and shut down to standby. Pressure remains in system.	N/A	N/A	N/A	N/A
Low Temperature	1.1.7	Generation of ice in winter seasons. For safeguards please refer item 1.1.2 and 1.1.4 above.		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Level	1.1.8	No high level case possible		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Low Level	1.1.9	No low level case possible		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Composition Change	1.1.10	Possibility to vent Nitrogen through stack.		None	N/A	When purging system	3	N/A	N/A	N/A	N/A	N/A	N/A

HAZOP Worksheet

Node 1.1
Description: Electrolyser H2 vent
Drawings: HYG-JEM-PRO-F03

Deviation / Guideword	#	Causes	Consequences			Frequency		Class	Safeguards			Recommendations / actions	Who
		description		description	rank	Description	rank		description	Risk reduction	SIL		
Impurities / contamination	1.1.11	A fraction of Oxygen in Hydrogen.		An explosive mixture.	B	Failure of components inside stack. If there is a rupture of the membrane.	3	II	-Considered in basis of design so that mixture can not occur. -Gas analyser in place. Oxygen concentration is measured. Instrument ATZ-1520.	10 10	1	N/A	N/A
Start up	1.1.12	Air in stack and venting hydrogen.		Explosive atmosphere within the stack.	C	On start up.	3	III	Correct vent stack design basis. Standard CGA 5.5 as guidance	10	N/A	N/A	N/A
Shut down	1.1.13	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Climactic conditions	1.1.14	Seismic event or storm causing stack to physically fail.		Stack failure (bending...), hydrogen venting in non classified area	B	Earthquake event / storm	3		All pipe work and stacks designed to accommodate site seismic accelerations and wind speeds accordingly.	100	N/A	N/A	N/A
Maintenance	1.1.15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

HAZOP Worksheet

Node 1.2
Description: Electrolyser outlet
Drawings: HYG-JEM-PRO-F03

Deviation / Guideword	#	Causes	Consequences			Frequency		Class	Safeguards			Recommendations / actions	Who
		description		description	rank	Description	rank		description	Risk reduction	SIL		
High Flow	1.2.1	High flow as a result of line rupture (physical impact from forklift or similar)		Hydrogen leak and thus explosive atmosphere at rupture zone.	B	Possible during Nitrogen bank replacement and other maintenance activities.	3	II	Physical barrier required to prevent moving machinery to travel between containers.	100		Collision protection must be provided to protect hydrogen user line	Customer
Low Flow	1.2.3	Low flow as a result of physical impact reducing bore size of the line.		Larger pressure drop in line. Low inlet pressure at user.	D	Possible during Nitrogen bank replacement and other maintenance activities.	3	IV	N/A	N/A	N/A	N/A	N/A
Reverse Flow	1.2.4	If the hydrogen user is a compressor; High pressure side of compressor breaking through into low pressure side. Internal leakages within the compressor. Potentially through non return valves.		Design pressure of the line would be exceeded. Potential rupture of line.	B	Possible if there is a failure of the internals of the compressor.	3	II	-PRV on inlet of compressor shall protect against over pressure of this line. This would vent gas and protect all equipment up stream.	100	N/A	N/A	N/A
High Pressure	1.2.5	Pressure control system failure of electrolyser		Exceeding design pressure of the line. Potential rupture.	B	As and when purging.	3	II	PRV on all vessels in electrolyser	100	N/A	N/A	N/A
High Pressure	1.2.6	High pressure as a result of elevated ambient temperature whilst plant is shut down.		Exceeding design pressure of the line. Potential rupture.	B	During plant shut downs.	3	II	Design pressure of line shall be higher than the highest pressure that can be expected as a result of elevated T.	100		Customer to select piping material with design pressure taken into acount pressure rise caused by temperature swing.	Customer
Low Pressure	1.2.7	Startup after maintencance		Vacuum drawn and air ingress into system creating an explosive mixture.	B	Any de-pressurising shut down situation.	5	I	- Design pressure of system is 38barg meaning equipment can contain an explosion. Max explosion pressure 17.0barg. - If system pressure drops below 0.2barg then safety system prevents the production of hydrogen. This system also checks that the purge was successful. -Nitrogen purge of system once pressure drops below 0.2barg which purges Oxygen out of system. Minimum amount of N2 required to be passed through the system before re-start.	100 10 100	 1 2	N/A	N/A

HAZOP Worksheet

Node 1.2
Description: Electrolyser outlet
Drawings: HYG-JEM-PRO-F03

Deviation / Guideword	#	Causes	Consequences			Frequency		Class	Safeguards			Recommendations / actions	Who
		description		description	rank	Description	rank		description	Risk reduction	SIL		
High Temperature	1.2.8	Error (heating element used for drying mole sieve beds stays on) in Hydrogen Purification System resulting in elevated temperatures outside of operating range 5-80degC.		Gas going to outlet will be at elevated temperature. Outside of design basis. Weaken line and create leak. Creates ignition. Could damage compressor.	B	Output flow would have to be very low and heating element would need to fail.	3	II	-TTZ-1160 temperature transmitter downstream to protect against high temperature. -TTZ-1123 / 1133 temperature transmitters on both driers (DA-H, DB-H) to protect against high temperature from vessels. -H-DA and H-DB heating elements: Current of both elements are measured. When there is current feedback and no requirement for element to be operational the PLC will stop hydrogen production.	10 10	I I		
Low Temperature	1.2.9	Low ambient temperature < 0°C		Line blockage	D		5	I	Dewpoint of H2 is -75°C, freezing is not possible since ambient temperature will not get this low.	100	N/A		
High Level	1.2.10	No level to consider.											
Low Level	1.2.11	No level to consider.											
Composition Change	1.2.12	H2 purge after N2 purge not propperly done --> high N2 content in H2		? --> depends on application		Automatic H2 purge procedure after N2 purge forced by software	3					Check application's tolerance to 100% nitrogen.	Customer
Impurities / contamination	1.2.13	A fraction of Oxygen in Hydrogen.		An explosive mixture.	B	Failure of components inside stack. If there is a rupture of the membrane.	3	II	- HPS deoxo vessel reaction - Gas analysers in place. Oxygen concentration is measured. . Instrument ATZ-1520 Instrument ATZ-1720. If gas is out of spec, it will be sent to vent stack.	10 10 10		Check application's tolerance to oxygen contamination	Customer
Start up	1.2.14	Refer O&M manual for maintenance requirements.		Explosive mixture - user line filled with air					At first start up Nitrogen shall be manually purged through the lines.				
Shut down	1.2.15	Refer O&M manual for maintenance requirements.							At shut down, Nitrogen shall be manually purged through lines to remove hydrogen from the system.				
Climactic conditions	1.2.16	Seismic event causing line rupture at rigid fixings.		Line failure. Potential explosive atmosphere	B	Earthquake event	3	II	All pipe work and stacks to be designed accommodate site seismic accelerations accordingly. Design with expansion loops and/or flexible hoses.				

HAZOP Worksheet

Node 1.2
Description: Electrolyser outlet
Drawings: HYG-JEM-PRO-F03

Deviation / Guideword	#	Causes	Consequences			Frequency		Class	Safeguards			Recommendations / actions	Who
		description		description	rank	Description	rank		description	Risk reduction	SIL		
Maintenance	1.2.17	Refer O&M manual for maintenance requirements. (reverse flow case !)							use tag and lock out procedures on valves before starting maintenance works				

HAZOP Worksheet

Node 2,1
Description: Electrolyser O2 vent
Drawings: HYG-JEM-PRO-F03

Deviation / Guideword	#	Causes		Consequences		Frequency		Class	Safeguards			Recommendations / actions	Who
		description		description	rank	Description	rank		description	Risk reduction	SIL		
High Flow	2.1.1	Producing more than 100Nm3/hr Oxygen and plant dump required.		N/A	N/A	Failure of the DC current measurement	3	N/A	Design conditions consider maximum flow rate of up to 3,600Nm3/hr in a dumping condition.	N/A	N/A	N/A	N/A
Low Flow	2.1.2	Blockage (partial) of vent stack		System unable to vent or relief pressure, safety relief valves don't work propperly	B	Freezing of condensate	3	II	Vent stack designed to avoid blockage (no water pockets), heat tracing provided when ambient temperatures < -20°C	100	N/A	N/A	N/A
Reverse Flow	2.1.3	System at atmospheric pressure in cooling cycle will end up with under pressure within the system.		Vacuum drawn and air ingress into system creating a mixture of Oxygen and air.	N/A	Any de-pressurising shut down situation.	5	N/A	N/A	N/A	N/A	N/A	N/A
High Pressure	2.1.4	Blockage of vent - Ice build up.		Rupture of vent stack	N/A	N/A	N/A	N/A	Vent stack is designed to 38barg which is design pressure of system. Stack will not rupture.	N/A	N/A	N/A	N/A
Low Pressure	2.1.5	No low pressure case possible		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Temperature	2.1.6	Failure of cooling system in electrolyser		Vent stack over temperature. Degradation of stack.	N/A	N/A	N/A	N/A	Temperature switch on electrolysis cell. If high temperature sensed then production shall stop and shut down to standby. Pressure remains in system.	N/A	N/A	N/A	N/A
Low Temperature	2.1.7	Generation of ice in winter seasons. For safeguards please refer item 1.1.2 and 1.1.4 above.		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Level	2.1.8	No high level case possible		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Low Level	2.1.9	No low level case possible		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Composition Change	2.1.10	Possibility to vent air (instead of Oxygen) through the stack.		Nil	Nil	When purging system	3	N/A	Nil	N/A	N/A	N/A	N/A
Impurities / contamination	2.1.11	A fraction of Hydrogen in Oxygen.		An explosive mixture.	B	Failure of components inside stack. If there is a rupture of the membrane.	3	II	Stack design to 38barg which is greater then any explosion pressure. 'Hydrogen in Oxygen analyser ATZ-1620 detects Hydrogen in the Oxygen stream. Threshold is set at 1.85%. If this is exceeded then the plant will stop and de-pressurize.	10 10	 1	N/A	N/A
Start up	2.1.12	Air in stack and venting Oxygen.				On start up.	3		N/A	N/A	N/A	N/A	N/A
Shut down	2.1.13	Nil		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Climactic conditions	2.1.14	Seismic event causing stack to physically fail.		Stack failure.		Earthquake event	N/A	N/A	All pipe work and stacks to be designed accommodate site seismic accelerations accordingly.	N/A	N/A	N/A	N/A
Maintenance	2.1.15	Nil		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

HAZOP Worksheet

Node 3.2
Description: N2 to PEM
Drawings: HYG-JEM-PRO-F03

Deviation / Guideword	#	Causes	Consequences			Frequency		Class	Safeguards			Recommendations / actions	Who
		description		description	rank	Description	rank		description	Risk reduction	SIL		
High Flow	3.2.1	Nitrogen supply line rupture. Forklift collision with overhead line.		Nitrogen leak (outside of containers). Personnel injury.	D	Possible during Nitrogen bank replacement and other maintenance activities.	3	IV	Physical barrier required to prevent moving machinery to travel between containers.	100		Customer to ensure nitrogen lines and system is protected from damage by collisions etc...	Customer
Low Flow	3.2.2	Low flow as a result of physical impact reducing bore size of the line.		Nitrogen purge will not work as flow switch will not feedback sufficient flow rate and thus purge = fail.	B	Possible during Nitrogen bank replacement and other maintenance activities.	3	IV	Two flow switches are in place FIZS-0125 / 0126.	100	II	N/A	N/A
Reverse Flow	3.2.3	Reverse flow of hydrogen back to Nitrogen system. Hydrogen system pressure 30barg vs Nitrogen bottle pressure of 10barg.		No Nitrogen being sent to purge. Rupture of 10barg system due to ingress of 30barg. Hydrogen purging system as oppose to Nitrogen.	B	When ever the electrolyser pressure is running.	5	I	Pressure transmitters PTZ-1107 (HPS) and PTZ-0303 (GGS) detect low system pressure equal to or lower than 0.2barg which feeds back the signal that the plant requires to be purged. Only then does instrument air feed supply double block and bleed solenoids valves to open the DBB to purge the system. Block valves are fail close and vent valve is fail open. DBB is de-energized in the closed position, thus cannot be opened in operation.	100 100		N/A	N/A
High Pressure	3.2.4	Malfunction of regulators on Nitrogen bottles and introduce 200barg pressure to the system.		Line over pressurization and line rupture.	B		3	II	PRV on Nitrogen panel shall safe guard against over pressurization of the system.	100		N/A	N/A
Low Pressure	3.2.5	Both cylinders run empty. Human error of not replacing.		Nitrogen purge will not work as flow switch will not feedback sufficient flow rate and thus purge = fail.	B	Possible during Nitrogen bank replacement and other maintenance activities.	3	IV	Two flow switches are in place FIZS-0125 / 0126.	100	II	N/A	N/A
High Temperature	3.2.6	Not possible to reach 80°C by ambient temperature.		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Low Temperature	3.2.7	Not an issue provided ambient does not fall below -40degC		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Level	3.2.8	No high level case possible		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Low Level	3.2.9	No low level case possible		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Composition Change	3.2.10	Incorrect supply of Nitrogen (supplies Oxygen for example)		Damage of cell stack sensor.	N/A	N/A	N/A	N/A	Ensure standard operating procedures cover the checking of bottles before connection made. Oxygen detection will read very high and alarm.	N/A	N/A	Confirm connection of Nitrogen bottles.	Customer

HAZOP Worksheet

Node 3.2
Description: N2 to PEM
Drawings: HYG-JEM-PRO-F03

Deviation / Guideword	#	Causes	Consequences			Frequency		Class	Safeguards			Recommendations / actions	Who
		description		description	rank	Description	rank		description	Risk reduction	SIL		
Impurities / contamination	3.2.11	Incorrect supply of Nitrogen purity. It needs to be 99.996%.		Damage of cell stack.	N/A	N/A	N/A	N/A	Ensure standard operating procedures cover the checking of bottles before connection made. Appropriate procurement processes in place.	N/A	N/A	Check available Nitrogen purity range that is available locally	Customer
Start up	3.2.12	Refer standard O&M for start up.		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Shut down	3.2.13	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Maintenance	3.2.14	N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

HAZOP Worksheet

Node 4.1
Description: AC power MV in
Drawings: HYG-JEM-ELE-E01

Deviation / Guideword	#	Causes	Consequences			Frequency		Class	Safeguards			Recommendations / actions	Who
		description		description	rank	Description	rank		description	Risk reduction	SIL		
Low Voltage	4.1.1	Voltage dip on 400V network		Hydrogen production will be compromised (low).					System shall trip if voltage drop is below 90% of nominal voltage.				
High Voltage	4.1.2	Voltage swell on 400V network.		Hydrogen generation will stop. Plant will trip.					System shall trip if voltage drop is above 110% of nominal voltage.				
Loss of power	4.1.3	Black out Tripped breaker Blown fuse		No 400V supply to Hydrogen plant.					System shall trip if voltage drop is below 90% of nominal voltage.				
Loss of power	4.1.4			Damaged cell stack if it freezes outside.					Back up power to be connected to enable cell stack heaters to operate. Automatic switching of back up line in a power loss situation.			Provide 400V backup power supply line for heaters	Customer
Lightning Strike	4.1.5	Lightning strike.		Direct hit on container resulting in controls failure.					Primary safeguard is lightning poles and appropriate connection to site earth grid.			Provide site lightning protection equipment	Customer

HAZOP Worksheet

Node 5.1
Description: Tap Water IN
Drawings: HYG-JEM-PRO-F03

Deviation / Guideword	#	Causes		Consequences		Frequency		Class	Safeguards			Recommendations / actions	Who
		description		description	rank	Description	rank		description	Risk reduction	SIL		
High Flow	5.1.1	Line rupture / physical damage. Loss of water.		Plant will not get water. Hydrogen generation will stop.	D	Vehicle movements. Earthquake.	3	IV	Physical barrier to protect the line. Adequate pipe supports. General maintenance inspections.	N/A	N/A	Provide physical barrier to protect the line	Customer
Low Flow	5.1.2	Line rupture / physical damage. Loss of water. Line restriction. Comms failure between buffer tank Level transmitter to supply pump.		Plant will not get water. Hydrogen generation will stop.	D	Vehicle movements. Earthquake.	3	IV	Physical barrier to protect the line. Adequate pipe supports. General maintenance inspections. Pressure switch PS-1212 on plant water line shall indicate low pressure and will shut plant down if low pressure indicated.	N/A	N/A	N/A	N/A
Reverse Flow	5.1.3	No reverse flow case possible. Water injected to intermediate buffer tank at atmospheric pressure.		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Pressure	5.1.4	?		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Incoming line to be protected via instrumentation and mechanically (relief valve) to restrict pressure to maximum 6barg.	Customer
Low Pressure	5.1.5	Ruptured incoming line line or other cause.		Plant will not get water. Hydrogen generation will stop.	D	Vehicle movements.	3	IV	Physical barrier to protect the line. Adequate pipe supports. General maintenance inspections. Pressure switch PS-1212 on plant water line shall indicate low pressure and will shut plant down if low pressure indicated.	N/A	N/A	N/A	N/A
High Temperature	5.1.6	Elevated temperature of water in lines due to thermal radiation on any exposed lines or buffer tank.		Slow degradation of RO membranes.	N/A	Possible on start up in summer months	N/A	N/A	All pipe shall be routed underground	N/A	N/A	All incoming water pipes should run underground or should be protected from heating up by solar irradiation	Customer
Low Temperature	5.1.7	Freezing of water filled lines.		Plant will not start as water will not flow. Rupture of lines.		35days/yr.	5		Pipe work is buried. Pressure transmitter on supply line shall protect pump and supply line.	N/A	N/A	Consideration of heat tracing above ground pipe work from pump to electrolyser container to be reviewed.	Customer
High Level	5.1.8	No high level case		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Low Level	5.1.9	No low level case		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Composition Change	5.1.10	No composition change case		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Impurities / contamination	5.1.11	Variances from required composition required for RO plant inlet. Formation of bacteria / algae.		Degradation of cell stack lifetime Degradation of RO membranes.	C	NA	3	NA	Conductivity transmitter (CT-1211) on water inlet. Conductivity transmitter (CT-1234) on outlet of RO membrane bank. Conductivity transmitter (CT-1271) on the outlet of mixed bed ion exchange process.	100	N/A	NA	NA

HAZOP Worksheet

Node 5.1
Description: Tap Water IN
Drawings: HYG-JEM-PRO-F03

Deviation / Guideword	#	Causes	Consequences			Frequency		Class	Safeguards			Recommendations / actions	Who
		description		description	rank	Description	rank		description	Risk reduction	SIL		
Start up	5.1.12	Commissioning start up: Air in line, contaminants in line.		Degradation of filters and RO membranes.	NA	NA	NA	NA	Double block and bleed valve on plant inlet shall be used to flush the line before putting water into the plant.	NA	NA	NA	NA
Shut down	5.1.13			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Climactic conditions	5.1.14	Earthquake damaging rigid pipe.		NA	NA	NA	NA	NA	Material selection - flexible pipe work.			Use non rigid pipe for water connection	Customer
Maintenance	5.1.15	Refer O&M for general maintenance.		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

HAZOP Worksheet

Node 5.2
Description: Drain Water Out
Drawings: HYG-JEM-PRO-F03

Deviation / Guideword	#	Causes	Consequences			Frequency		Class	Safeguards			Recommendations / actions	Who
		description		description	rank	Description	rank		description	Risk reduction	SIL		
High Flow	5.2.1	No high flow case.							Drain can handle maximum inlet flow case.				
Low Flow	5.2.2	Blockage of drain. Birds nest, animal, ice.		Plant will shut down. No hydrogen generation	E	During plant shut down periods.	3	IV	Drain to be closed loop until the outfall. Mesh cap on outfall end. Conductivity transmitter CT-1271 to shut plant down when water composition constraints is not met.				
Reverse Flow	5.2.3	No reverse flow case possible.											
High Pressure	5.2.4	Blockage of drain. Birds nest, animal, ice.		Plant will shut down. No hydrogen generation	E	During plant shut down periods.	3	IV	Drain to be closed loop until the outfall. Mesh cap on outfall end. Conductivity transmitter CT-1271 to shut plant down when water composition constraints is not met.				
Low Pressure	5.2.5	No low pressure case											
High Temperature	5.2.6	No high temperature case											
Low Temperature	5.2.7	Freezing of water filled lines.		Plant will shut down. No hydrogen generation	E	During plant shut down periods.	3	IV	Drain to be closed loop until the outfall. Mesh cap on outfall end. Conductivity transmitter CT-1271 to shut plant down when water composition constraints is not met.				
High Level	5.2.8	No high level case											
Low Level	5.2.9	No low level case											
Composition Change	5.2.10	No composition change case											
Impurities / contamination	5.2.11	No impurities / contamination case.											
Start up	5.2.12	No start up issues.											
Shut down	5.2.13	No shut down issues.											
Climactic conditions	5.2.14	Earthquake damaging rigid pipe.							Material selection - non rigid pipe work. Provides flexibility.				
Maintenance	5.2.15	Refer O&M for general maintenance.											

APPENDIX 4 EVENT TREE FREQUENCY CALCULATIONS

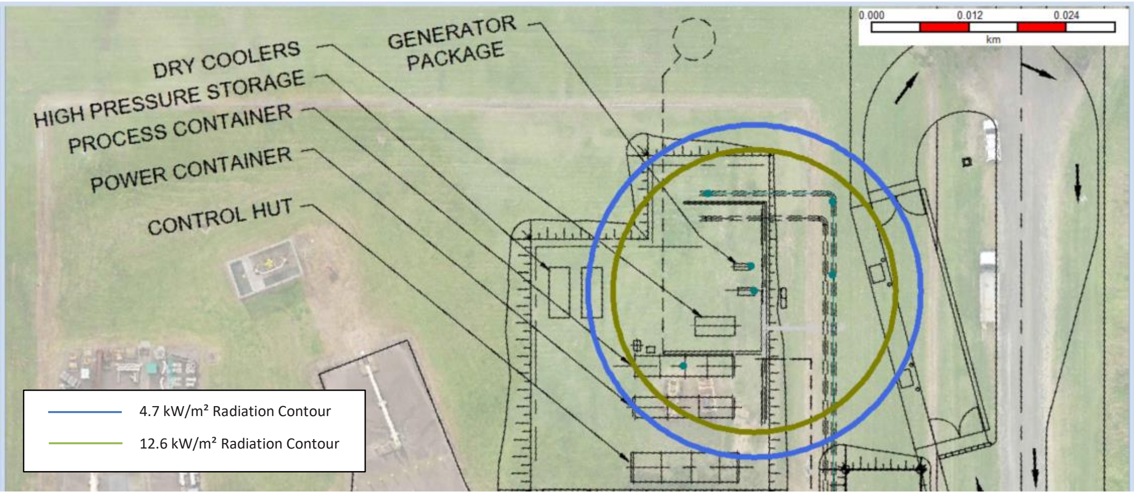
18667 WSGGT Event Tree Frequency Estimations -

Equipment	Plant Location	Frequency Data Used	Leak Frequency Units y -1	Parts Count	Cumulative Leak Frequency	Modelling Scenario	Substance	Leak Detected and Isolated? 80% Yes 20% No	Continuous leak rate kg/s	Ignition Probability	% of Jets Directed toward site boundary	Delayed Ignition Probability	Jet Fire Frequency (Directed Offsite)	Flash Fire Frequency	Total Frequency for Potential offsite fatal consequences	Comments
Flanges 500 NB	Buffer Storage riser	78 mm	1.00E-07	2	2.00E-07	3d	Hydrogen	0.2	1.46	0.063	0.3	0.027	7.56E-10	1.0E-09	**7.56E-10**	Only the jet fire extends beyone the boundary

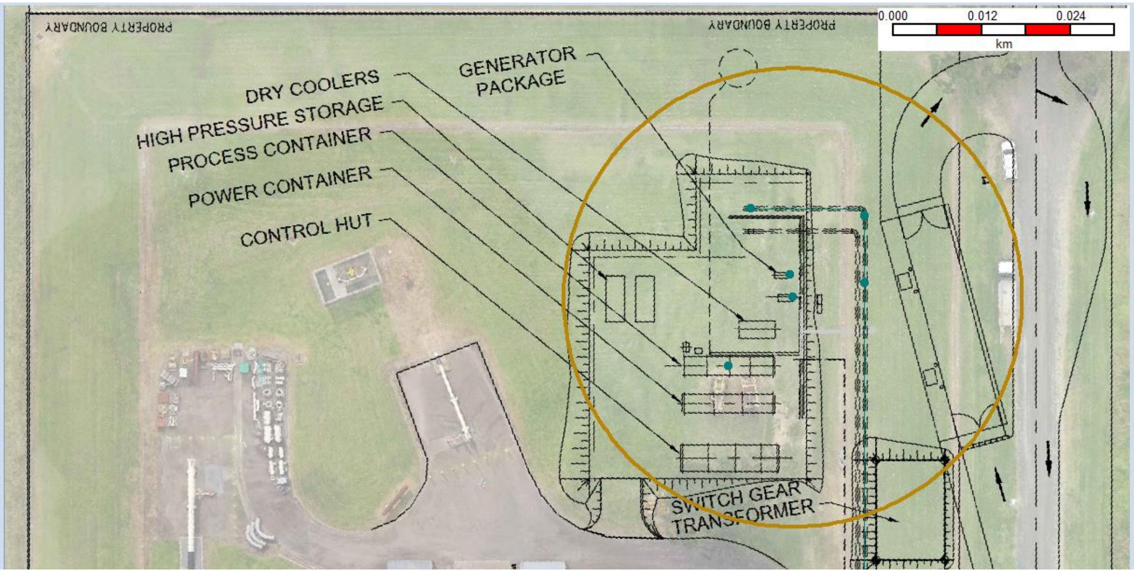
APPENDIX 5 PHAST CONTOURS

APPENDIX 5A CASE 1B

Case 1b: Jet Fire Radiation Contours

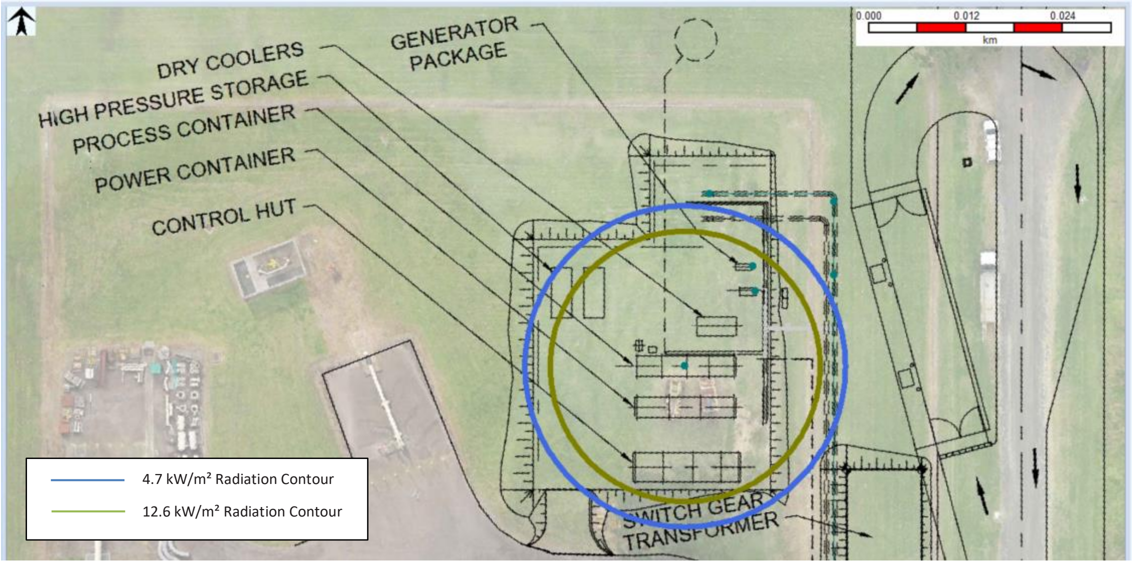


Case 1b: Flash Fire Contour

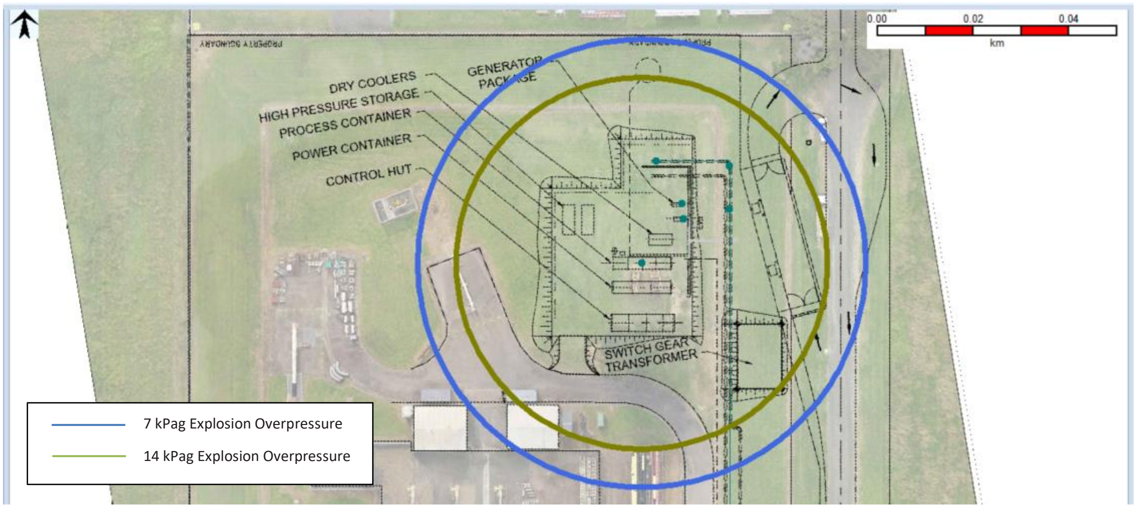


APPENDIX 5B CASE 2B

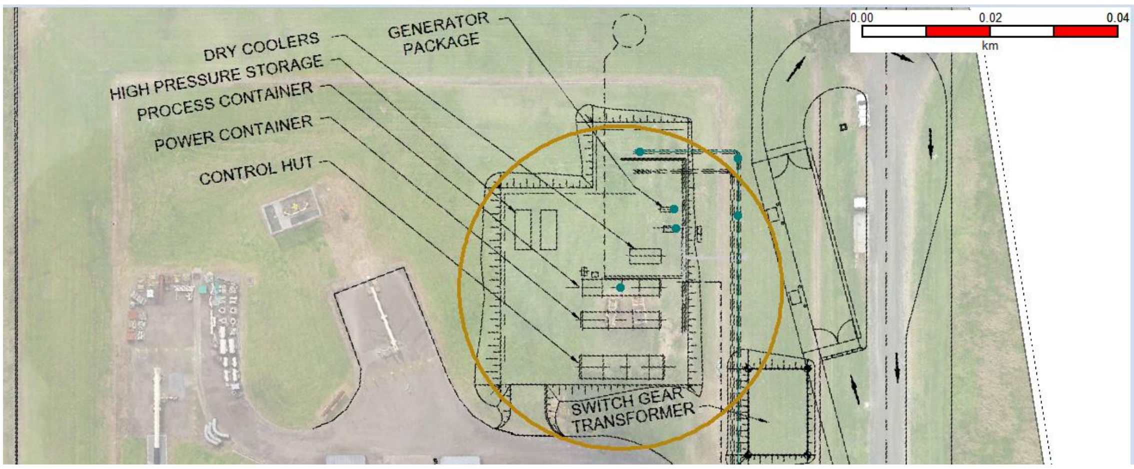
Case 2b: Jet Fire Radiation Contours



Case 2b: Explosion Contour

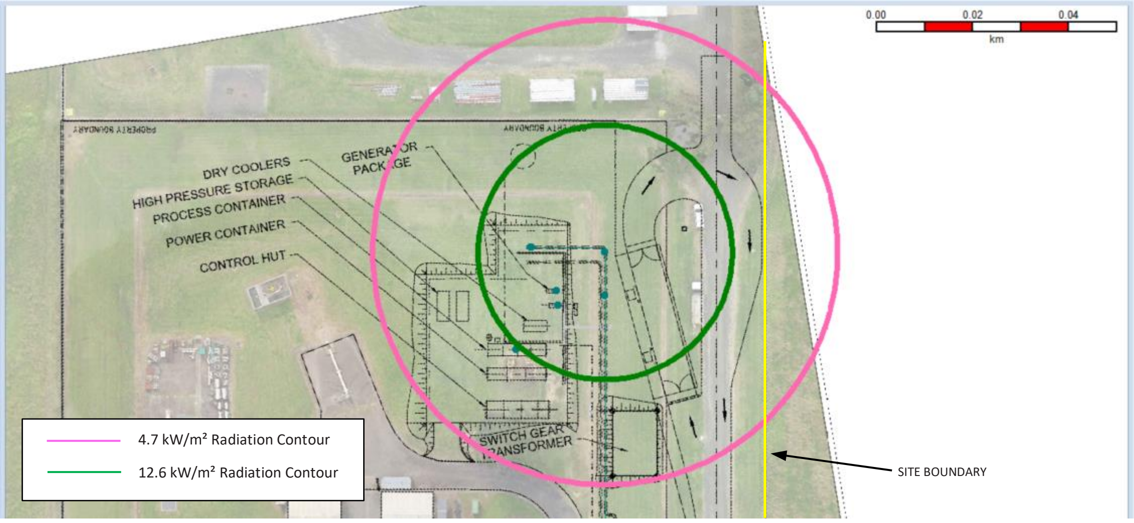


Case 2b: Flash Fire Contour

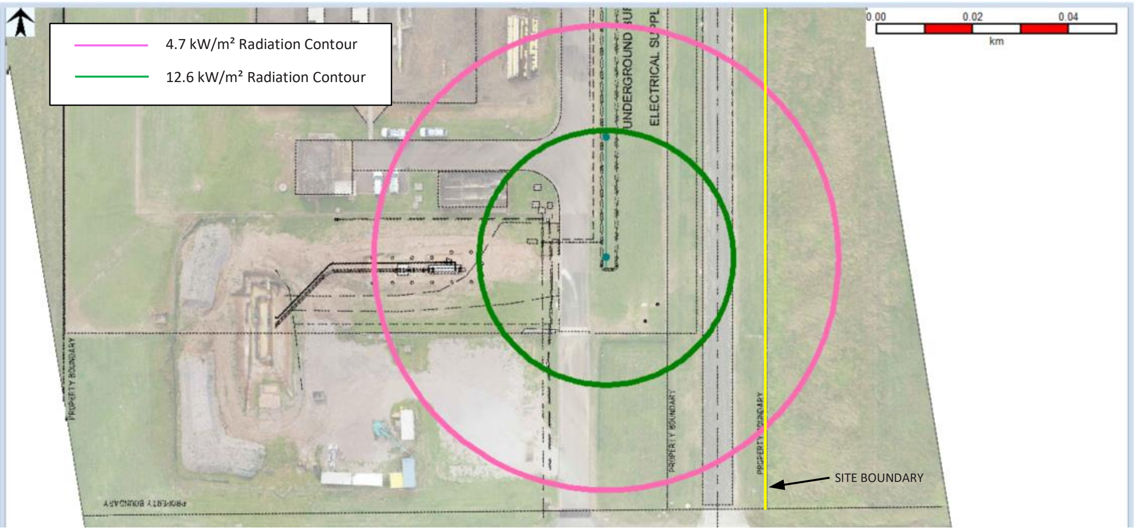


APPENDIX 5C CASE 3B

Case 3b: Jet Fire Radiation Contours (plant north)

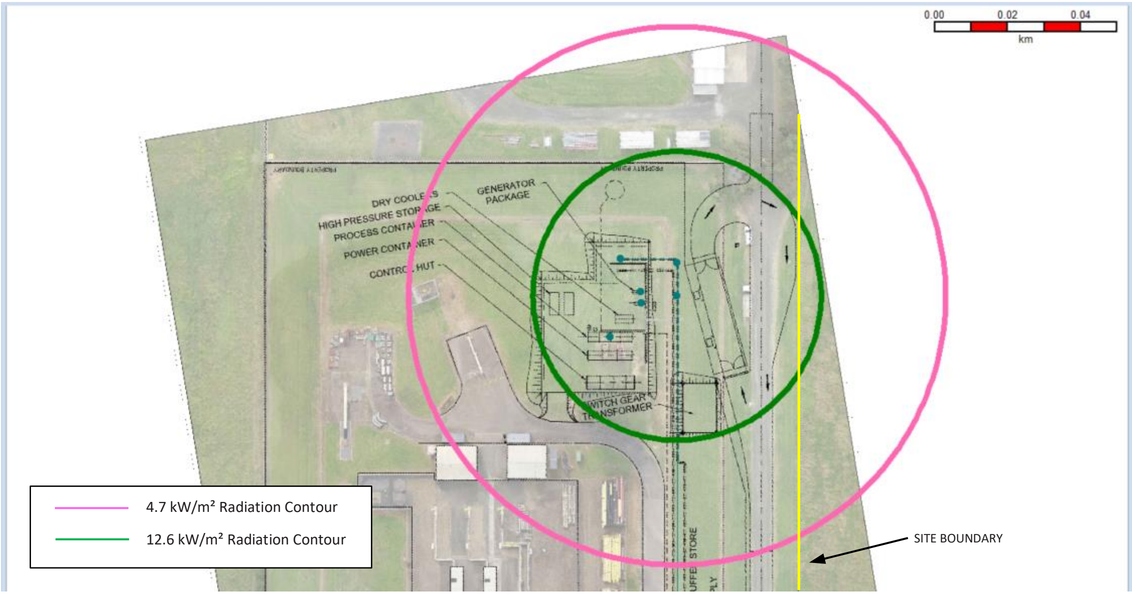


Case 3b: Jet Fire Radiation Contours (plant south)

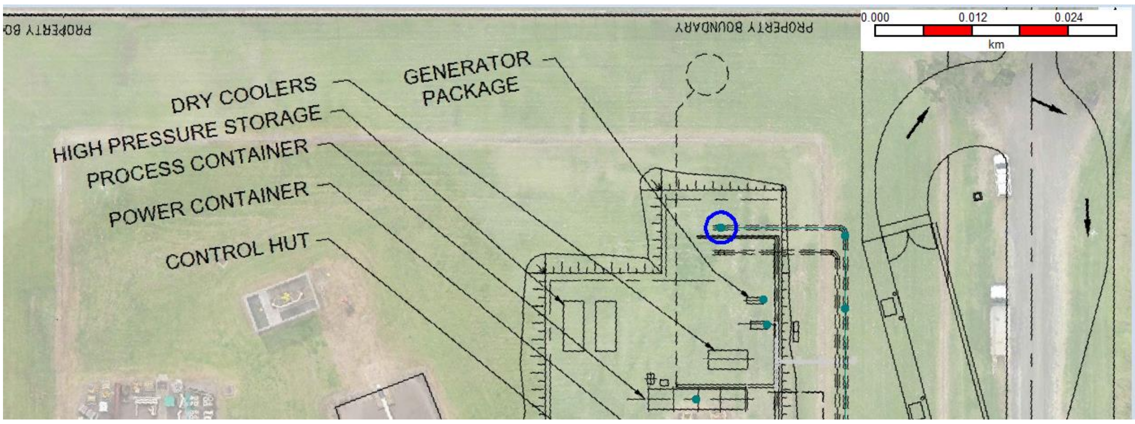


APPENDIX 5D CASE 3D

Case 3d: Jet Fire Radiation Contours

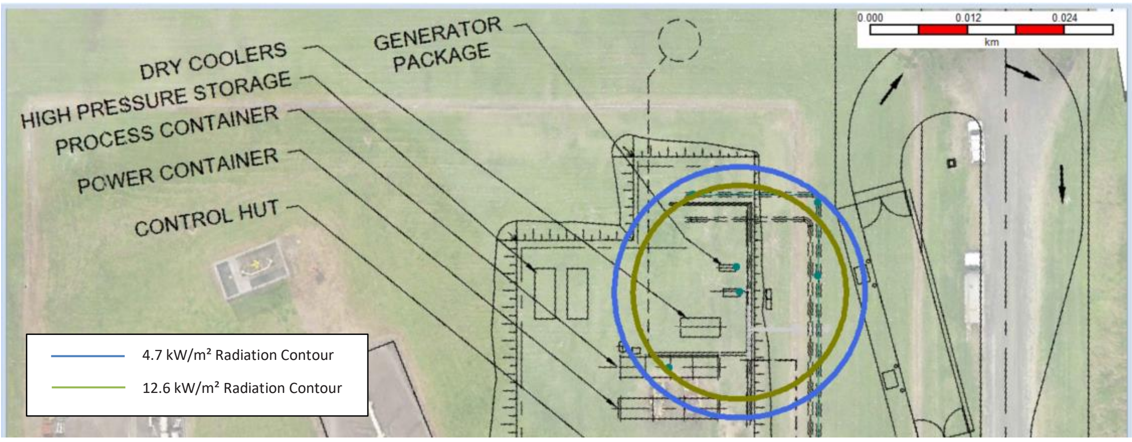


Case 3d: Flash Fire Contour



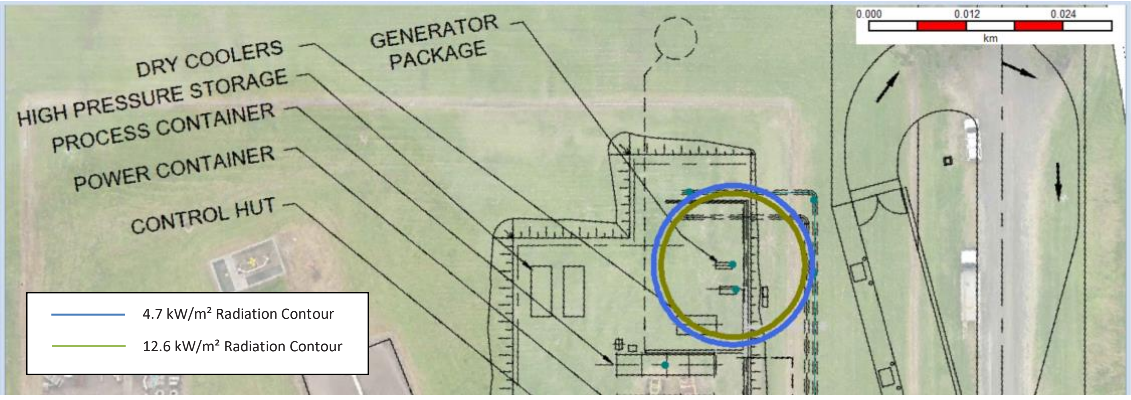
APPENDIX 5E CASE 4B

Case 4b: Jet Fire Radiation Contours

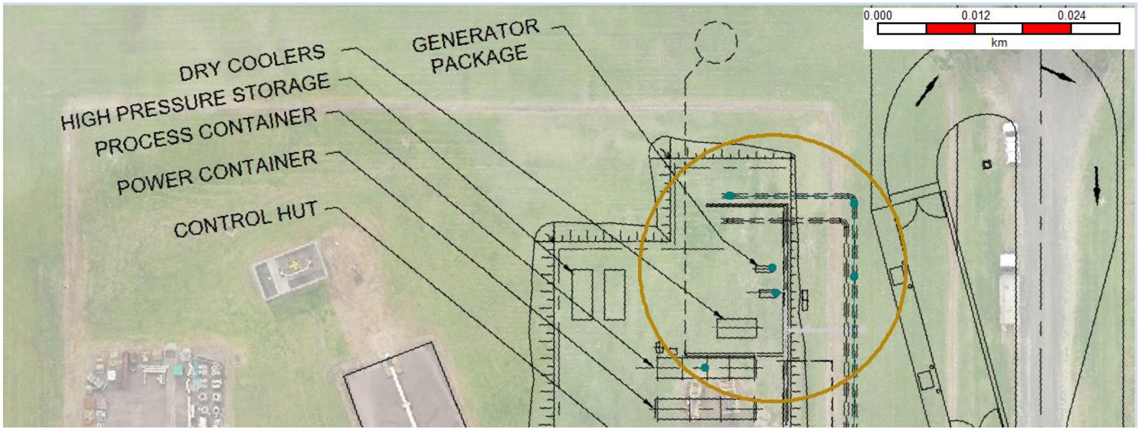


APPENDIX 5F CASE 6B

Case 6b: Jet Fire Radiation Contours



Case 6b: Flash Fire Contour



APPENDIX 5G CASE 7B

Case 7b: Jet Fire Radiation Contour