WSGGP HAZOP Report

Jemena Western Sydney Green Gas Project

Jemena Ltd

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Revision 1

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0	6/8/2019	LAH	SH	LTJ	Issued for client use
1	17/8/2020	FPL	AMB	LTJ	Revised post second workshop

CONTENTS

1 INTRODUCTION

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, 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 (microturbine) 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:

- 500 kW electrolyser package (including water treatment system, hydrogen production, hydrogen purification, cooling system and analyser systems)
- Waste water disposal system
- Hydrogen storage pipeline
- Natural gas network injection package (including provision for natural gas withdrawal)
- Gas panel package (for regulating hydrogen flow to other users)
- Gas fuelled generator package (capable of running on natural gas and, in the future, hydrogen)
- 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 a future additional 500 kW electrolyser stack and associated additional 100 Nm^3/h of hydrogen gas (double capacity)
- Electrical supply from 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 balance of plant.

Revision 1 of this document covers a second HAZOP workshop that was held subsequent to the initial workshop following provision of vendor package information and a small number of minor scope changes.

2 SCOPE OF STUDY

The scope and methodology adopted for the HAZOP study was communicated to participants prior to the workshop by means of a Participant's Briefing, attached in Appendix 3.

The scope of this project included within the first HAZOP workshop was balance of plant equipment, as follows:

- The waste water disposal system
- Hydrogen storage pipeline
- Natural gas network injection package
- Gas panel package, and
- Plant interfaces to mains water and natural gas distribution network.

The second workshop covered the following:

- The fuel gas supply to the microturbine repurposed as a hydrogen supply to the fuel cell
- Instrument air distribution system
- Natural gas supply to the microturbine
- Hydrogen compressor package suction line
- Hydrogen compressor package discharge line to cylinder filling, and the
- Nitrogen supply line.

The scope of this project excluded from the HAZOP workshops is as follows:

- Electrolyser package
- Gas fuelled microturbine generator package
- Hydrogen refuelling station package (future), and
- Hydrogen cylinder filling package.

These aspects shall be reviewed as part of subsequent dedicated formal studies.

A HAZID study was also conducted in this workshop as a basis for the Hazard Analysis required to be submitted to the NSW Government. The guidewords used can be found in Appendix 4.

Prior to this HAZOP a 30% design review had been conducted.

The following was assumed or used as the basis in the HAZOP:

- That the P&IDs of the existing facilities are true and correct.
- The vendor supplied information about the various packages is adequate for the purpose of the balance of plant review.

3 METHODOLOGY

The methodology adopted for this HAZOP is based on a facilitated workshop environment, whereby the facilities were broken down into small defined sections or "nodes" and reviewed via prompts from a selected guideword set.

The facilitator worked through the nodes and guidewords, encouraging constructive discussion from workshop attendees. Formal minutes of the workshop were taken, recording all key discussions and any actions identified. Actions were assigned to responsible persons or organisations.

The key findings are recorded in the formal minutes attached in Appendix 1

The minutes were reviewed by the HAZOP study team, allocation of the action item responsibilities was completed and priority categories assigned as detailed in Table 1.

Table 1: HAZOP Action Priority Categories

Priority	Description
1	Prior to design completion
2	Prior to commissioning
3	Post-commissioning

4 STUDY TEAM

The study team comprised the following personnel with their responsibilities in relation to this project outlined below.

The first workshop took place on 25-26 July 2019.

Table 2: HAZOP Study Team Members – First Workshop

HAZOP Team Member	Position/Role	Company
Lisa Hein	Chairperson / Facilitator	GPA Engineering
Nick Kastelein	Mechanical Engineer	GPA Engineering
Briony O'Shea	Senior Project Manager	GPA Engineering
Daniel Krosch	Mechanical Engineer	GPA Engineering
Sam Hatwell	Process Engineer	GPA Engineering
Steve Drinkald	Senior Project Engineer (E&I, Elec)	GPA Engineering
Nathan Tickle	Mechanical Technical Officer	Jemena
Paul Dixon	E&I Technical Officer	Jemena
Frank Libri	Commissioning Manager	Jemena
Norman Sim	Prn. Mechanical Engineer	Jemena
Andrew MacKay	Prn. Process Engineer	Jemena
Mark Rathbone	Snr. Project Manager	Jemena
Aldo Pace	Project Manager	Jemena
James de Gois	Projects / Engineering	ANT
Marcoen Stoop	Sales Director	ANT
Leon Terenyi	Project Engineer	Hydrogenics
Alistair Wardrope	Technical Lead	Jemena
J.P. Van Der Vyer	Principal E&I Engineer	Jemena
Bessim Geusher	O&M Integration	Jemena

The second workshop took place on 4 and 12 August 2020. The team is listed below.

Table 3: HAZOP Study Team Members – Second Workshop

HAZOP Team Member	Position/Role	Company
Francois Lambrechts	Chairperson/Facilitator	GPA Engineering
Josh Wickham (P/T)	Project Manager	GPA Engineering
Astrid Bealing	Senior Process Engineer	GPA Engineering
Nick Kastelein	Mechanical Engineer	GPA Engineering
Cameron Ryan	Senior Mechatronics Engineer	GPA Engineering
Jason Dini	Senior Electrical Engineer	GPA Engineering
Alistair Wardrope (P/T)	Technical Lead	Jemena
Nathan Tickle (P/T)	Mechanical Technical Officer	Jemena
Paul Dixon (P/T)	E&I Technical Officer	Jemena
Norman Sim (P/T)	Principal. Mechanical Engineer	Jemena
Andrew MacKay (P/T)	Principal Process Engineer	Jemena
Rahul Dorairaj (P/T)	H&S Advisor	Jemena
Craig Dugan (P/T)	Chief Executive Officer	Optimal
Mathew Moore (P/T)		Optimal
Chris Rouse (P/T)		Coregas
Wodek Jakubik (P/T)	Innovation Manager	Coregas
Donald Guan (P/T)	Applications Engiineer	Ballard

5 DISCUSSION OF FINDINGS

The overall process was successful in achieving the objectives of the study. The study team possessed the necessary experience and knowledge to be able to address the majority of the issues at the time within the confines of the meeting.

Where information was not adequate, actions have been assigned to GPA Engineering, Jemena or vendor personnel to follow up and obtain further clarification.

The study is considered to be at a 90% design completion and no further safety in design reviews are planned. Several other safety in design reviews have already been completed, including:

- 60 and 90% design reviews
- Pipeline Safety Management Study (SMS)
- Vendor HAZOPS for the Electrolyser and Gas Fuelled Generator Packages
- Layer of Protection Analysis (LOPA) / Safety Integrity Level (SIL) review
- Human Factors Review (as part of the model review)
- Constructability review (as part of the model review)
- Environmental Impact Statement
- Noise Study, and
- A preliminary hazard analysis (PHA) prepared in accordance with the NSW Planning Department's Hazardous Industry Planning Advisory Paper No. 6, 'Hazard Analysis' and Multi-level Risk Assessment.

Key aspects of the process design and the layout of the facility have been finalised to approximately 90% overall, although aspects of the additional/new scope relating to the hydrogen compressor, cylinder filling package, microturbine, fuel cell and natural gas/nitrogen supplies were not confirmed yet, as vendor details were not fully available. The design was progressed enough, however, that a HAZOP was considered appropriate in finalising requirements to be included in the final design.

Details of all discussions and findings are presented in the formal HAZOP study minutes attached in Appendix 1.

Key issues that may significantly impact on the final system design, implementation and operation are summarised below. This information is prefixed with the following notable physical properties of hydrogen and oxygen:

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. The hazardous area associated with hydrogen (that is, the region in which a flammable atmosphere may exist) is therefore relatively small.

Prolonged exposure to hydrogen can affect some materials to compromise their mechanical properties. In particular, steel and other metals experience hydrogen embrittlement. Hydrogen embrittlement results in a reduced tolerance to defects and a reduction in fatigue life; this can be accommodated in design by ensuring that materials are defect-free, 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 material, stress level, metal tensile strength, grain size and microstructure.[1]

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 be the result 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.

Overview of key actions:

Leak prevention and management

- To manage the integrity of the piping and equipment in the facility, above ground piping is stainless steel which is more resistant than carbon steel to H2 embrittlement. All piping, including buried, has been design as ‘no rupture" and uses a low design factor and relatively low-strength grade (X52) material (guidance as per ASME B31.12) to ensure low stress conditions protecting against rupture due to H2 embrittlement. There is an action to further review requirements relating to hydrogen-assisted fatigue crack growth (HA-FCG) relating to defect inspection, weld defect tolerances, and monitoring.
- To ensure integrity of soft materials e.g. Swagelok fittings, gaskets, hot-tap O-rings, insulation joints, instrument seals instrumentation in hydrogen service, there is an action to confirm with vendors their compatibility with hydrogen.
- To further reduce likelihood of large leaks, review potential alternatives for mechanical connections on large diameter joins.
- Although separate from hydrogen leaks, actions were also raised to check for materials impact through cooling of natural gas due to expansion, which could lead to weakened materials, rupture, fire and then escalation due to fire impact on nearby or adjacent hydrogen piping and equipment.

Leak Detection

- Add a short-term isolation function, which shuts in the system for 15 minutes and monitors pressure change during shut-in to detect leaks. Include the function as a routine test in operating procedures.
- A low pressure trip or rate-of-change trip PALL-06015 downstream of the electrolyser will be added to shut down the electrolyser in the event of a leak/rupture.

[1] https://www.energy.gov/sites/prod/files/2014/03/f12/fcm01r0.pdf

- Hydrogen detectors will be made a requirement for all personnel entering site. Hydrogen detectors will be installed in the electrolyser building and there is an action to install a hood with a hydrogen detector over the gas panel and any other equipment with high potential for leaks.
- Determine the requirement for an oxygen detector in the electrolyser building – both for leak detection (high oxygen) and nitrogen leak (low oxygen),
- Hydrogen leak detection is required to initiate a local beacon/siren at the site entrance gate to alarm on hydrogen detection so that operators do not approach faulted equipment. Make siren interlock with gate (so only alarms if someone is there).
- Create a leak response procedure for hydrogen leak detection.
- Determine requirements for an infrared camera to be installed on site as hydrogen flames are not visible in the daylight. Provide Infrared cameras for personnel entering the site.
- Determine if any further fire detection is required.
- For oxygen and hydrogen vents: determine if gas breakthrough is feasible from the electrolyser oxygen or hydrogen streams into the drains/waste water system. If breakthrough is possible, conduct a LOPA/SIL study on low level instrumentation.
- Confirm SIL rating requirements of exhaust fan failure detection as well as H2 and O2 detection in the building.
- A particular scenario was checking for leaks following maintenance or temporary shutdowns, as these may not receive the same level of scrutiny as commissioning and initial construction. It was pointed out that hand held gas detectors may be more sensitive, and therefore better able to detect even small leaks, than permanently installed gas detectors which should not be relied upon for testing flanges and joints.

Oxygen

- Hydrogenics to provide input from package HAZOP on management of oxygen risks.
- Oil and grease are particularly hazardous in the presence of oxygen as they can ignite spontaneously. They should never be used to lubricate oxygen or enriched-air equipment. Special lubricants which are compatible with oxygen must be used. Hydrogenics to specify and provide any oil/grease in this service.

Ignition Control

- Design of all vents to be made non-sparking. Vents also to be routed to safe location, including using dispersion models to make sure vented gas will not impact on nearby equipment.
- Determine if any modifications to Jemena's existing ignition control management procedures are required such as hot work permit system, antistatic clothing requirements or non-sparking tooling.
- Specify access control requirements for the electrolyser package.
- Any air left in hydrogen facility equipment after construction or maintenance can result in an explosive atmosphere on start-up. Prepare a commissioning plan for quality, with focus on pipeline cleanliness and dryness. Strict use of nitrogen purging after maintenance to be enforced in hydrogen service, and included in all start-up/re-commissioning operating procedures.

Product Specification

- There is a scenario where an incorrect false high reading from the natural gas flow meter at the upstream pressure reduction metering station could result in higher hydrogen flows, resulting in high concentrations of hydrogen in the pipeline stream (higher than the upper limit agreed with the technical regulator). In the extreme case, if a near pure slug of hydrogen enters the secondary gas main, which some customer appliances are not suitable for, a flame out could result and an explosive atmosphere could accumulate. There is an action to conduct a LOPA/SIL study to determine safety integrity requirements for flow metering to prevent over injection of H2 into the gas mains.

- Add low natural gas flow shut-off of hydrogen injection, so that there is a minimum NG flow required to be injecting.
- Microturbine cannot accept natural gas with more than 17 % hydrogen (as mentioned in the HAZOP – note that this is different from the fuel requirements specification, document 410002H TR Fuel Requirements, that quotes a maximum of 1%; it is understood that the higher value is the limit to prevent damage, as opposed to ensuring stable operation, and will be confirmed with the OEM). When the future connection to the hydrogen supply is made, it must only be connected once operation on hydrogen has been certified, and the connection from the natural gas supply has been removed (not just isolated).

Overpressure

- Hydrogen supply could potentially overpressure the natural gas line – high pressure shutdowns are in place in the design. Conduct a review (LOPA/SIL) of overpressure safety equipment, with consideration to integrity level required and ensure compliant with Jemena's existing design requirements for JGN.
- The hydrogen compressor produces a very high pressure hydrogen stream used to fill cylinders. It is important that the correct rating cylinders are delivered and checked, and appropriate overpressure protection is fitted, including reconsidering bursting discs that will result in a large uncontrolled hydrogen release if they burst.
- Similarly, natural gas and nitrogen cylinders are typically at much higher pressure than the systems they will feed. Uncertainty in the supply information may result in inadequate overpressure pressure (and regulation) protection; care is to be taken when specifying the connections and the scope of design to ensure no item is missed during design and construction and subsequent operation.

Maintenance

- Special materials suitable for hydrogen and or oxygen service are required. Jemena is to develop a critical spares management program for the facility.
- Sparing philosophy to ensure that natural gas service components are not used in hydrogen system when incompatible, or nitrogen components in hydrogen or natural gas service, and vice versa.

Training and Competency

- Hydrogen production is new to Jemena. Jemena are to develop competency based training module for the new facility. Make competency based training a requirement for all hydrogen service operators. Create register for management of accredited personnel.

Waste Water

- Conduct review to minimise wastewater production. Design pre-filtration system to reduce waste water production rate from RO system.

- Sizing basis for on-site water inventory is 5 m3 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.

Commissioning

- There will be a number of different packages from various suppliers ultimately commissioned at the same time. The potential exists that conflicts arise that could result in hazards being missed. A commissioning coordination plan is to be produced with the aim of ensuring that the various parts are commissioned and started up in such a way that everyone is clear on the plan, the steps, and the schedule.

6 CONCLUSIONS

The study was able to adequately review the design of the systems associated with the WSGGP, which is estimated to be at 90% completion.

The review concluded that, in most respects, the proposed designs were in accordance with requirements of the applicable industry standards and that the design had been documented and completed to the point where the Study Team was confident in the successful implementation of the project.

However a number of key issues requiring final resolution were identified. These have been described in detail in Section 5. Additionally – it is strongly recommended that the package vendors – ANT/Hydrogenics, Coregas, Ballard and Optimal – provide HAZOP reports/closeouts for their equipment, and further specific input into the design as required to close out HAZOP action items and fully detail the remaining balance of plant design.

A detailed close-out review is essential in guaranteeing that all design and safety objectives are met following final detailed design and construction.

All HAZOP study actions must be closed out prior to system commissioning and the requirement for further formal reviews assessed during the project implementation as the detailed design develops.

Any further HAZOP will depend on the magnitude of the changes from the design assessed in this HAZOP.

APPENDIX 1 FORMAL STUDY MINUTES

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.

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**

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.

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		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

		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-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

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		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.							

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		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.							

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		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
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).

			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

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			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. H_2, CH_4, O_2 & H_2O.	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*							

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		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								

			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*							

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			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

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		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.					

			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).							

			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.				

			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*							

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			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*							

		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		

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			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.							

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		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.							

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		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.							

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			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		

			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.							

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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.					

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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.

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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

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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.					

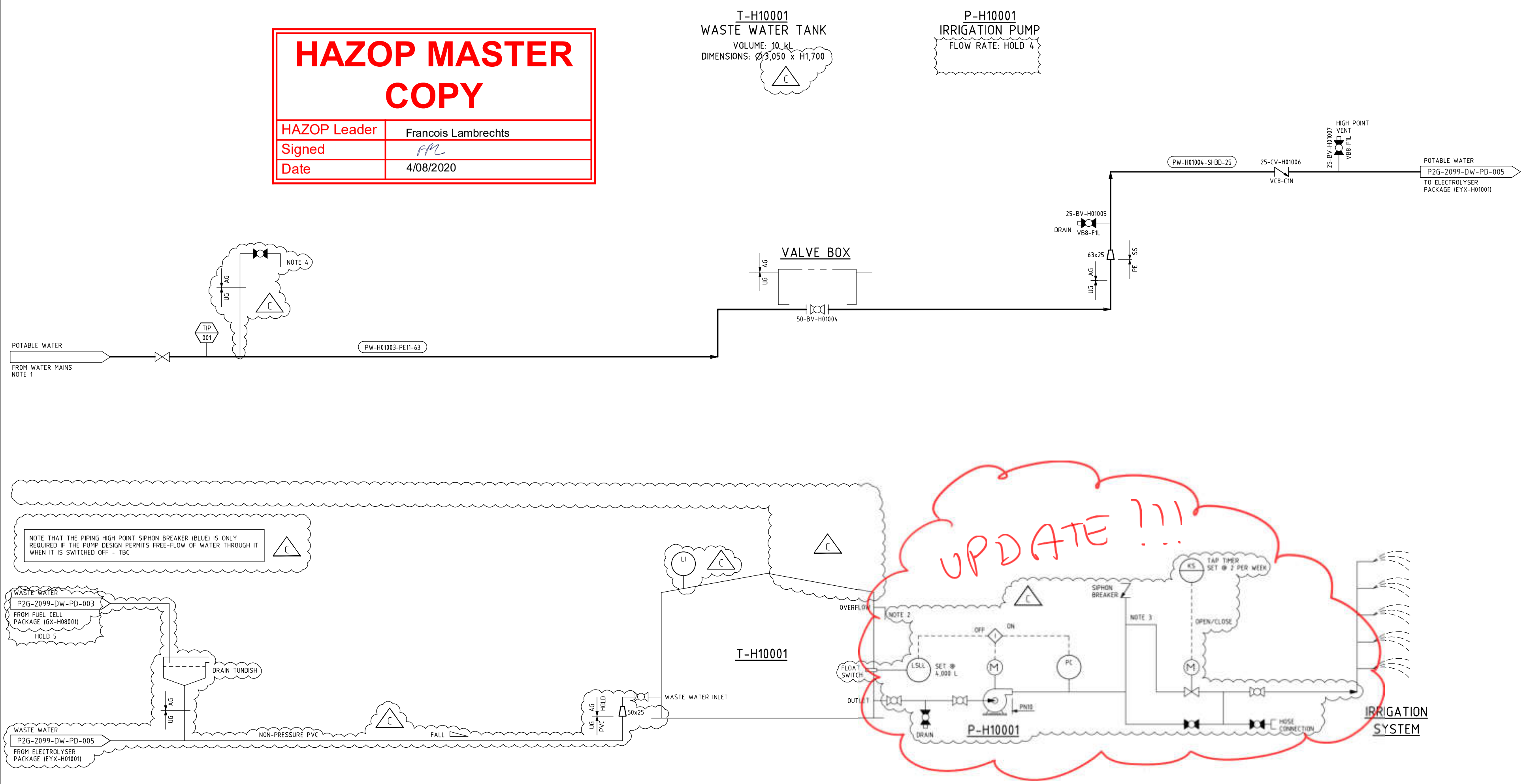
HAZID Minutes

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 2 HAZOP MASTER DRAWINGS

HAZOP MASTER COPY

HAZOP Leader	Francois Lambrechts
Signed	FPL
Date	4/08/2020



NOTES:

1. FACILITY BOUNDARY TO BE PROVIDED WITH REDUCED PRESSURE ZONE (RPZ) VALVE FOR BACK-FLOW PREVENTION CONSISTENT WITH SYDNEY WATER REQUIREMENTS FOR INDUSTRIAL CONNECTIONS.
2. OVERFLOW TO DISCHARGE ONTO THE LAWN ADJACENT THE IRRIGATION SYSTEM.
3. PUMP DISCHARGE HIGH POINT TO BE AT LEAST ABOVE THE HEIGHT OF THE FLOAT SWITCH TO PREVENT GRAVITY DRAINING THROUGH INACTIVE PUMP AND KEEP PUMP FLOODED IN NORMAL OPERATION.
4. PROVISION OF AN ABOVE-GROUND WATER TAP AT FRONT OF FACILITY, E.G. FOR CLEANING OF SOLAR PANELS.

HOLDS:

1. DELETED.
2. DELETED.
3. DELETED.
4. SIZING DETAILS.
5. HYDROGEN FUEL-CELL PACKAGE WATER EXHAUST DRAIN REQUIREMENTS.

ASSET MANAGER: Jemena

Produced by Jemena Asset Management (6) Pty Ltd ABN 52 104 352 650

ASSET OWNER: Jemena

REV	DATE	DESCRIPTION	DRAWN	CHECKED	ENG CHK	APPRV
C	28/07/20	ISSUED FOR HAZOP #2	GPA	NK	AB	IIK
B	04/03/20	ISSUED FOR REVIEW (18667)	GPA	DK	AMB	LTJ
A	27/11/19	ISSUED FOR 90% REVIEW	GPA	JHW	NPK	IIK

DRAWING No.	REFERENCE DRAWINGS

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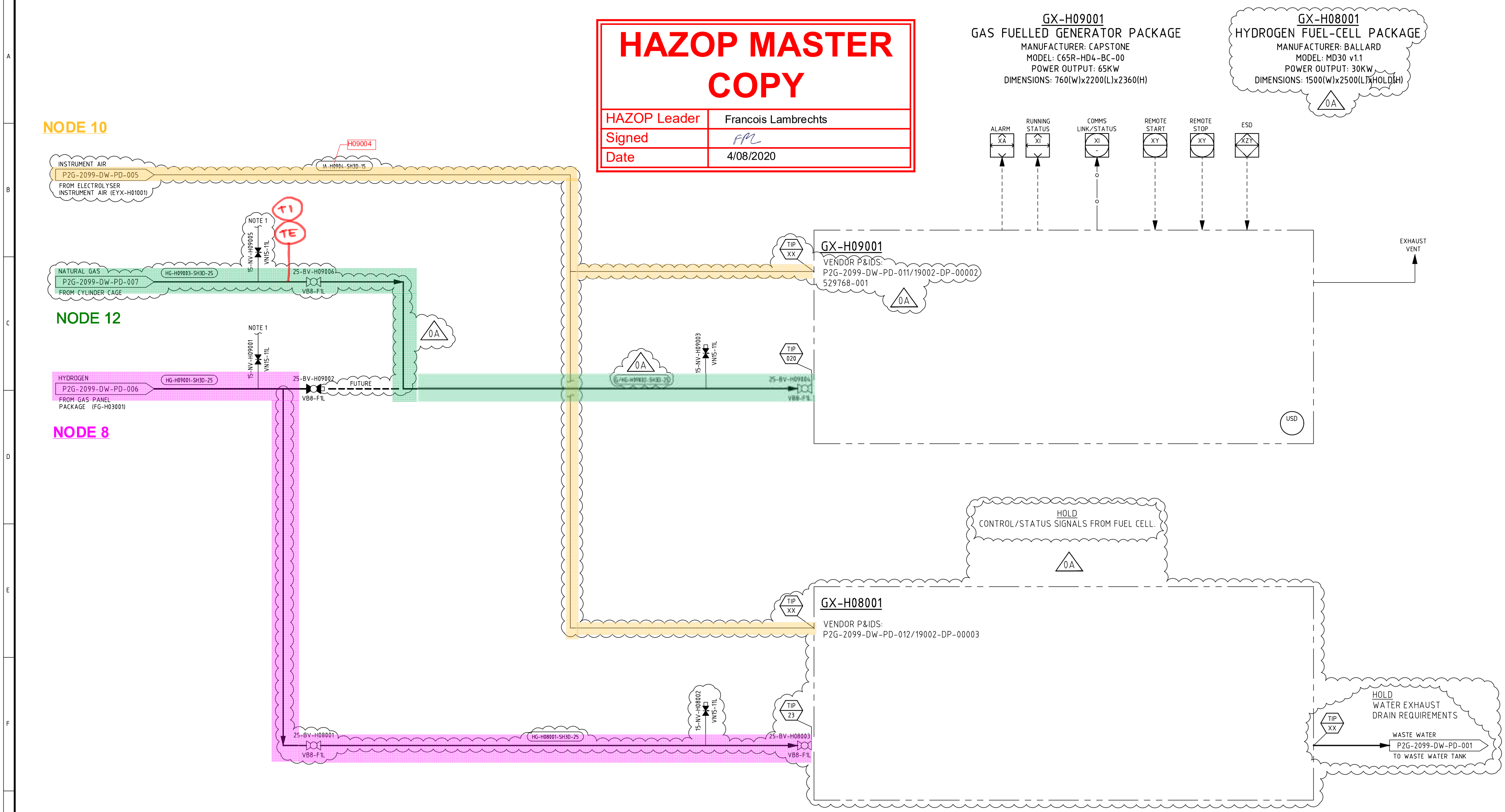
WESTERN SYDNEY GREEN GAS PROJECT
WATER SUPPLY & DISPOSAL SYSTEM
PIPING & INSTRUMENTATION DIAGRAM

DRAWN	GPA		
DESIGN	JHW	SCALE	N.T.S
CHECKED	NPK	SUPERSEDES	A1
APPROVED	IIK	DRAWING NUMBER	REV
DATE	27/11/19	P2G-2099-DW-PD-001	C

HAZOP MASTER COPY

HAZOP Leader	Francois Lambrechts
Signed	FPL
Date	4/08/2020



NOTES:
1. VENT IS DIRECTED INTO THE FACILITY VENT, LINE V-H03007-SH3D-025 ON P&ID P2G-2099-DW-PD-006.

REV	DATE	DESCRIPTION	DRAWN	CHECKED	ENG CHK	APPRV
0A	28/07/20	ISSUED FOR HAZOP #2	GPA	NK	AB	IIK
0	04/03/20	ISSUED FOR CONSTRUCTION WITH HOLDS (18667)	GPA	DK	AMB	LTJ

DRAWING No. | REFERENCE DRAWINGS

ASSET MANAGER
Jemena
Produced by
Jemena Asset Management Pty Ltd
ABN 53 086 013 461

ASSET OWNER
Jemena
Jemena Gas Networks (NSW) Ltd
ABN 87 003 004 322

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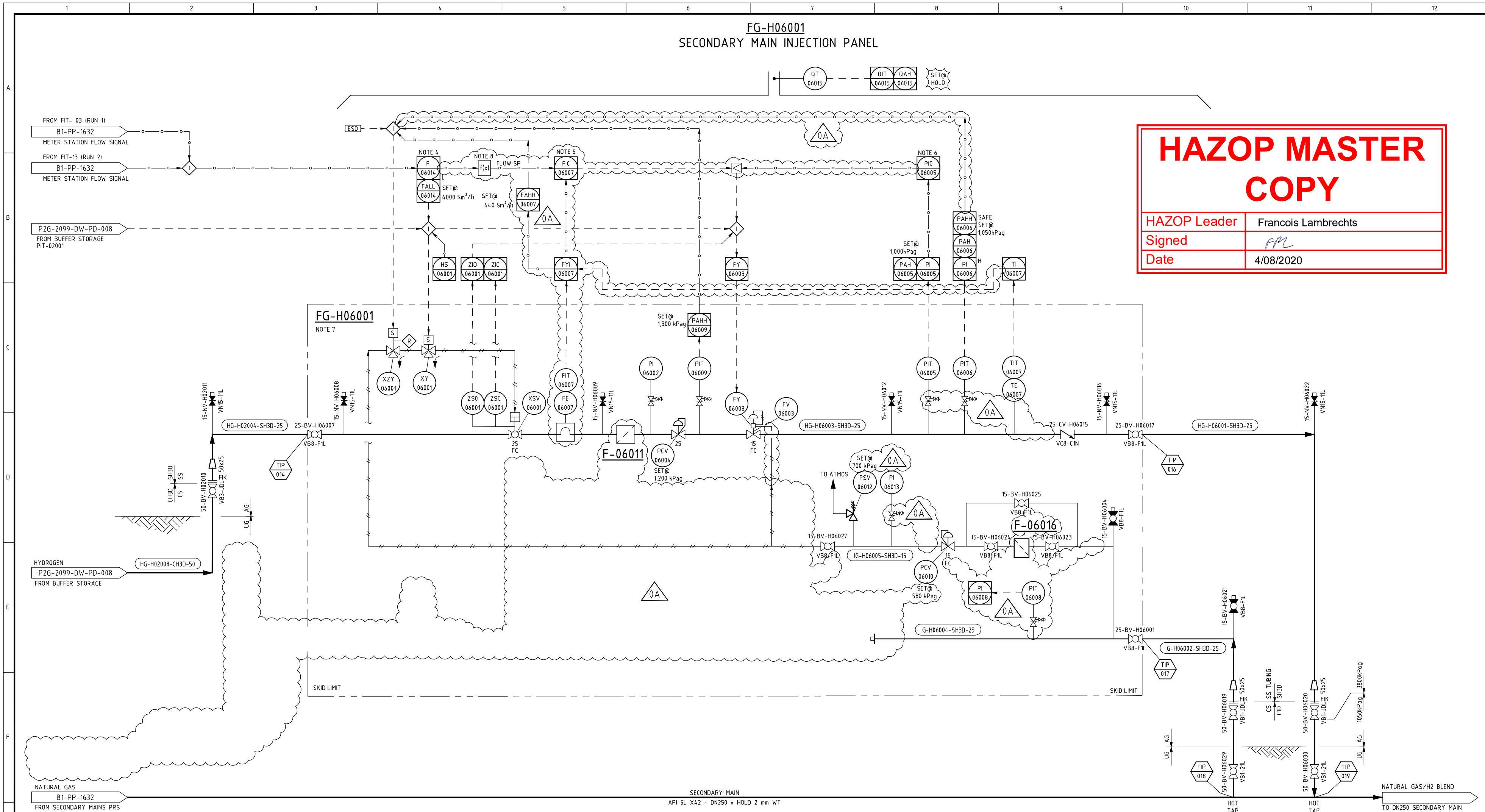
WESTERN SYDNEY GREEN GAS PROJECT
GAS FUELLED GENERATOR & FUEL CELL PACKAGE
PIPING & INSTRUMENTATION DIAGRAM

DRAWN	GPA		
DESIGN	SH	SCALE	N.T.S
CHECKED	NPK	SUPERSEDES	A1
APPROVED	LTJ	DRAWING NUMBER	
DATE	05/04/19	P2G-2099-DW-PD-003	REV 0A



HAZOP MASTER COPY

HAZOP Leader	Francois Lambrechts
Signed	FPL
Date	4/08/2020

NOTES:

1. TRANSITION PIECE.
2. SHUTDOWN ON HIGH HYDROGEN BLEND.
3. INTERLOCK TO ENSURE XSV-06001 IS OPENED BEFORE FV-06003.
4. FLOW SIGNAL FROM METER STATION TAKEN AS MOVING AVERAGE OVER PAST 6 HOURS.
5. FLOW CONTROLLER FIC-06007 CONTROLS FLOW BASED ON OPERATOR-CONFIGURED HYDROGEN FLOW SET POINT (WITH HARD-CODED MAXIMUM OF 400 Sm^3/h). OR OPERATOR-CONFIGURED BLEND-RATE (WITH HARD-CODED MAXIMUM OF 10%)
6. PRESSURE CONTROLLER PIC-06005 DECREASES FV-06003 OPENING ON HIGH PRESSURE BETWEEN 1,000 kPag (100% OPEN) AND 1050 kPag (0% OPEN).
7. ALL VENTS/BLEEDS ON FG-H06001 TO BE MANIFOLDED TOGETHER AND VENTED TO A SAFE ELEVATED LOCATION.
8. HYDROGEN RATIO CONTROL INITIALLY SET AT 2 MOL% HYDROGEN BLEND IN NATURAL GAS.

HOLDS:

1. PSV SETPOINT AND DESIGN DETAILS TO BE CONFIRMED.
2. SECONDARY MAIN MATERIALS OF CONSTRUCTION.

REV	DATE	DESCRIPTION	DRAWN	CHECKED	ENG CHK	APPRV
0A	28/07/20	ISSUED FOR HAZOP #2	GPA	NK	AB	IIK
0	04/03/20	ISSUED FOR CONSTRUCTION WITH HOLDS (18667)	GPA	DK	AMB	LTJ

DRAWING No. | REFERENCE DRAWINGS

ASSET MANAGER
Jemena
Produced by
Jemena Asset Management Pty Ltd
ABN 53 086 013 461

ASSET OWNER
Jemena
Jemena Gas Networks (NSW) Ltd
ABN 87 003 004 322

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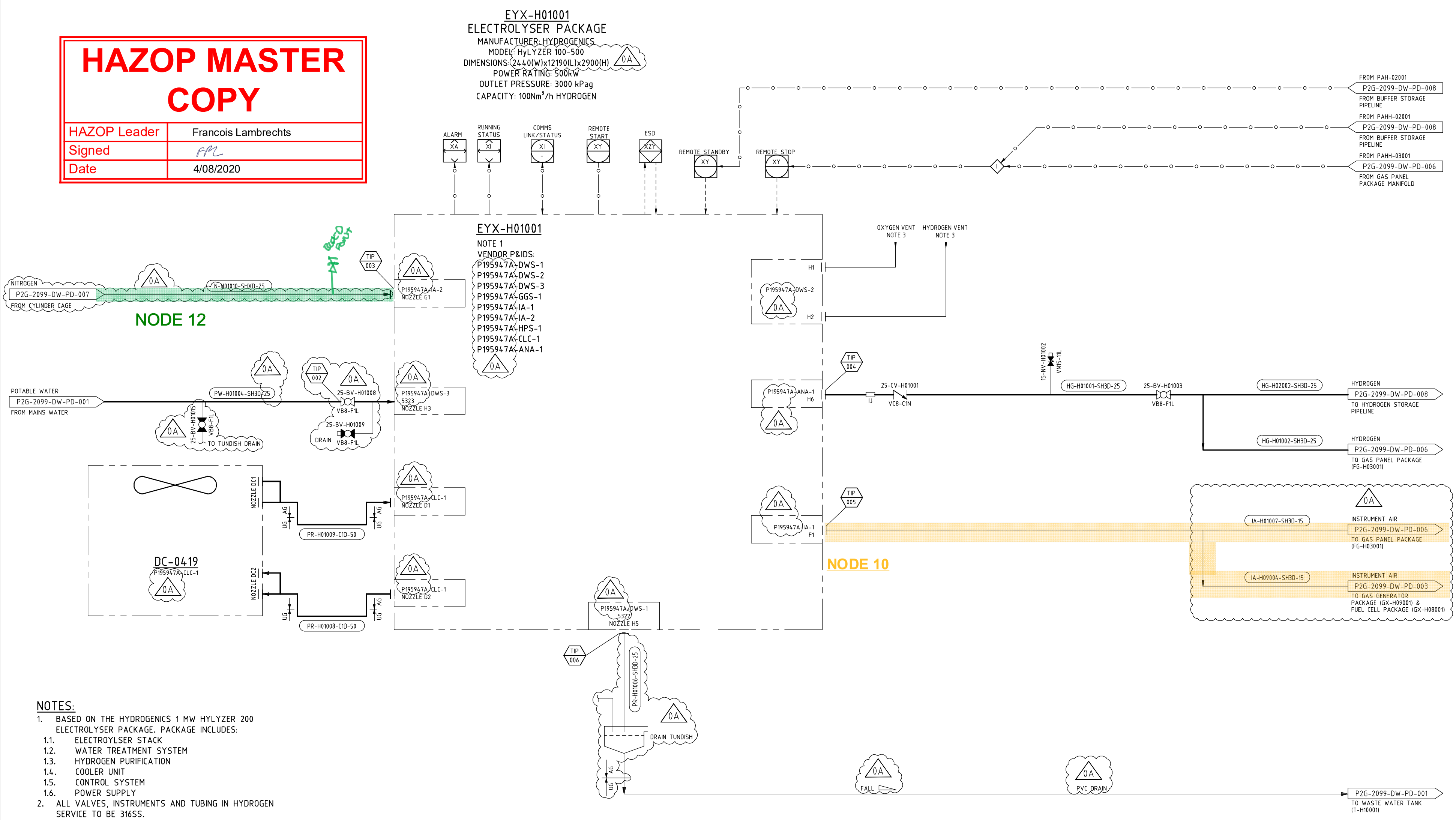
WESTERN SYDNEY GREEN GAS PROJECT
SECONDARY MAIN INJECTION PANEL

PIPING & INSTRUMENTATION DIAGRAM

DRAWN	GPA		
DESIGN	SH	SCALE	N.T.S
CHECKED	NPK	SUPERSEDES	A1
APPROVED	LTJ	DRAWING NUMBER	P2G-2099-DW-PD-004
DATE	05/04/19	REV	0A

HAZOP MASTER COPY

HAZOP Leader	Francois Lambrechts
Signed	FL
Date	4/08/2020



NOTES:

1. BASED ON THE HYDROGENICS 1 MW HYLYZER 200 ELECTROLYSER PACKAGE. PACKAGE INCLUDES:
   - 1.1. ELECTROYLSER STACK
   - 1.2. WATER TREATMENT SYSTEM
   - 1.3. HYDROGEN PURIFICATION
   - 1.4. COOLER UNIT
   - 1.5. CONTROL SYSTEM
   - 1.6. POWER SUPPLY
2. ALL VALVES, INSTRUMENTS AND TUBING IN HYDROGEN SERVICE TO BE 316SS.
3. VENT TO SAFE LOCATION. VENT REQUIREMENTS TO BE CONFIRMED BY THE ELECTROLYSER PACKAGER. VENTS TO BE SUPPLIED BY ELECTROYSER PACKAGER. DESIGN TO BE CONFIRMED.

DRAWING No.	REFERENCE DRAWINGS

ASSET MANAGER
Jemena
Produced by Jemena Asset Management Pty Ltd
ABN 53 086 013 461

ASSET OWNER
Jemena
Jemena Gas Networks (NSW) Ltd
ABN 87 003 004 322

REV	DATE	DESCRIPTION	DRAWN	CHECKED	ENG CHK	APPRV
0A	28/07/20	ISSUED FOR HAZOP #2	GPA	NK	AB	IIK
0	04/03/20	ISSUED FOR CONSTRUCTION WITH HOLDS (18667)	GPA	DK	AMB	LTJ

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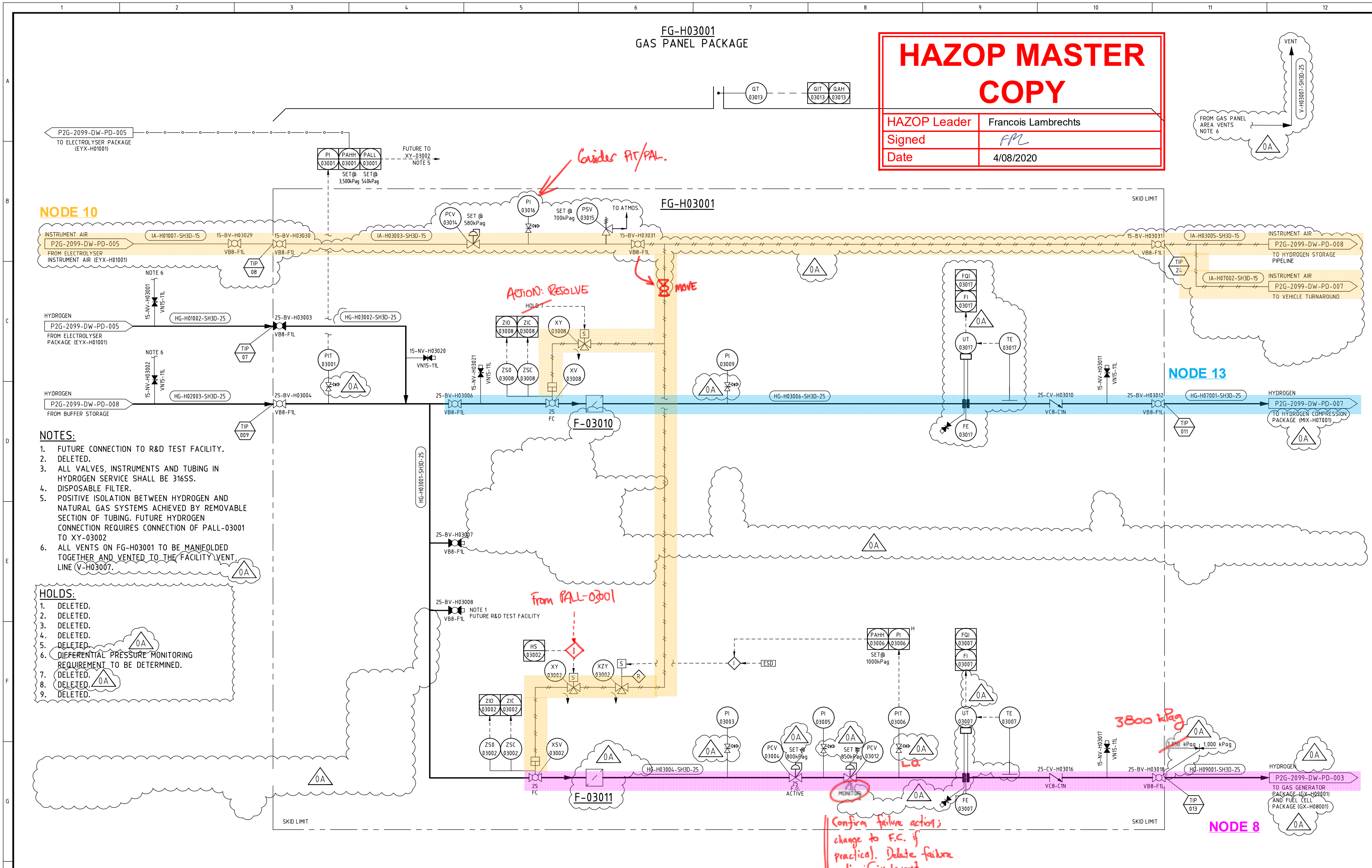
WESTERN SYDNEY GREEN GAS PROJECT
ELECTROYLSER PACKAGE
PIPING & INSTRUMENTATION DIAGRAM

DRAWN	GPA		
DESIGN	SH	SCALE	N.T.S
CHECKED	NPK	SUPERSEDES	A1
APPROVED	LTJ	DRAWING NUMBER	REV
DATE	05/04/19	P2G-2099-DW-PD-005	0A



NOTES:

1. FUTURE CONNECTION TO R&D TEST FACILITY.
2. DELETED.
3. ALL VALVES, INSTRUMENTS AND TUBING IN HYDROGEN SERVICE SHALL BE 316SS.
4. DISPOSABLE FILTER.
5. POSITIVE ISOLATION BETWEEN HYDROGEN AND NATURAL GAS SYSTEMS ACHIEVED BY REMOVABLE SECTION OF TUBING. FUTURE HYDROGEN CONNECTION REQUIRES CONNECTION OF PALL-03001 TO XY-03002
6. ALL VENTS ON FG-H03001 TO BE MANIFOLDED TOGETHER AND VENTED TO THE FACILITY VENT LINE (V-H03007).

HOLDS:

1. DELETED.
2. DELETED.
3. DELETED.
4. DELETED.
5. DELETED.
6. DIFFERENTIAL PRESSURE MONITORING REQUIREMENT TO BE DETERMINED.
7. DELETED.
8. DELETED.
9. DELETED.

REV	DATE	DESCRIPTION	DRAWN	CHECKED	ENG CHK	APPRV
0A	28/07/20	ISSUED FOR HAZOP #2	GPA	NK	AMB	IIK
0	04/03/20	ISSUED FOR CONSTRUCTION WITH HOLDS (18667)	GPA	DK	AMB	LTJ

DRAWING No. | REFERENCE DRAWINGS

ASSET MANAGER
Jemena
Produced by Jemena Asset Management Pty Ltd
ABN 53 086 013 461

ASSET OWNER
Jemena
Jemena Gas Networks (NSW) Ltd
ABN 87 003 004 322

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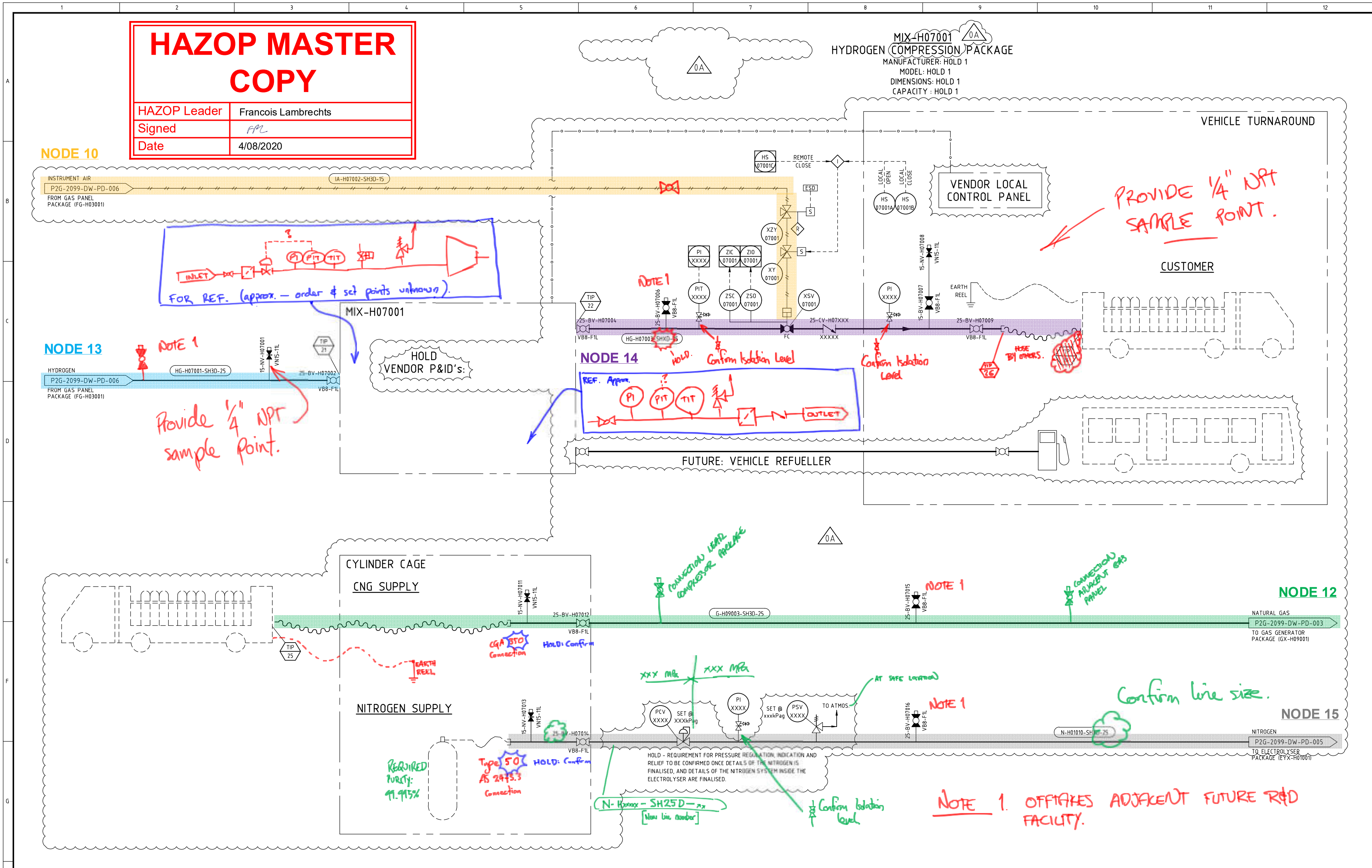
WESTERN SYDNEY GREEN GAS PROJECT
GAS PANEL PACKAGE
PIPING & INSTRUMENTATION DIAGRAM

DRAWN	GPA		
DESIGN	SH	SCALE	N.T.S
CHECKED	NPK	SUPERSEDES	A1
APPROVED	LTJ	DRAWING NUMBER	
DATE	05/04/19	P2G-2099-DW-PD-006	REV 0A



ASSET MANAGER: Jemena — Produced by Jemena Asset Management Pty Ltd, ABN 53 086 013 461

ASSET OWNER: Jemena — Jemena Gas Networks (NSW) Ltd, ABN 87 003 004 322

REV	DATE	DESCRIPTION	DRAWN	CHECKED	ENG CHK	APPRV
0A	28/07/20	ISSUED FOR HAZOP #2	GPA	NK	AB	IIK
0	04/03/20	ISSUED FOR CONSTRUCTION WITH HOLDS (18667)	GPA	DK	AMB	LTJ

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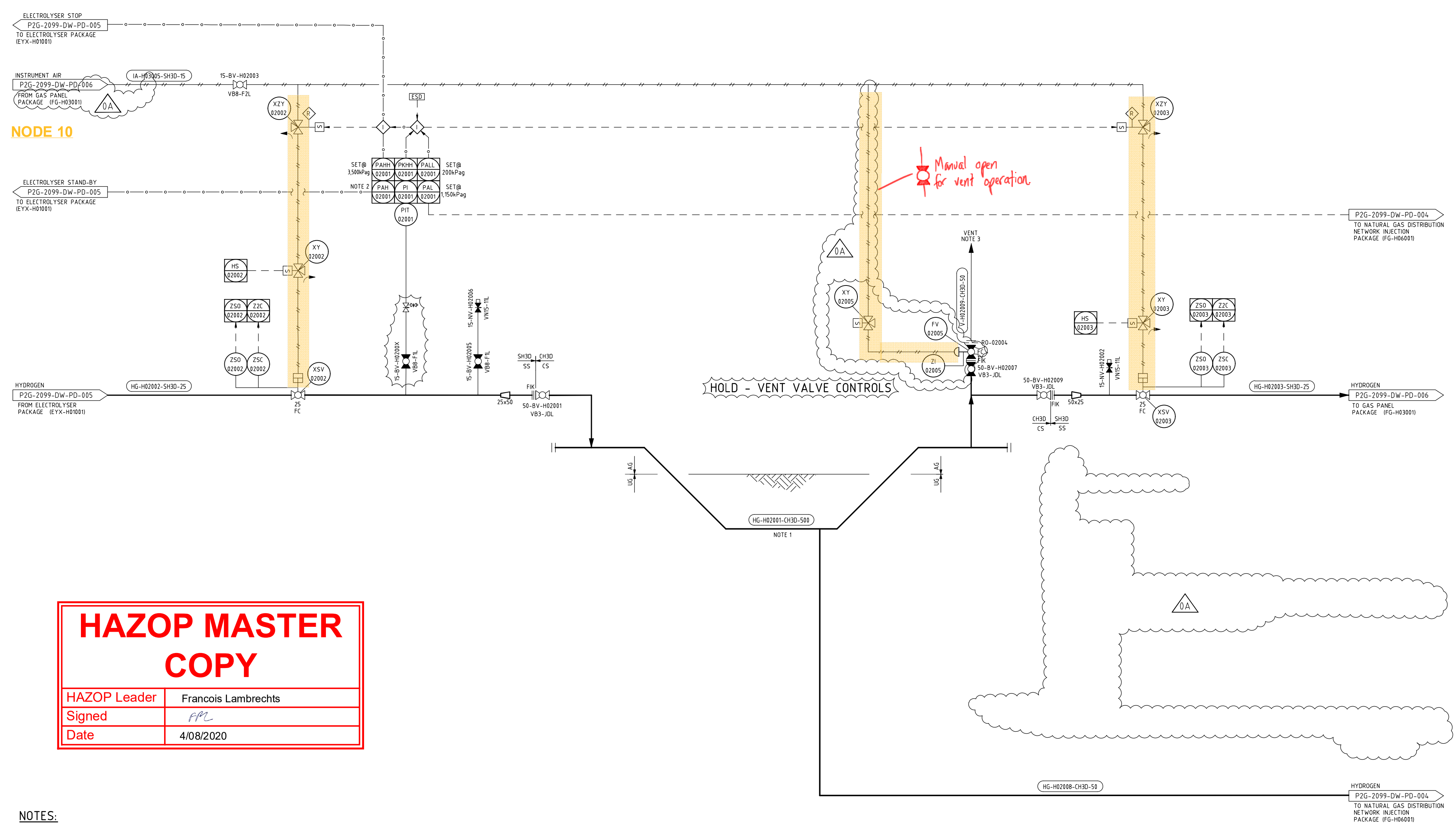
WESTERN SYDNEY GREEN GAS PROJECT
CYLINDER CAGE AND HYDROGEN COMPRESSION PACKAGE
PIPING & INSTRUMENTATION DIAGRAM

DRAWN	GPA	SCALE	N.T.S
DESIGN	SH	SUPERSEDES	
CHECKED	NPK	DRAWING NUMBER	P2G-2099-DW-PD-007
APPROVED	LTJ	SIZE	A1
DATE	05/04/19	REV	0A

DRAWING No. | REFERENCE DRAWINGS



HAZOP MASTER COPY

HAZOP Leader	Francois Lambrechts
Signed	FL
Date	4/08/2020

NOTES:

1. CARBON STEEL UNDERGROUND BUFFER STORAGE PIPELINE. APPROXIMATELY 300m OF DN500 CARBON STEEL LOOPED AT THE BOUNDARY OF THE FACILITY.
2. OPERATOR CONFIGURABLE HIGH PRESSURE TRIP WILL PUT ELECTROLYSER IN STANDBY MODE.
3. HYDROGEN VENT OPENING TO BE EARTHED AND PROVIDED WITH TOROIDAL OPENING TO DISCOURAGE STATIC IGNITION.
4. OPERATOR CONFIGURABLE PRESSURE RATE OF CHANGE TRIP FOR PIPELINE LEAK DETECTION.

ASSET MANAGER: Jemena. Produced by Jemena Asset Management Pty Ltd ABN 53 086 013 461

ASSET OWNER: Jemena. Jemena Gas Networks (NSW) Ltd ABN 87 003 004 322

REV	DATE	DESCRIPTION	DRAWN	CHECKED	ENG CHK	APPRV
0A	28/07/20	ISSUED FOR HAZOP #2	GPA	NK	AMB	IIK
0	04/03/20	ISSUED FOR CONSTRUCTION WITH HOLDS (18667)	GPA	DK	AMB	LTJ

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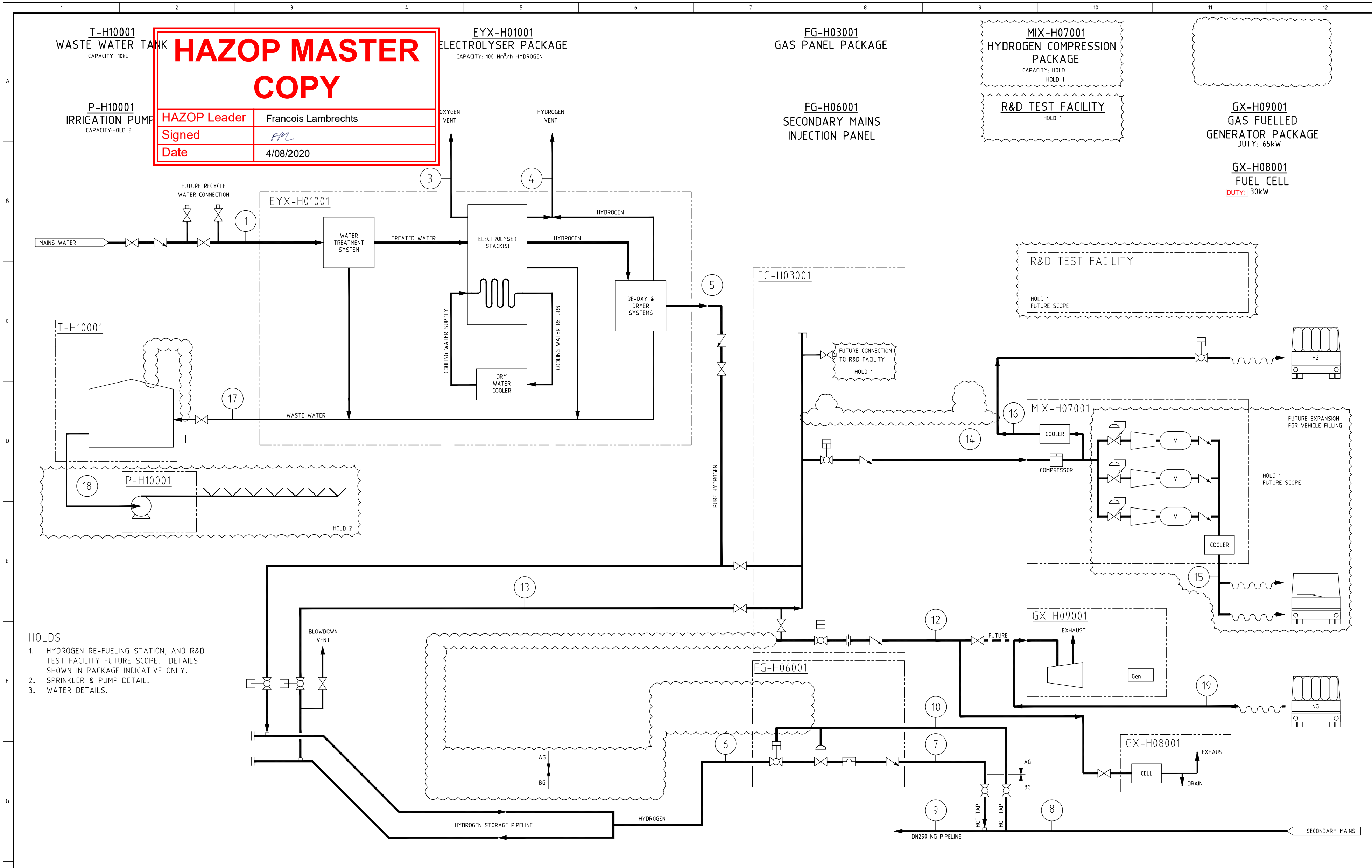
WESTERN SYDNEY GREEN GAS PROJECT
HYDROGEN STORAGE PIPELINE
PIPING & INSTRUMENTATION DIAGRAM

DRAWN	GPA		
DESIGN	SH	SCALE	N.T.S
CHECKED	NPK	SUPERSEDES	A1
APPROVED	LTJ	DRAWING NUMBER	
DATE	31/10/19	P2G-2099-DW-PD-008	REV 0A

DRAWING No. | REFERENCE DRAWINGS



HOLDS

1. HYDROGEN RE-FUELING STATION, AND R&D TEST FACILITY FUTURE SCOPE. DETAILS SHOWN IN PACKAGE INDICATIVE ONLY.
2. SPRINKLER & PUMP DETAIL.
3. WATER DETAILS.

DRAWING No.	REFERENCE DRAWINGS
P2G-2099-DW-PF-002	WESTERN SYDNEY GREEN GAS PROJECT FACILITY STEAM TABLES

ASSET MANAGER
Jemena
Produced by
Jemena Asset Management (6) Pty Ltd
ABN 52 104 352 650

ASSET OWNER
Jemena
Jemena DDP(1) P/L
ABN 52 072 109 865
Jemena DDP(2) P/L
ABN 93 125 873 869
Jemena DDP(3) P/L
ABN 83 127 059 152

REV	DATE	DESCRIPTION	DRAWN	CHECKED	ENG CHK	APPRV
F	28/07/20	ISSUED FOR HAZOP #2 (18667)	GPA	NK	AB	IIK
E	21/02/20	ISSUED FOR REVIEW (18667) - UPDATED WATER SYSTEM	GPA	DJK	AB	IIK
D	28/11/19	ISSUED FOR 90% DESIGN REVIEW (18667)	GPA	NPK	AB	IIK
C	12/07/19	ISSUED FOR HAZOP (18667)	GPA	SH	NPK	LTJ
B	13/05/19	ISSUED FOR REVIEW (18667)	GPA			
A	02/05/19	ISSUED FOR 30% DESIGN REVIEW (18667)	GPA			

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WESTERN SYDNEY GREEN GAS PROJECT
P2G PLANT
PROCESS FLOW DIAGRAM

DRAWN	GPA		
DESIGN	SH	SCALE	NTS
CHECKED	NPK	SUPERSEDES	A1
APPROVED	LTJ	DRAWING NUMBER	REV
DATE	08/03/19	P2G-2099-DW-PF-001	F

APPENDIX 3 PARTICIPANT BRIEFING – METHODOLOGY

GPA ENGINEERING

Jemena Western Sydney Green Gas Trial

HAZOP Brief

Jemena Ltd

GPA Document No: 18667-REP-007

Client Document No: P2G-2099-RC-HZ-001

Client Project No: P2G-2099

Rev	Date	By	Checked	QA	Description
0	22/07/2019	SH	LH	LTJ	Issued for HAZOP
1	22/07/2020	MJL	FPL	IIK	Issued for new scope HAZOP
		M.Lewe	FPL	M.	

Adelaide Brisbane Perth Darwin Melbourne
enquiries@gpaeng.com.au www.gpaeng.com.au

CONTENTS

1 SCOPE

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, 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:

- Electrolyser package (including water treatment system, hydrogen production, hydrogen purification, cooling system and analyser systems)
- Waste water disposal system
- Hydrogen storage pipeline
- Natural gas network injection package (including provision for natural gas withdrawal)
- Gas panel package (for regulating hydrogen flow to other users)
- Gas fuelled generator package (capable of running on natural gas and, in the future, hydrogen)
- 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 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 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.

2 HAZOP/CHAZOP METHODOLOGY

2.1 GENERAL

The methodology adopted for this HAZOP shall be based on a workshop environment attended by key personnel representing the operations, maintenance and engineering teams. Given the current travel restrictions associated with COVID-19, the workshop will be facilitated via Microsoft Teams.

The HAZOP is intended to be a detailed study dealing with the specific process, control and interface issues related to the proposed Western Sydney Green Gas Trial project.

The workshop shall focus on each aspect of the process individually; the facilitator will use a set of guidewords to prompt and promote discussion between participants. Guidewords shall be based on the Orica system of guidewords, as attached in Appendix 1.

The hazards and any key issues identified during the workshop shall be recorded in formal minutes and presented in a tabular format.

The workshop shall progress in the following order:

- General overview of the scope of the project. Boundaries for the study shall be established and interface points between existing and new systems clearly defined.
- Overview of the facilities/changes to facilities, the processes and control philosophies.
- A detailed review of each process subsystem as defined in Section 3 as nodes. An overview of the function of each subsystem shall take place followed by the nodal analysis utilising the standard guidewords.
- Following completion of the nodal review, general hazard identification for the proposed facility layout will be undertaken and any other generic operational issues discussed utilising the set of standard overview guidewords.
- Review of minutes and allocation of action item responsibility.

2.2 PROCESS REPRESENTATION

In order to apply guidewords and carry out a systematic analysis of the system a representation of the facility must be used.

The facility is represented using drawings and documents from the following categories:

- Process Flow Diagrams (PFD)
- Process and Instrumentation Diagrams (P&ID)
- Mechanical layout drawings, and
- Control system philosophy.

A complete list of documentation referenced for this study is provided in Appendix 2.

3 NODE DEFINITIONS

The HAZOP study will proceed by making use of guidewords, as appropriate, to analyse the following subsystems and attributes. The node definitions shown in **black** in Table 1 were those used in the original HAZOP. Nodes shown in colours other than black are those that have been prepared for use in this study. These nodes are a combination of new nodes and updates of original nodes.

Table 1 - HAZOP node definitions

NODE	DESCRIPTION
1	**Description: Electrolyser outlet, hydrogen storage pipeline and bypass** **Drawings: P2G-2099-DW-PD-005, P2G-2099-DW-PD-006, P2G-2099-DW-PD-004** **Plant and Equipment: EYX-H01001, FG-H03001, PIT-06015, FG-H02001, XSV-06001, PIT-03016, XSV-03001** **Line: HG-H01001-SH3D-25, HG-02001-SH3D-25, HG-02001-CH5D-500, G-H02003-SH3D-25**
2	**Description: Electrolyser Package Water Supply** **Drawings: P2G-2099-DW-PD-005** **Plant and Equipment: EYX-H01001** **Line: PW-H01001-C1TD-50**
3	**Description: Waste Water Disposal System** **Drawings: P2G-2099-DW-PD-005** **Plant and Equipment: T-H01002, P-H01001, T-H01001, LSHH-01005, LIT-01004, PI-01001, LIT-01002, LSHH-01003** **Line: n/a**
4	**Description: Electrolyser Vents** **Drawings: P2G-2099-DW-PD-005** **Plant and Equipment: EYX-H01001** **Line: n/a (oxygen vent and hydrogen vent)**
5	**Description: Natural Gas Distribution Network Injection Run** **Drawings: P2G-2099-DW-PD-004** **Plant and Equipment: FG-H02001, XSV-06001, PI-06002, FV-06003, PIT-06005, PIT-06006, TIT-06007** **Line: HG-06001-SH3D-25**
6	**Description: Natural Gas Distribution Network Withdrawal Run** **Drawings: P2G-2099-DW-PD-004, P2G-2099-DW-PD-006** **Plant and Equipment: FG-H02001, XSV-06011, PIT-06008, FG-H03001, XSV-03003** **Line:G-H02003-SH3D-25, G-H02001-PE HOLD-50, G-H02001-SH3D-25**
7	**Description: Gas Fuelled Generator Package Hydrogen Pressure Regulation Run** **Drawings: P2G-2099-DW-PD-006, P2G-2099-DW-PD-003** **Plant and Equipment: XSV-03001, PI-03003, PCV-03017, PI-03018, PCV-03019, PIT-03006, UT-03007, TE-03007, GX-H09001** **Line: HG-H09001-SH3D-25, G-H09003-SH3D-25**

NODE	DESCRIPTION
8	**Description: Gas Fuelled Generator Package Natural Gas Pressure Regulation Run** **Drawings: P2G-2099-DW-PD-005** **Plant and Equipment: XSV-03003, PI-03009, PCV-03020, PI-03021, PCV-03022, PIT-03012, UT-03013, TE-03013, GX-H09001** **Line: G-H09001-SH3D-25, G-H09003-SH3D-25** **Note: Node 8 will be reviewed during this HAZOP. This node has been repurposed to regulate hydrogen to the target pressure for both the micro turbine and fuel cell. The updated details on this node are below:** **Description: Hydrogen Fuel Cell supply line (review)** **Drawings: P2G-2099-DW-PD-003, P2G-2099-DW-PD-006,** **Plant and Equipment: XSV-03002, PI-03003, PCV-03004, PI-03005, PCV-03012, PIT-03006, UT-03007, TE-03007, GX-H08001** **Line: HG-H03004-SH3D-25, HG-H09001-SH3D-25, HG-H08001-SH3D-25**
9	**Description: Natural Gas Distribution Network Instrument Gas Offtake** **Drawings: P2G-2099-DW-PD-004** **Plant and Equipment: F-HOLD, PCV-06014, PI-06013, PSV-06012** **Line: n/a**
10	**Description: Instrument Air Balance of Plant** **Drawings: P2G-2099-DW-PD-005, P2G-2099-DW-PD-003, P2G-2099-DW-PD-006, P2G-2099-DW-PD-007, P2G-2099-DW-PD-008** **Plant and Equipment: PCV-03014, PI-03016, PSV-03015** **Line: IA-H10007-SH3D-15, IA-H03003-SH3D-15, IA-H03005-SH3D-15, IAH07002-SH3D-15, IA-H09004,SH3D-15**
11	**General Hazard Identification and Facility Overview** **Drawings: P2G-2099-DW-PD-001, P2G-2099-DW-PD-002, P2G-2099-DW-PD-004, P2G-2099-DW-PD-005, P2G-2099-DW-PD-006**
12	**Description: Micro turbine natural gas supply line** **Drawings: P2G-2099-DW-PD-007** **Plant and Equipment: N/A** **Line:G-H09003-SH3D-25, G/HG-H09002-SH3D-25**
13	**Description: Hydrogen Compressor package supply line** **Drawings: P2G-2099-DW-PD-006, P2G-2099-DW-PD-007** **Plant and Equipment: XV-03008, F-03010, PI-03009** **Line: HG-H03006-SH3D, HG-H07001-SH3D-25**
14	**Description: Hydrogen Compressor discharge line** **Drawings: P2G-2099-DW-PD-007** **Plant and Equipment: PIT-XXXX, XSV-07001, PIT-XXXX** **Line: HG-H07003-SHXD-25**
15	**Description: Electrolyser Nitrogen supply line** **Drawings: P2G-2099-DW-PD-005, P2G-2099-DW-PD-007** **Plant and Equipment: PCV-XXXX, PI-XXXX, PSV-XXXX** **Line: N-H01010-SHXD-25**

NODE	DESCRIPTION
16	**General Hazard Identification and Facility Overview (review)** **P2G-2099-DW-PD-001, P2G-2099-DW-PD-003, P2G-2099-DW-PD-004, P2G-2099-DW-PD-005, P2G-2099-DW-PD-006, P2G-2099-DW-PD-007, P2G-2099-DW-PD-008**

4 PROPOSED WORKSHOP AGENDA

The second workshop will be held via Microsoft Teams on the 4th August 2020.

A proposed agenda for the workshop is detailed below.

The agenda may vary depending on the detailed discussions required to fully understand the hazard, controls or any additional topics identified by the workshop facilitator or participants.

4th August 2020 HAZOP	
8:45 to 9:00	Join Microsoft Teams meeting
9:00 to 9:15	Introductions and overview of HAZOP workshop methodology
9:15 to 9.30	Project Scope Changes Overview: 1. Removal of natural gas supply 2. Addition of hydrogen fuel cell 3. Addition of hydrogen compression package and associated cylinder filling
9.30 to 10:00	**Node 8 – Hydrogen Fuel Cell supply line (review of existing HAZOP node)**
10:00 to 10:30	**Node 12 – Micro turbine Natural Gas Supply line**
10:30 to 10:45	Break
10:45 to 11:30	**Node 10 - Instrument Air Balance of Plant** Note: Optimal participation is required for nodes 8, 12 and 10. Ballard participation is required for nodes 8 and 10. Following completion of these nodes Optimal and Ballard personnel are permitted to leave the meeting.
11:30 to 12:00	**Node 13 - Hydrogen Compressor package supply line**
12.00 to 12:45	LUNCH
12:45 to 13:15	**Node 14 - Hydrogen Compressor package discharge line** Note: Coregas participation is required for nodes 10, 13 & 14. Following completion of these nodes Coregas personnel are permitted to leave the meeting.
13:15 to 13:45	**Node 15 – Electrolyser Nitrogen Supply line**
13:45 to 14:00	**Node 16 - General Hazard Identification and Facility Overview (review)**

APPENDIX 1 HAZOP GUIDEWORDS

The following Guidewords shall be used by the HAZOP facilitator to promote discussion between the participants.

Formal minutes record any action items arising out of the detailed review. Where no specific issue is identified in relation to a guide word, a specific minute item may not be recorded.

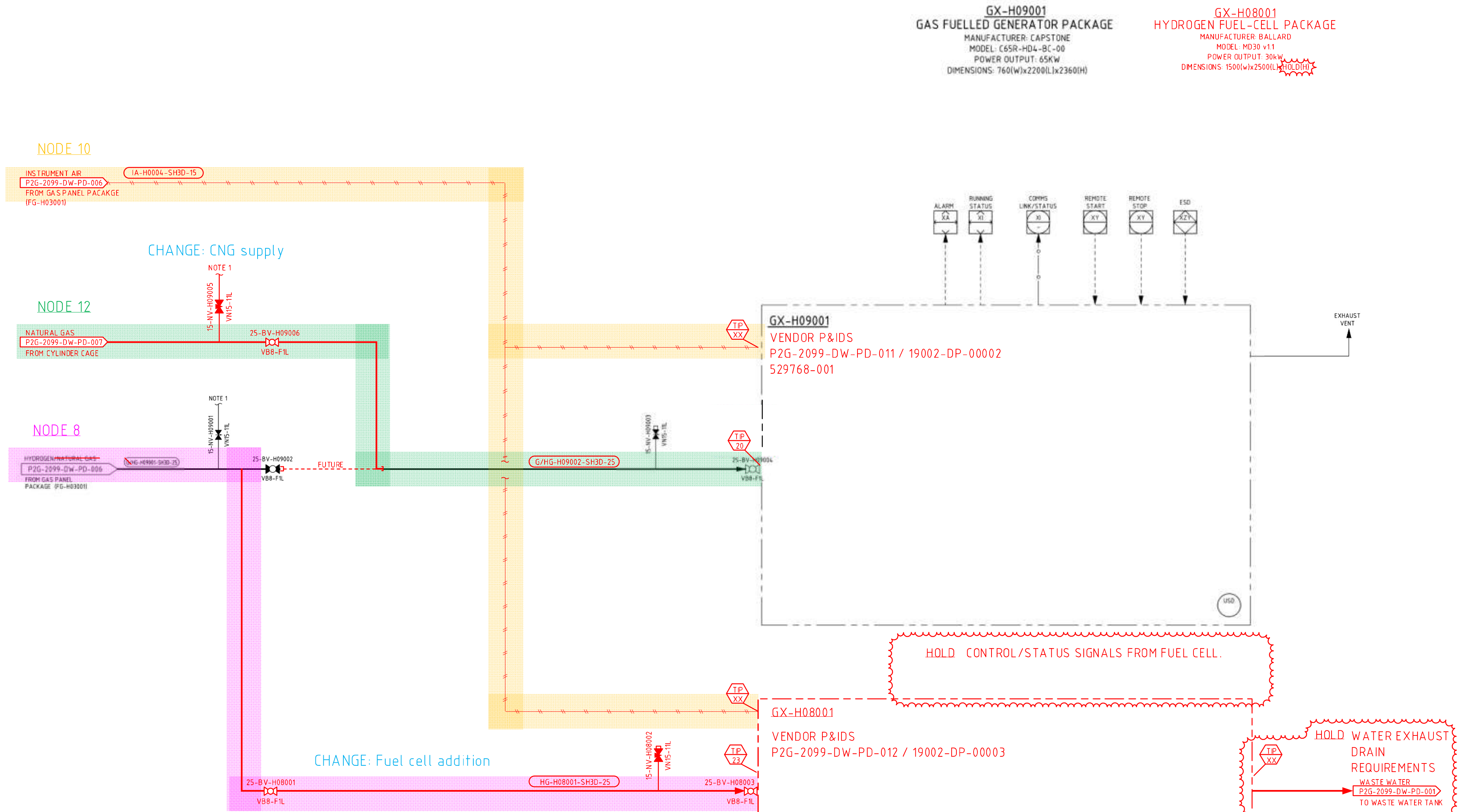
Nodal Analysis Guidewords
HIGH FLOW / HIGH LEVEL
LOW FLOW / LOW LEVEL
ZERO FLOW / EMPTY
REVERSE FLOW
HIGH PRESSURE
LOW PRESSURE
HIGH TEMPERATURE
LOW TEMPERATURE
IMPURITIES (Gaseous, Liquid, Solid)
CHANGE IN COMPOSITION (Gaseous/Liquid/Solid, Two phase flow)
CHANGE IN CONCENTRATION
REACTIONS
TESTING (Equipment, Product, Effluent, Sample points)
OPERABILITY / MAINTAINABILITY
ELECTRICAL (Hazardous area classification, Isolation, Earthing)
INSTRUMENTS (Sufficient for control, Too many/few, Correct location, Consistent philosophy, Control separate from shutdown/trips)

Overview Guidewords
TOXICITY
UTILITIES / SERVICES – Air, Instrument air/gas, Nitrogen, Water, Electric power generation and distribution, Fuel, Flare access, Drains, etc.
FLARE / VENT CAPACITY – Does the proposed design affect the flare/vent design cases?
FUEL GAS (Changes in composition and heating values, suitability for the installed gas engine and gas turbine drives).
UPSTREAM / DOWNSTREAM PLANT IMPACTS – Have they been traced far enough, identified and satisfactorily resolved?
MIXTURES – If different gas streams are mixed in the process, can the plant handle the full range of combinations of the individual gas streams?
MATERIALS OF CONSTRUCTION (Vessels, Pipelines, Pumps, Other items)
COMMISSIONING
START-UP (First start-up, Normal start-up, start-up after abnormal shutdown)
SHUTDOWN (Isolation, Purging, Potential for abnormal operating conditions or compositions)
BREAKDOWN (Power Failure, Air, Steam, Water, Vacuum, Fuel, Vents, Computer, etc. - consider required direction of valve movement)
EFFLUENT (Gaseous, Liquid, Solid - consider possibility of reactions and treatment methods)
NOISE / VIBRATION
FIRE
EXPLOSION
SAFETY EQUIPMENT (Personal, Fire Detection, Fire Fighting, Means of Escape)
QUALITY AND CONSISTENCY (What will cause quality to fail or vary?)
EFFICIENCY - Losses (Where will we lose material, conversion, etc?)
SIMPLICITY (Can anything be removed or simplified?)

APPENDIX 2 REFERENCE DOCUMENTATION

The following drawings and documents have been utilised during the preparation for the HAZOP workshop. Red-line mark-ups of the P&IDs have been issued with this brief. Drafted revisions of these drawings will be available for the HAZOP.

Document / Drawing Number	Revision	Description
P2G-2099-DW-PF-001	F	WSGGP Process Flow Diagram
P2G-2099-DW-PD-003	0A	WSGGP Gas Fuelled Generator & Fuel Cell Package
P2G-2099-DW-PD-004	0A	WSGGP Hydrogen Storage Pipeline and Natural Gas Distribution Network Injection Package
P2G-2099-DW-PD-005	0A	WSGGP Electrolyser Package
P2G-2099-DW-PD-006	0A	WSGGP Gas Panel Package
P2G-2099-DW-PD-007	0A	WSGGP Cylinder Cage & Hydrogen Compression Package
P2G-2099-DW-PD-008	0A	WSGGP Hydrogen Storage Pipeline
18667-CAE-001	0A	WSGGT Cause and Effects Matrix Note: This document has not been updated with the new scope items at the time of issuing this HAZOP brief.
P2G-2099-DW-CV-001	0	Piping Key Plan
P2G-2099-DW-PI-003	0A	Piping Plan 3
P185765A-IA-1	01	HyLYZER 200 Instrument Air Supply
P185765A-IA-2	01	HyLYZER 200 Nitrogen Supply
17012-DP-00001	1	C65 Microturbine – LPG System
P2G-2099-DW-PD-011 / 19002-DP-00002	A	Fuel Gas System (Microturbine)
P2G-2099-DW-PD-012 / 19002-DP-00003	A	Fuel Cell
529768-001	B	C65 Fuel System HP Gaseous



NOTES:

1. VENT IS DIRECTED INTO THE ~~NATURAL GAS~~ FACILITY VENT, LINE V-H0~~2002~~3007-SH3D-025 ON P&ID P2G-2099-DW-PD-~~008~~ 006

REV	DATE	DESCRIPTION	DRAWN	CHECKED	ENG CHK	APPRV
0A	23/07/20	ISSUED FOR HAZOP #2	GPA	NK	AB	IIK
0	04/03/20	ISSUED FOR CONSTRUCTION WITH HOLDS (18667)	GPA	DK	AMB	LTJ

DRAWING No. | REFERENCE DRAWINGS

ASSET MANAGER
Jemena
Produced by
Jemena Asset Management Pty Ltd
ABN 53 086 013 461

ASSET OWNER
Jemena
Jemena Gas Networks (NSW) Ltd
ABN 87 003 004 322

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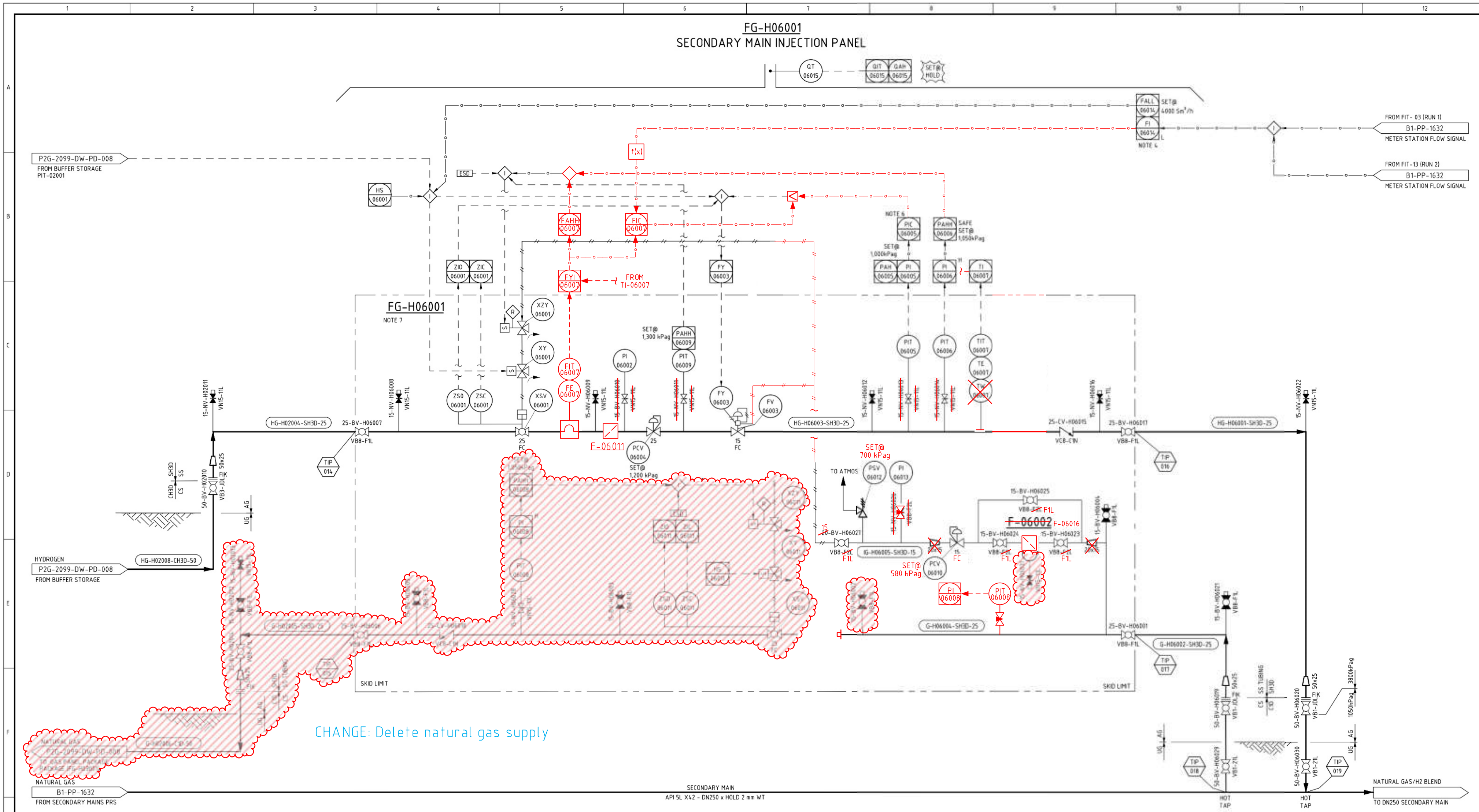
WESTERN SYDNEY GREEN GAS PROJECT
GAS FUELLED GENERATOR & FUEL CELL PACKAGE
PIPING & INSTRUMENTATION DIAGRAM

DRAWN	GPA		
DESIGN	SH	SCALE	N.T.S
CHECKED	NPK	SUPERSEDES	A1
APPROVED	LTJ	DRAWING NUMBER	REV
DATE	05/04/19	P2G-2099-DW-PD-003	0A



NOTES:

1. TRANSITION PIECE.
2. SHUTDOWN ON HIGH HYDROGEN BLEND.
3. INTERLOCK TO ENSURE XSV-06001 IS OPENED BEFORE FV-06003.
4. FLOW SIGNAL FROM METER STATION TAKEN AS MOVING AVERAGE OVER PAST 6 HOURS.
5. FLOW CONTROLLER FIC-06007 CONTROLS FLOW BASED ON OPERATOR-CONFIGURED HYDROGEN FLOW SET POINT (WITH HARD-CODED MAXIMUM OF 400 Sm^3/h). OR OPERATOR-CONFIGURED BLEND-RATE (WITH HARD-CODED MAXIMUM OF 10%)
6. PRESSURE CONTROLLER PIC-06005 DECREASES FV-06003 OPENING ON HIGH PRESSURE BETWEEN 1,000 kPag (100% OPEN) AND 1050 kPag (0% OPEN).
7. ALL VENTS/BLEEDS ON FG-H06001 TO BE MANIFOLDED TOGETHER AND VENTED TO A SAFE ELEVATED LOCATION.
8. HYDROGEN RATIO CONTROL INITIALLY SET AT 2 MOL% HYDROGEN BLEND IN NATURAL GAS.

DRAWING No.	REFERENCE DRAWINGS

ASSET MANAGER — Jemena — Produced by Jemena Asset Management Pty Ltd ABN 53 086 013 461

ASSET OWNER — Jemena — Jemena Gas Networks (NSW) Ltd ABN 87 003 004 322

REV	DATE	DESCRIPTION	DRAWN	CHECKED	ENG CHK	APPRV
0A	23/07/20	ISSUED FOR HAZOP #2	GPA	NK	AB	IIK
0	04/03/20	ISSUED FOR CONSTRUCTION WITH HOLDS (18667)	GPA	DK	AMB	LTJ

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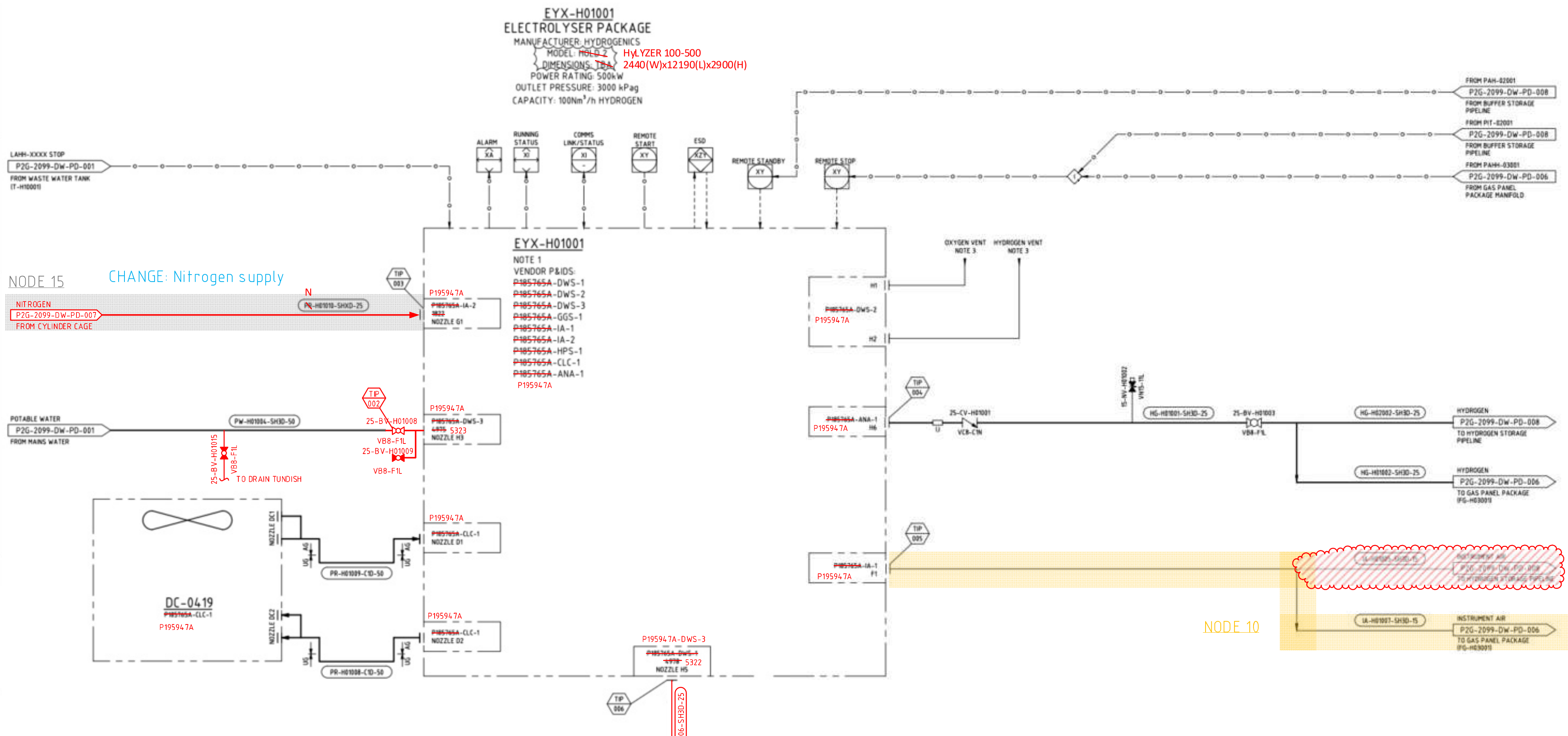
WESTERN SYDNEY GREEN GAS PROJECT
SECONDARY MAIN INJECTION PANEL
PIPING & INSTRUMENTATION DIAGRAM

DRAWN	GPA	SCALE	N.T.S
DESIGN	SH	SUPERSEDES	
CHECKED	NPK		A1
APPROVED	LTJ	DRAWING NUMBER	REV
DATE	05/04/19	P2G-2099-DW-PD-004	0A



NOTES:

1. BASED ON THE HYDROGENICS 1 MW HYLYZER 200 ELECTROLYSER PACKAGE. PACKAGE INCLUDES:
   1.1. ELECTROYLSER STACK
   1.2. WATER TREATMENT SYSTEM
   1.3. HYDROGEN PURIFICATION
   1.4. COOLER UNIT
   1.5. CONTROL SYSTEM
   1.6. POWER SUPPLY
2. ALL VALVES, INSTRUMENTS AND TUBING IN HYDROGEN SERVICE TO BE 316SS.
3. VENT TO SAFE LOCATION. VENT REQUIREMENTS TO BE CONFIRMED BY THE ELECTROLYSER PACKAGER. VENTS TO BE SUPPLIED BY ELECTROYSER PACKAGER. DESIGN TO BE CONFIRMED.

DRAWING No.	REFERENCE DRAWINGS

ASSET MANAGER
Jemena
Produced by Jemena Asset Management Pty Ltd
ABN 53 086 013 461

ASSET OWNER
Jemena
Jemena Gas Networks (NSW) Ltd
ABN 87 003 004 322

REV	DATE	DESCRIPTION	DRAWN	CHECKED	ENG CHK	APPRV
0A	23/07/20	ISSUED FOR HAZOP #2	GPA	NK	AB	IIK
0	04/03/20	ISSUED FOR CONSTRUCTION WITH HOLDS (186671)	GPA	DK	AMB	LTJ

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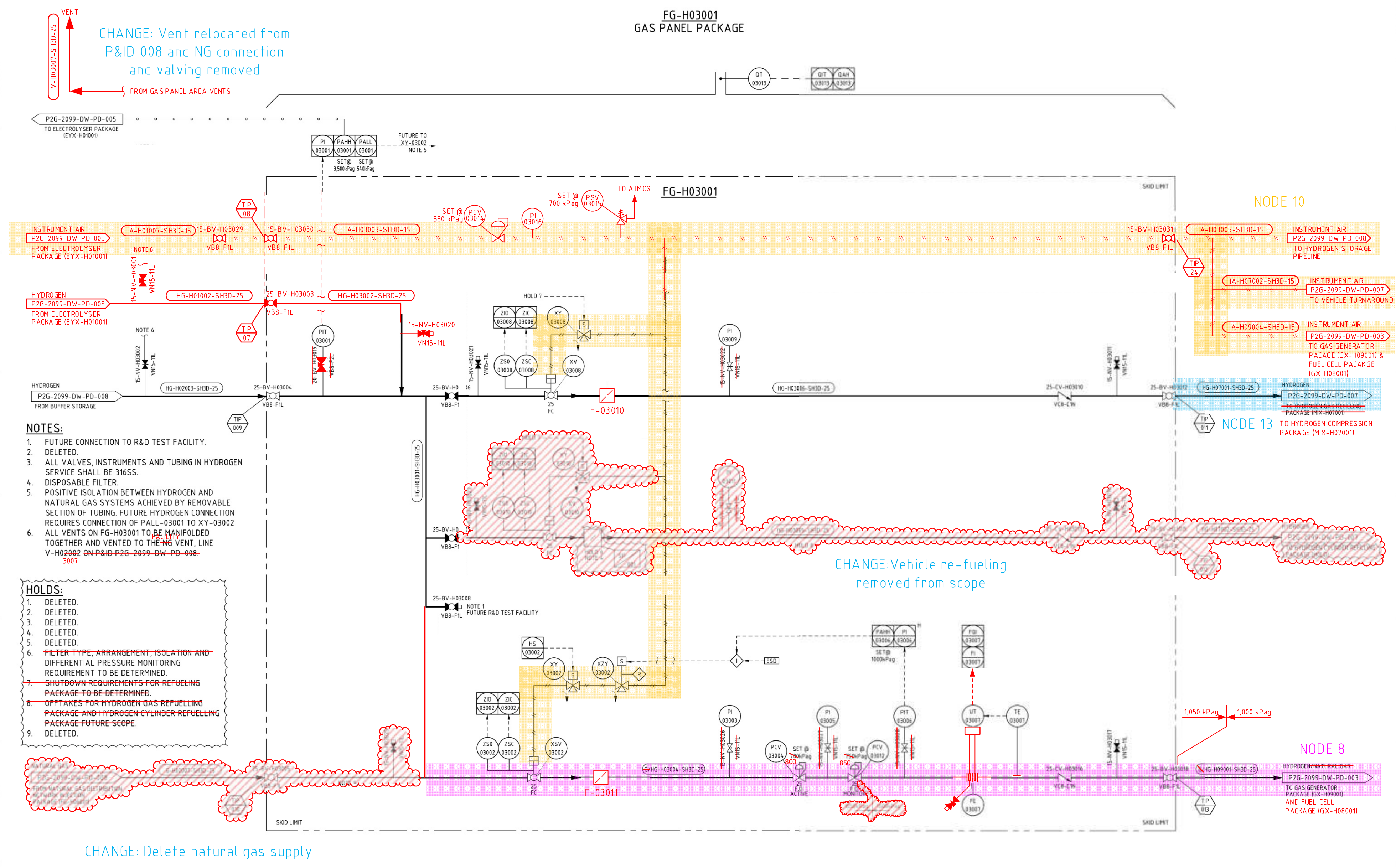
WESTERN SYDNEY GREEN GAS PROJECT
ELECTROYLSER PACKAGE
PIPING & INSTRUMENTATION DIAGRAM

DRAWN	GPA		
DESIGN	SH	SCALE	N.T.S
CHECKED	NPK	SUPERSEDES	
APPROVED	LTJ	DRAWING NUMBER	A1
DATE	05/04/19	P2G-2099-DW-PD-005	REV 0A 0

FG-H03001
GAS PANEL PACKAGE



NOTES:

1. FUTURE CONNECTION TO R&D TEST FACILITY.
2. DELETED.
3. ALL VALVES, INSTRUMENTS AND TUBING IN HYDROGEN SERVICE SHALL BE 316SS.
4. DISPOSABLE FILTER.
5. POSITIVE ISOLATION BETWEEN HYDROGEN AND NATURAL GAS SYSTEMS ACHIEVED BY REMOVABLE SECTION OF TUBING. FUTURE HYDROGEN CONNECTION REQUIRES CONNECTION OF PALL-03001 TO XY-03002
6. ALL VENTS ON FG-H03001 TO BE MANIFOLDED TOGETHER AND VENTED TO THE ~~NG~~ VENT, LINE V-H0~~2002~~ 3007 ~~ON P&ID P2G-2099-DW-PD-008.~~

HOLDS:

1. DELETED.
2. DELETED.
3. DELETED.
4. DELETED.
5. DELETED.
6. ~~FILTER TYPE, ARRANGEMENT, ISOLATION AND~~ DIFFERENTIAL PRESSURE MONITORING REQUIREMENT TO BE DETERMINED.
7. ~~SHUTDOWN REQUIREMENTS FOR REFUELING PACKAGE TO BE DETERMINED.~~
8. ~~OFFTAKES FOR HYDROGEN GAS REFUELLING PACKAGE AND HYDROGEN CYLINDER REFUELLING PACKAGE FUTURE SCOPE.~~
9. DELETED.

REV	DATE	DESCRIPTION	DRAWN	CHECKED	ENG CHK	APPRV
0A	23/07/20	ISSUED FOR HAZOP #2	GPA	NK	AB	IIK
0	04/03/20	ISSUED FOR CONSTRUCTION WITH HOLDS (18667)	GPA	DK	AMB	LTJ

DRAWING No. | REFERENCE DRAWINGS

ASSET MANAGER
Jemena
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Jemena Gas Networks (NSW) Ltd
ABN 87 003 004 322

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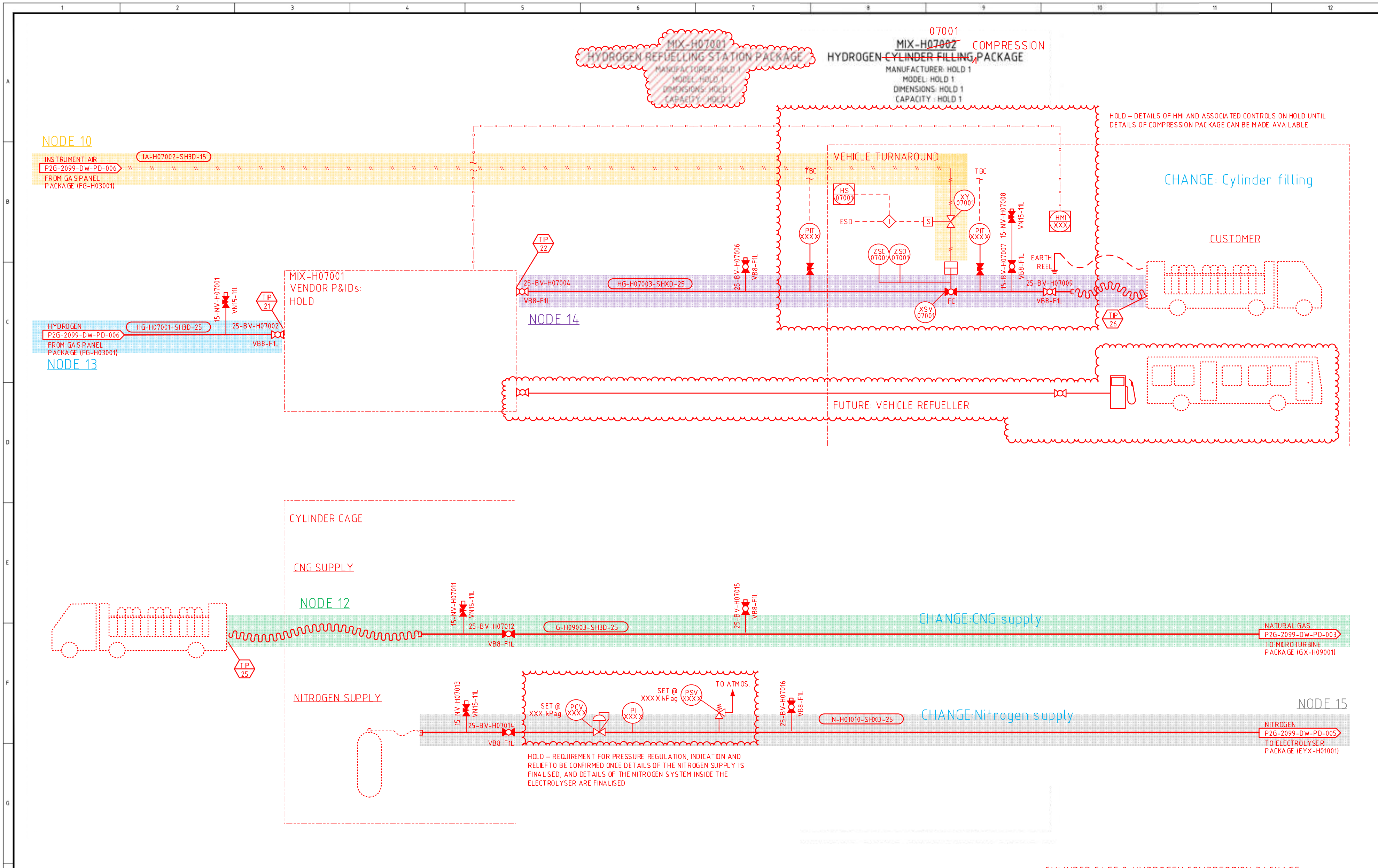
WESTERN SYDNEY GREEN GAS PROJECT
GAS PANEL PACKAGE
PIPING & INSTRUMENTATION DIAGRAM

DRAWN	GPA	SCALE	N.T.S
DESIGN	SH	SUPERSEDES	A1
CHECKED	NPK	DRAWING NUMBER	REV
APPROVED	LTJ	P2G-2099-DW-PD-006	0A
DATE	05/04/19		



CYLINDER CAGE & HYDROGEN COMPRESSION PACKAGE

DRAWING No.	REFERENCE DRAWINGS

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Jemena Gas Networks (NSW) Ltd
ABN 87 003 004 322

REV	DATE	DESCRIPTION	DRAWN	CHECKED	ENG CHK	APPRV
0A	23/07/20	ISSUED FOR HAZOP #2	GPA	NK	AB	IIK
0	04/03/20	ISSUED FOR CONSTRUCTION WITH HOLDS (18667)	GPA	DK	AMB	LTJ

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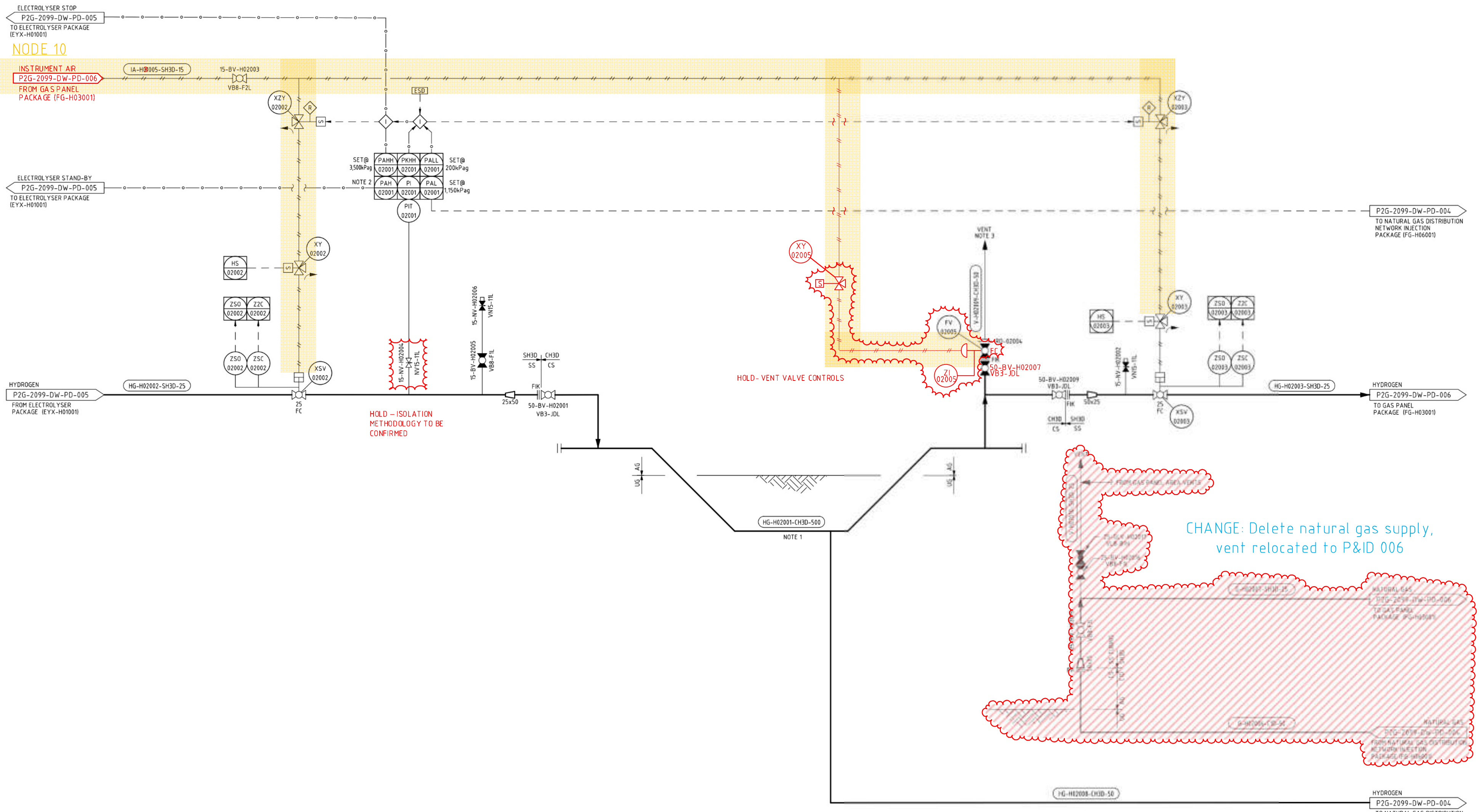
WESTERN SYDNEY GREEN GAS PROJECT
~~REFUELLING STATION PACKAGE AND HYDROGEN CYLINDER FILLING PACKAGE~~
PIPING & INSTRUMENTATION DIAGRAM

DRAWN	GPA	SCALE	N.T.S
DESIGN	SH	SUPERSEDES	
CHECKED	NPK		A1
APPROVED	LTJ	DRAWING NUMBER	REV
DATE	05/04/19	P2G-2099-DW-PD-007	0A



NOTES:

1. CARBON STEEL UNDERGROUND BUFFER STORAGE PIPELINE. APPROXIMATELY 300m OF DN500 CARBON STEEL LOOPED AT THE BOUNDARY OF THE FACILITY.
2. OPERATOR CONFIGURABLE HIGH PRESSURE TRIP WILL PUT ELECTROLYSER IN STANDBY MODE.
3. HYDROGEN VENT OPENING TO BE EARTHED AND PROVIDED WITH TOROIDAL OPENING TO DISCOURAGE STATIC IGNITION.
4. OPERATOR CONFIGURABLE PRESSURE RATE OF CHANGE TRIP FOR PIPELINE LEAK DETECTION.

DRAWING No.	REFERENCE DRAWINGS

ASSET MANAGER: Jemena — Produced by Jemena Asset Management Pty Ltd ABN 53 086 013 461

ASSET OWNER: Jemena — Jemena Gas Networks (NSW) Ltd ABN 87 003 004 322

REV	DATE	DESCRIPTION	DRAWN	CHECKED	ENG CHK	APPRV
0A	23/07/20	ISSUED FOR HAZOP #2	GPA	NK	AB	IIK
0	04/03/20	ISSUED FOR CONSTRUCTION WITH HOLDS (18667)	GPA	DK	AMB	LTJ

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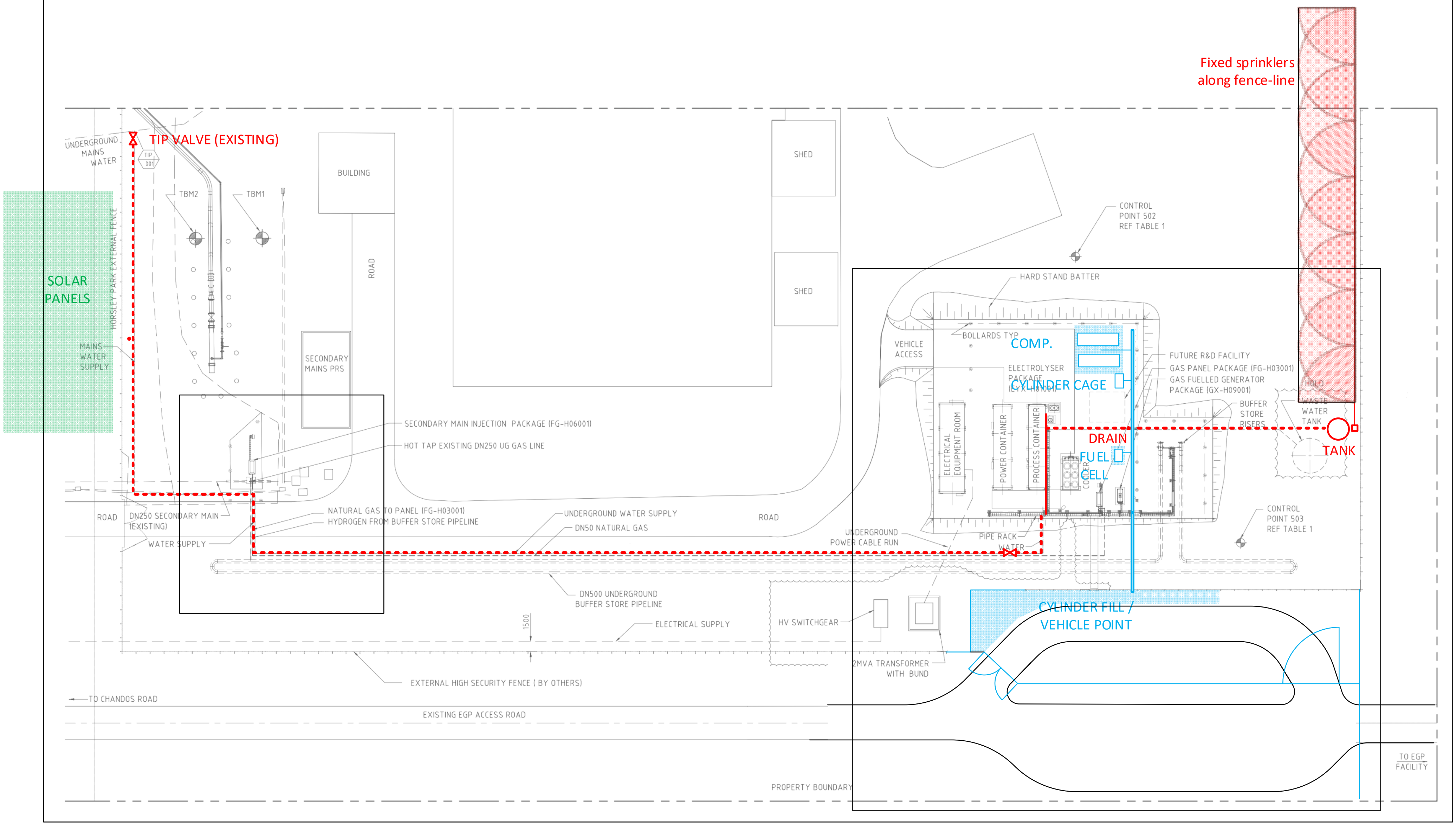
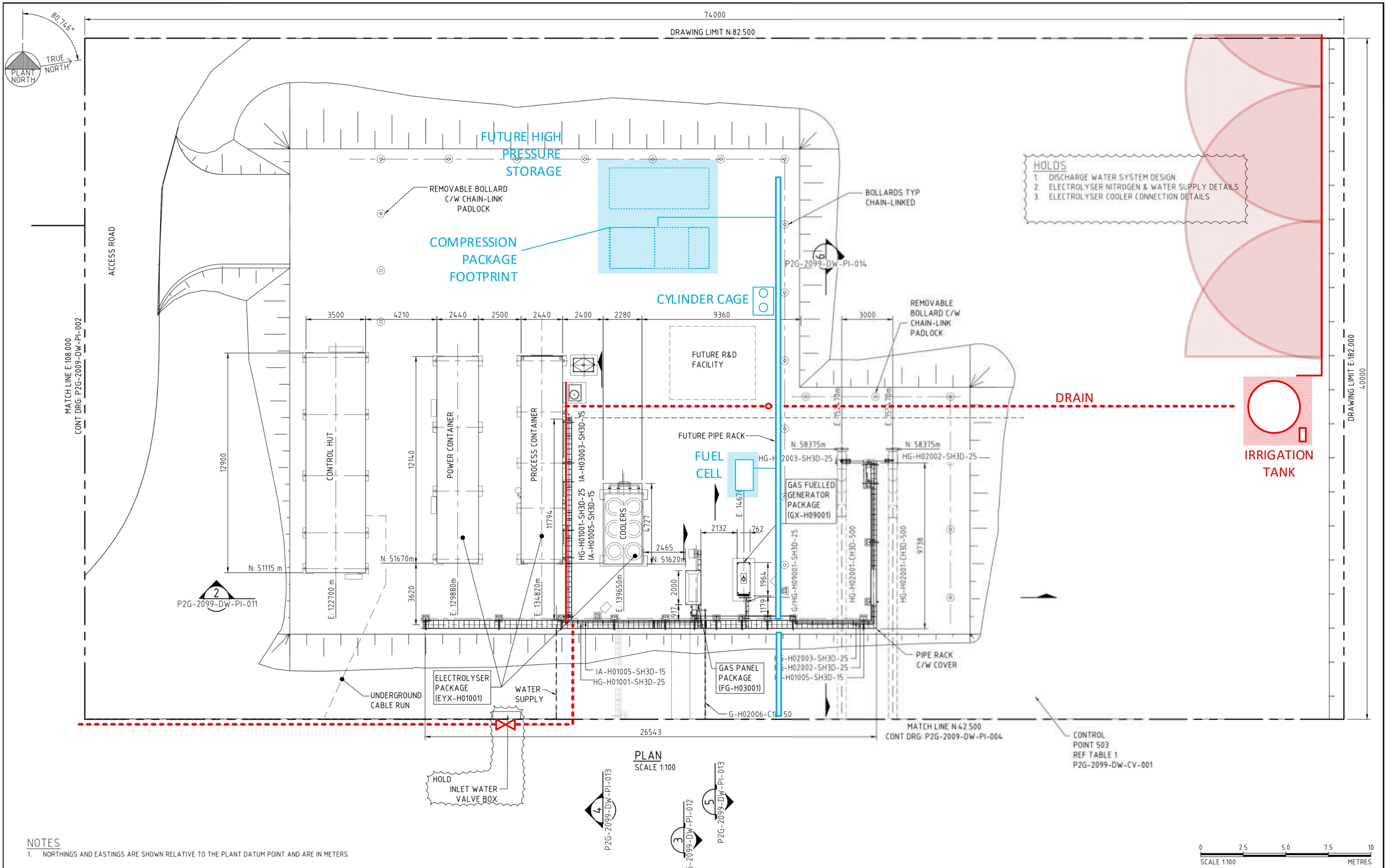
WESTERN SYDNEY GREEN GAS PROJECT
HYDROGEN STORAGE PIPELINE
PIPING & INSTRUMENTATION DIAGRAM

DRAWN	GPA		
DESIGN	SH	SCALE	N.T.S
CHECKED	NPK	SUPERSEDES	A1
APPROVED	LTJ	DRAWING NUMBER	REV
DATE	31/10/19	P2G-2099-DW-PD-008	0A

PRELIMINARY LAYOUT OF CYLINDER FILL AND FUEL CELL



PROPOSED LAYOUT



NOTES
1. NORTHINGS AND EASTINGS ARE SHOWN RELATIVE TO THE PLANT DATUM POINT AND ARE IN METERS.

DRAWING No.	REFERENCE DRAWINGS
P2G-2099-DW-PI-014	PIPING SECTIONS
P2G-2099-DW-PI-013	PIPING SECTIONS
P2G-2099-DW-PI-012	PIPING SECTIONS
P2G-2099-DW-PI-011	PIPING SECTIONS
P2G-2099-DW-PI-002	PIPING PLAN 2
P2G-2099-DW-PI-004	PIPING PLAN 4
P2G-2099-DW-PI-005	PIPING KEY PLAN
P2G-2099-DW-CV-001	PLOT PLAN

ASSET MANAGER
Jemena
Produced by Jemena Asset Management Pty Ltd
ABN 53 086 013 461

ASSET OWNER
Jemena
Jemena Gas Networks (NSW) Ltd
ABN 87 003 004 322

REV	DATE	DESCRIPTION	DRAWN	CHECKED	ENG CHK	APPRV
0	21/02/20	ISSUED FOR CONSTRUCTION (GPA 18667)	GPA	NJM	NPK	DP

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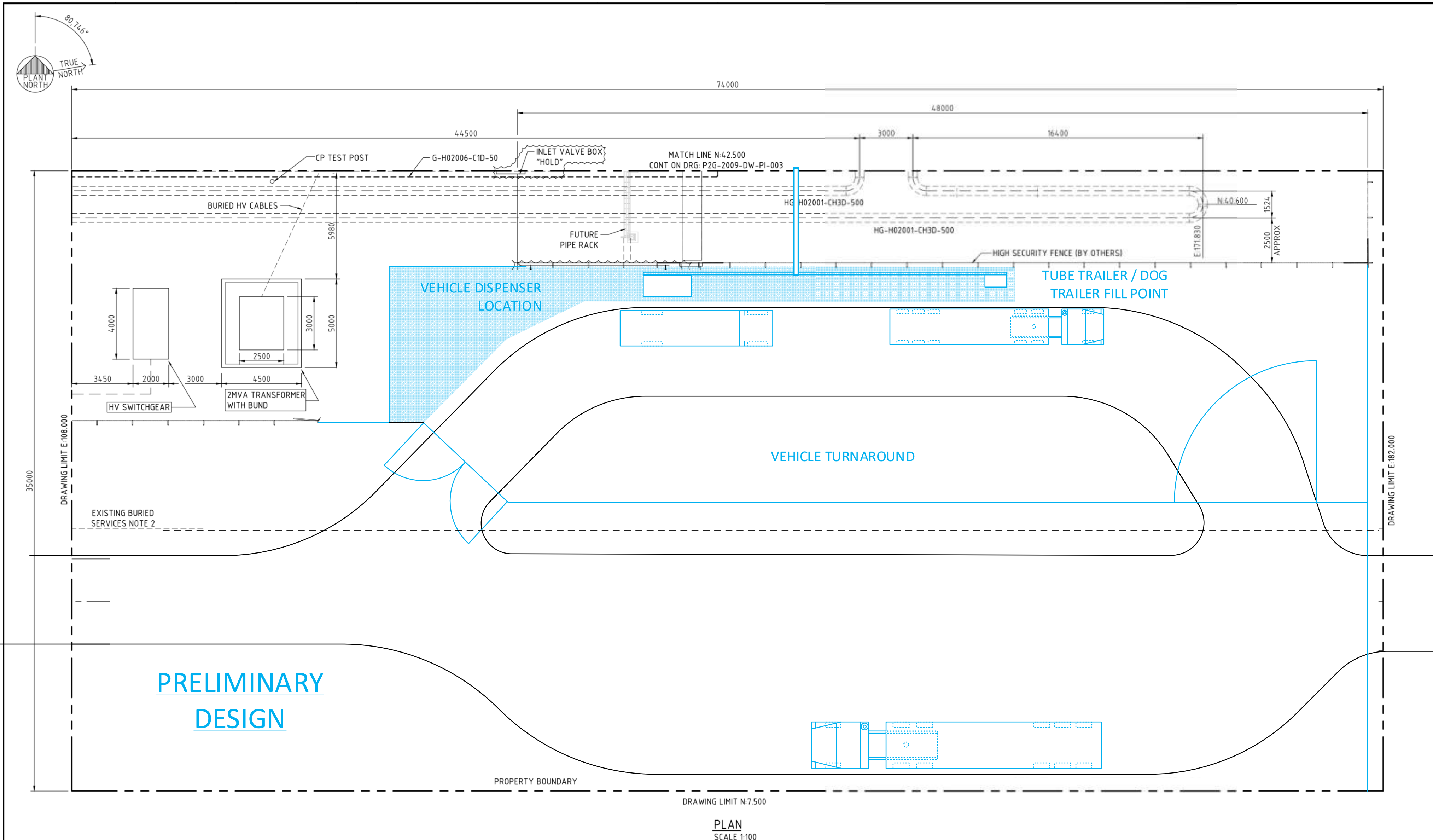
WESTERN SYDNEY GREEN GAS PROJECT
HYDROGEN GENERATION FACILITY
PIPING PLAN 3

DRAWN	GPA
DESIGN	NPK
CHECKED	NJM
APPROVED	DP
DATE	21/02/20

SCALE 1:100
SUPERSEDES
A1
DRAWING NUMBER P2G-2099-DW-PI-003
REV 0A



PLAN
SCALE 1:100

NOTES
1. NORTHINGS AND EASTINGS ARE SHOWN RELATIVE TO THE PLANT DATUM POINT AND ARE IN METERS.
2. EXACT LOCATION OF BURIED SERVICES SUPPLYING EGP FACILITY IS UNKNOWN.

0 2.5 5.0 7.5 10
SCALE 1:100 METRES

DRAWING No.	REFERENCE DRAWINGS
P2G-2099-DW-PI-005	PIPING KEY PLAN
P2G-2099-DW-CV-001	PLOT PLAN

ASSET MANAGER
Jemena
Produced by
Jemena Asset Management
Pty Ltd
ABN 53 086 013 461

ASSET OWNER
Jemena
Jemena Gas Networks (NSW) Ltd
ABN 87 003 004 322

REV	DATE	DESCRIPTION	DRAWN	CHECKED	ENG CHK	APPRV
0	21/02/20	ISSUED FOR CONSTRUCTION (GPA 18667)	GPA	NJM	NPK	DP

GPA ENGINEERING
www.gpaeng.com.au

WESTERN SYDNEY GREEN GAS PROJECT
VEHICLE TURN AROUND & LOAD OUT FACILITY
PIPING PLAN 4

DRAWN	GPA		
DESIGN	NPK	SCALE	1:100
CHECKED	NJM	SUPERSEDES	A1
APPROVED	DP	DRAWING NUMBER	REV
DATE	21/02/20	P2G-2099-DW-PI-004	0

APPENDIX 4 HAZID - ENERGY SOURCE GUIDEWORDS

Guideword	Threat	This Project
Chemical Energy	• Explosive reactions	• Hydrogen • Oxygen • Natural gas
	• Corrosion reactions	• Brine • Atmosphere / rain • Soil environment (buried) • Stray currents
Thermal Energy	• High temperature • Low temperature • Rapidly changing temperature	• Natural gas decompression • Heating from compression • Electrolyser cooling systems • Generator combustion system • Ambient temperature
Radiant Energy	• Electromagnetic radiation • Ionizing radiation • Thermal radiation	• Solar radiation • Electrical equipment / comm. equipment
Elastic Energy / Compression	• High pressure • Pressure differential • Elastic strain in components, such as springs	• Energy of compression • Valve failure state
Electrical Energy	• High voltage • Accumulation of static charges	• Site AC supply • Electrolyser DC supply • Generator output • Transformer / rectifier • Cathodic protection system • Static electricity • Turbine battery
Kinetic Energy (Acceleration Deceleration Shock)	• Change in velocity • Impact energy • Machine motion (linear, rotary, swinging) • Mechanical vibration	• Vehicles • Generator moving parts • Valve/actuator moving parts • (construction phase)
Gravitational Energy	• Unsecured equipment at height • Work at height • Soil settlement • Liquid storage head	• Stored water (pressure head) • Lifting (construction phase)
Natural Energy	• Lightning • Wind • Flood / rain • Seismic event / ground movement • Plants / weeds	• Lightning • Wind • Flood/rain • Hail
Noise Energy	• High-noise equipment • Explosion • Continuous high noise source	• Generator noise • Venting noise • Gas regulator noise

Guideword	Threat	This Project
Controls & Controllers	• Errors • Accidents • Intentional harm • System failure	• Operators • Instrument air • Software
Third Party Hazards	• Any hazardous scenarios (esp. fire, explosion) from surrounding facilities	• Adjacent gas facility

Consequence / Affected party Guidewords

Guideword	Consequences	This Project
Harm to Humans / Biology	• Asphyxiation • Disease • Toxicity • Temperature • Radiation • Strain / ergonomics • Shock	• Operators and delivery personnel • Closed environment • Cooling water system (salmonella)
Harm to Environment	• Flora • Fauna • Waterways / water resources	• Reject water (brine) • Plants/weeds
Harm to Public / Community	• Social nuisance • Interruption to services	• Secondary gas main supply • H_2 customers • Electricity customers • Noise pollution
Harm to plant	• Wear • Deterioration • Damage	• Electrolyser • Generator • Control hut
Harm to adjacent property (third party)	• Knock-on effects of hazards	• Horsley park PRS • Pipeline risers / launchers
Downstream / upstream effects	• Interface requirements and protections • Contractual requirements	• Secondary main composition • Generated electricity specifications

APPENDIX 5 ATTENDANCE REGISTERS

Due to COVID-19 and completing the HAZOP remotely, the HAZOP minutes are the record of attendance for the second HAZOP.

GPA ENGINEERING	HAZOP ATTENDANCE REGISTER DAY 1	18667-REP-009
	Jemena - Detailed Design for Hydrogen Generation (Western Sydney Green Gas Trial)	SHEET 1 OF 1

ATTENDEE	COMPANY	POSITION	SIGNATURE	DATE
NORMAN SIM	JEMENA	PRINCIPAL MECH ENGR		25/7/19
James D Gas	AMT	Projects / Engineering		25/7/19
Marcoen Stoop	Hydrogenics	Sales director		25/07/19
ALDO PACE	AMT	PROJECT MANAGER		25/7/19
LEON TERENYI	JEMENA	PROJ. ENG		25-JUL-19
MARK RATHBONE	JEMENA	SENIOR PROJ. MNGR		25/07/19.
Briony O'Shea.	GPA Engineering	Project Manager.		25
Steve Drinkald	GPA Engineering	Senior Project Eng (E,I&C)		25/7/19
Daniel Krosel	GPA Engineering	MECHANICAL ENGINEER		25/7/19
Frank Libri	Jemena	Commissioning Manager		25/7/19
Nathan Tickle	Jemena	Mechanical TO		25-7-19
Paul Dixon	Jemena	E and I TO		25-7-19
SAM HATWELL	GPA ENGINEERING	PROCESS ENGINEER		25/07/2019
ALISTAIR WARDROPE	JEMENA	TECHNICAL LEAD		25/07/19
Nick KASTELEIN	GPA ENGINEERING	Mechanical Engineer		25/07/19

GPA ENGINEERING	HAZOP ATTENDANCE REGISTER DAY 1	18667-REP-009
	Jemena - Detailed Design for Hydrogen Generation (Western Sydney Green Gas Trial)	SHEET 1 OF 1

ATTENDEE	COMPANY	POSITION	SIGNATURE	DATE
BESIM GREUSHER	JEMENA	O&M INTEGRATION		25/07/19 (PT)
ANDREW MACKAY	JEMENA	PROCESS ENGINEER		25/07/19

GPA ENGINEERING	HAZOP ATTENDANCE REGISTER DAY 2	18667-REP-010
	Jemena - Detailed Design for Hydrogen Generation (Western Sydney Green Gas Trial)	SHEET 1 OF 1

ATTENDEE	COMPANY	POSITION	SIGNATURE	DATE
Daniel Kroschl	GPA Engineering	Mechanical Engineer	[signature]	26/7/19
Nathan Tickle	Jemena	Mechanical TO	[signature]	26-7-19
Frank Libri	Jemena	Commissioning Manager	[signature]	26/7/19
Steve Drinkald	GPA Engineering	Sen. Proj. Eng (E, I & C)	[signature]	26/7/19
J.P van der Uyver	Jemena	Principal E&I Engineer	[signature]	26/7/19
MARK RATHBONE	JEMENA	SNR PROJ MNGR	[signature]	26/07/19
LEON TERENYI	JEMENA	PROJ. ENG	[signature]	26-JUL-19
Briony O'Shea	GPA Eng	Snr Proj. Mngr.	[signature]	"
SAM HATWELL	GPA ENGINEERING	PROCESS ENGINEER	[signature]	26/07/2019
NORMAN SIM	JEMENA	PRINCIPAL MECH ENGR	[signature]	26/7/19
Paul Dixon	JemenA	E and I TO	[signature]	26/7/19
ANDREW MACKAY	JEMENA	PROCESS ENGINEER	[signature]	26/07/19
ALISTAIR WARDROPE	JEMENA	TECHNICAL LEAD	[signature]	"
NICK KASTELEIN	GPA ENGINEERING	MECHANICAL ENG.	[signature]	"