ATCO REFUELLER OPERATIONAL KNOWLEDGE SHARING REPORT - PUBLIC

GAS DIVISION

22/11/2023

Contents

OVERVIEW

ATCO, in partnership with Fortescue Future Industries, has completed construction of Western Australia's first hydrogen passenger vehicle refuelling station at Jandakot. The station was officially opened on the 5th December 2022.

The project was completed with the allocation of $1 Million funding from Western Australia Government Department of Jobs, Tourism, Science & Innovation (JTSI) Renewable Hydrogen Fund – Capital Works Program for the design, construction, installation and commissioning of a complete industry standard fast-fill capable Hydrogen Refuelling Station (HRS).

The HRS is fully integrated with the existing Clean Energy Innovation Hub (CEIH) infrastructure, which includes hydrogen production, at ATCO's Jandakot Operational Centre. The HRS has the capability to fast-refuel up to 5 vehicles per day to support a small fleet of passenger hydrogen Fuel Cell Electric Vehicles (FCEV), initially 15 vehicles. The fast refuel is to enable the vehicles to be filled from empty in approximately 6-8 minutes.

Disclaimer

The information contained within this report has been prepared to provide an overview of the Hydrogen Refuelling Station installed at ATCO's Jandakot Operations Centre. Whilst ATCO has taken all due care in the preparation of this report, the information is current at the time of publishing, is subject to change and is not to be relied upon. ATCO makes no warranties to the completeness or accuracy of the information contained within this report. ATCO will not be liable for any errors or omissions or any loss or damage of any kind sustained as a result of any person relying on this report, and any such liability is expressly disclaimed.

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1. FUNDING ACKNOWLEDGEMENT

Government of **Western Australia**
Department of **Jobs, Tourism, Science and Innovation**

Acknowledgement of Funding

"The project (Project) received grant funding from the Western Australian Government's Renewable Hydrogen Fund, which is administered by the Department of Jobs, Tourism, Science and Innovation (the Department).

Disclaimer

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2. PROJECT DETAILS

This project consisted of the installation of an industry standard fast refuelling station taking hydrogen from the existing 65 kg per day (nameplate capacity) green hydrogen production plant located at ATCO's CEIH facility, in Jandakot.

The $4 Million AUD project included the design, construction, installation and commissioning of a complete Hydrogen Refuelling Station (HRS), fully integrated with the existing CEIH infrastructure at ATCO's Jandakot Operational Centre. The project cost does not include the existing hydrogen production and CEIH infrastructure as detailed in Section 4.

The installed HRS supports the fast filling (in accordance with SAE J2601 H70/T40 protocol) to support a small fleet of FCEV, initially 15 vehicles. The HRS is capable of completing up to five FCEV vehicle refuels from empty (approximate 5kg vehicle tank capacity) per day. The refuel rate is up to a maximum of 60 grams per second (3.6 kilograms per minute), with a typical refuel taking approximately 6-8 minutes.

The HRS consists of Hydrogen Compression (from the CEIH storage), Storage, Chilling and Dispensing, along with all associated equipment and overarching control and safety systems.

2.1 Project Location

The HRS has been installed at ATCO's Gas Division Operation Centre, located at 81 Prinsep Road Jandakot.

3. OPERATIONAL DATA

3.1 Vehicles & Refuelling

3.1.1 Number of Vehicles

The number of vehicles approved to access the HRS has increased from the initial 15 to 20 vehicles.

3.1.2 Volume of Hydrogen dispensed

An average of 19kg of Hydrogen has been dispensed per week. This is much lower than the forecasted 75kg due to vehicle usage and subsequently refuelling frequency.

3.1.3 Refuel Rate

Since commissioning, the average refuelling time is 7 minutes. The minimum refuel time is 4 minutes and maximum is 16 minutes.

The variation on refuelling times is due to a number of factors, with longer refuel times more often recorded immediately post commissioning whilst the system optimisation was still occurring, or due to minor equipment faults.

3.1.4 Fuel Efficiency

Actual efficiency of the vehicles vary depending on driving style, usage and settings. Average fuel efficiency calculated from a sample of vehicle data is 106km/kg. Published Toyota Mirai fuel efficiency is 67MPGe which is approximately 107km/kg of Hydrogen.

3.1.5 Station Availability

Station availability since commissioning is approximately 76%. It is noted that there have been periods of unplanned maintenance affecting the station availability levels.

3.2 Maintenance

3.2.1 Planned Maintenance

Planned maintenance tasks include routine ongoing operational checks, visual inspections, and minor maintenance activities.

The only yearly planned maintenance item of not is the pressure vessel first yearly inspection.

The majority of key components in the HRS system are on a 3-5 year major maintenance cycle.

3.2.2 Unplanned Maintenance

A number of significant unplanned maintenance activities have been conducted, these include:

- Repairs to the chiller coolant system.
- Repairs to the dispenser control valve.
- Replacement of failed pressure gauges.
- Replacement of failed compressor seals.

3.3 Operating expenditure

	Forecast	Actual	
Total Annual OPEX (not incl. vehicle lease)	220,537	309,022	The actual OPEX is significantly higher due unplanned maintenance requirements.

4. HRS PLANT AND EQUIPMENT

The compressed hydrogen is stored onsite until such time as a vehicle is required to be refuelled. The HRS consists of a number of plant and equipment required to achieve the hydrogen refuelling process. The major items of plant and equipment for the HRS are provided below.

4.1 Hydrogen Compressor (booster) and Hydraulic Power Unit (HPU)

The hydrogen from the existing production facility (refer Section 4), is compressed to achieve the pressure and volume required for the refuelling process. In order to achieve the pressure required a single Haskel H-drive piston style compressor HGT-150/63-2-2 has been installed to take gas from the existing 30bar CEIH storage tank into the HRS high pressure storage vessels.

The H-Drive booster is driven from a 75kW Bosch Rexroth hydraulic power unit (HPU). The booster requires up to 24kW hydraulic power, however a 75kW unit has been installed for potential increased flow in the future.

The booster assembly including associated heat exchangers, piping, valves & fittings are installed within a compartment contained withing a 20ft shipping container. This compartment also contains necessary safety features including a ventilation extraction fan, gas and flame detection systems.

The HPU and associated piping valves and fittings, are installed in an adjacent compartment of the same container.

The process is driven via a customised PLC which is programmed to control the HRS system operations.

4.2 Hydrogen Storage Vessels

The compressed hydrogen is stored onsite, comprising of;

- 4 x 500L (10.1 kg) Medium Pressure forged steel vessels (~40 kg @ 500 bar)
- 2 x 264L (12.7kg) High Pressure forged steel vessels (~25 kg @ 930 bar)

The storage vessels are located external to the container and adjacent to other items of HRS plant. The amount of storage has been designed to meet the specified number of vehicle refuels per day.

The differing storage vessel pressures have been purposefully designed are arranged in ‘cascades’ near to the compression unit to allow for the most efficient use of the stored gas. Each of the cascades includes associated valving and control assemblies.

The pressure vessels, valving and control assemblies and safety functions are monitored and controlled by the PLC.

4.2.1 Testing and certification

The vessels have been manufactured by FIBA in the USA to the relevant ASME VIII pressure vessel codes which are accepted in line with Australian Standard 1200:2015 Pressure Equipment.

The pressure vessels also have local design verification and registration of plant as required by Worksafe WA.

4.2.1.1 Inspection schedule

The vessels are inspected in accordance with Australian Standard AS/NZS 3788:2006 Pressure equipment – In-Service inspection. The pressure equipment requires a first yearly inspection, with an inspection nominally every 4 years, or as extended in accordance with the Standard.

4.3 Dispenser

A standalone dispenser has been installed on the site adjacent to a refuelling bay constructed for the works.

The dispenser comprises of the following equipment;

- 1x WEH TK17 IrDA Nozzle suitable for 70MPa vehicle fills with high pressure hose and TSA1 breakaway coupling.
- HMI screen interface.
- Safety equipment including emergency stop button and pressure relief devices.
- Flow meter.

The hydrogen is dispensed to the vehicle via the dispenser, fitted with a nozzle with Infra-Red communications for 700 bar vehicles, this nozzle is not suitable for 350 bar vehicles. The control of the discharge is via a HMI screen on the dispenser, linked to the main PLC, which controls both the hydrogen storage cascades via a flow control valve to govern the flow rate of the hydrogen through the nozzle to the vehicle.

The interface between the station and the vehicle is through the WEH SAE J2600 compliant fuelling nozzle, featuring an SAE J2799 infra-red communication device.

Dispenser flow is rated to a maximum 60 grams/sec.

4.4 Chiller

A dual purpose chiller has been installed as part of the HRS package. This chiller contains both Water/Glycol and CO2 cooling processed. The water & glycol cooling is utilised for the Heat exchangers required for the compression and HPU processes. The CO2 cooling is required for the dispensing process. The cooling of the dispensed hydrogen will be via a diffusion bonded heat exchanger, located within the dispenser column.

The supplied Kustec chiller is a -50°C CO2 (R744) chiller, which will enable the HRS to meet the requirements of the SAE J2601-1:2016 H70T40 table-based fuelling protocol. The chiller is free standing and located within the maximum 50 metre pipe run from the dispenser.

The chiller is a closed circuit and does not consume water.

4.5 Balance of plant

Additional HRS equipment includes;

Description	Manufacturer	Purpose
Air compressor	Atlas Copco	Operating pneumatic valves
Piping, valves and fittings	BuTech MP (20,000PSI rated)	Hydrogen conveyance
Sensors, transducers, etc.	Various	Various

4.6 HRS energy consumption

The total expected energy (electric power) consumption for the HRS equipment is 10.6 kWh/kg of hydrogen dispensed. The electricity required is purchased, backed by the surrender of Large-scale Generation Certificates (LGCs) to ensure the electricity used for the hydrogen refuelling is recognised as renewable.

4.6.1 Forecast and actual energy consumption of HRS

Forecast energy, (kWh/kg)	Actual energy, (kWh/kg)	Comments
10.6	32.5	The energy consumption for the HRS is higher than anticipated. This is likely due to both variance in operational parameters and incorrect assumptions used in initial calculations.

5. HYDROGEN PRODUCTION

ATCO's Clean Energy Innovation Hub (CEIH), completed in July 2019, aims to investigate the potential role of hydrogen in the future energy mix by developing and utilising an industry-leading research facility. Testing will be conducted on a microgrid set-up enabled by renewable gas technology (including hydrogen) and on the integration of renewable gas with solar and batteries.

ATCO's CEIH is an Australian-first, which integrates renewable hydrogen production and fuel cell technology with a renewable energy stand-alone-power-system in a "living lab" microgrid setup. At the CEIH, 1003 solar panels will produce renewable energy to supply ATCO's Jandakot Operations Centre. Excess renewable energy generated from the 300 kW of rooftop solar photovoltaics is used to produce renewable hydrogen[1] from a 260 kW electrolyser. Excess renewable energy is also stored for non-sunshine hours-usage in 500 kWh (478 kWh useable) of onsite battery energy storage. Pure green hydrogen is stored in a 30-bar high-pressure storage vessel for future uses.

Further details on the CEIH, including existing hydrogen production infrastructure can be found in the public report published on ARENAs website here; Report: Clean Energy Innovation Hub (PDF 2MB).

The CEIH Project received funding from ARENA as part of ARENA's Advancing Renewables Program. The views expressed herein are not necessarily the views of the Australian Government, and the Australian Government does not accept responsibility for any information or advice contained herein.

5.1 Hydrogen production & usage

Hydrogen will be produced from the existing CEIH electrolyser, which has the capacity to generate up to 65kg/day (~2.7kg/hr) of hydrogen, which is then stored in the onsite 4kL storage vessel at the electrolyser outlet pressure of 30bar (~11kg H2 storage volume).

Existing and planned uses for the Hydrogen include;

1. Hydrogen vehicle refuelling – Mon-Fri 8am to 5pm, up to 30kg/day.
2. Hydrogen Blending – Peak Gas Flow Periods (6am – 8am & 6pm – 8pm), up to 5kg/hr, or 20kg per day.
3. Hydrogen Fuel Cell - 0.3kg/hr at full load, up to 2.5kg/day.
4. On-site intermittent testing– as required, up to 3.8 sm3/hr (~2kg/hr).

Whilst these uses sum to below the nominal capacity of the electrolyser production rate of 65kg/day, the limiting factor is the 4kL storage vessel. This volume is a depleting source as the usage rate is higher than the electrolyser production rate.

Maximum forecast annual production of hydrogen for the above uses is estimated to be up to 12.6 tonnes.

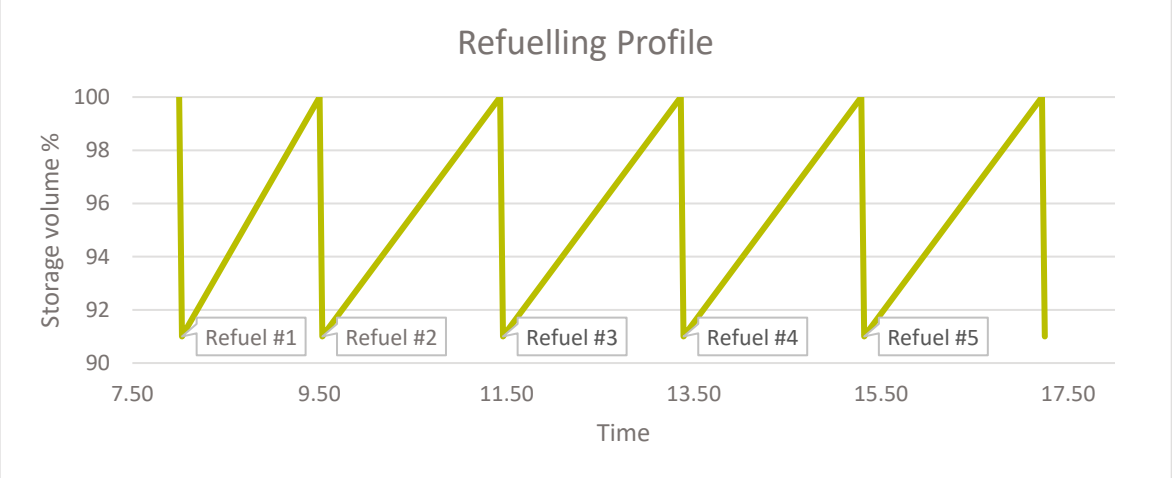
[1] To produce sufficient hydrogen for the Project, ATCO will supplement the solar energy by purchasing electricity, backed by the surrender of Large-scale Generation Certificates (LGCs) to ensure the electricity used to produce hydrogen is recognised as renewable.

5.1.1 Forecast and Actual Hydrogen Production

	Forecast Hydrogen, year (kg)	Actual Hydrogen (year to-date) (kg)
Refuelling	4,800	869
Blending	3,200	32.7
Fuel Cell	400	290
Testing, other uses etc.	-	78.3
Total Annual	8,400	1,290

5.1.2 Hydrogen refuelling profile

When a hydrogen FCEV vehicle is refuelled, the hydrogen in the HRS storage vessels flow through the dispenser to charge to vehicle to nominally 700bar. The refuelling event depletes the storage vessels pressure and requires recharging from the compressor. An approximate profile is shown below. Note that the profile assumes the tanks are topped up to 100% prior to the next refuelling event and that the recharge period is determined by the electrolyser hydrogen production rate.



5.2 Electricity & water consumption

5.2.1 Forecast annual electricity and water consumption of electrolysis unit.

Whilst it is not expected that the maximum volume of hydrogen specified above will be required on a day to day basis, the electrolyser is likely to operate for 10 hours a day to produce approximately 25kg of Hydrogen for use across the various functions.

- At the manufacturer published rate of 64.5kW/kg of Hydrogen produced the annual electricity consumption is estimated at approximately 387MW.

  To produce sufficient hydrogen for the uses listed in Section 4.1, ATCO will supplement the solar energy by purchasing electricity, backed by the surrender of Large-scale Generation Certificates (LGCs) to ensure the electricity used to produce hydrogen is recognised as renewable.

- At the manufacturer published rate of 26.9L of water consumption per hour, the annual consumption is estimated to be approximately 65kL.

5.2.2 Forecast and actual 6 monthly electricity and water consumption of electrolysis unit

	Forecast	Actual	Comments
Water consumption	32.5 kL	21.6 kL	Whilst water consumption is lower, the original consumption calculation did not include the associate process chiller which makes consumes water at a higher rate than the electrolyser process itself.
Power consumption	193.5 MW	26.5 MW	Power consumption is significantly lower due to much lower hydrogen production requirements.

5.3 Electrolyser Efficiency & Utilisation

As noted in Section 3.1, the full capacity of the electrolyser is unable to be used due to the variation in production and usage rates, along with the specific utilisation times. At the maximum theoretical consumption, the electrolyser utilisation may be up to 14 hours of operation per day, producing 38kg of Hydrogen or approximately 60% of the electrolysers rated production capacity.

The manufacturer stated efficiency is listed at 64.5kW per kg of hydrogen produced.

5.3.1 Actual Electrolyser efficiency and utilisation

	Forecast	Actual	Comments
Electrolyser efficiency	64.5 kWh/kg	65.05 kWh/kg	-
Daily Electrolyser utilisation	60% maximum	35% maximum	The average electrolyser utilisation is significantly lower than forecast due to lower usage requirements across blending, refuelling and fuel cell.

5.4 Fuel (hydrogen) quality

Required hydrogen quality is specified in AS ISO 14687:2020 Hydrogen fuel quality - Product specification as referenced by ISO 19880.1 Gaseous Hydrogen – Fuelling Stations.

Please see below excerpt from the sample taken prior to commissioning at the Jandakot site. The ongoing sampling frequency is a minimum of once per year or immediately after any significant works on the infrastructure.

Hydrogen Impurity Analysis.

Sample Number				ACS2233517-1
Client ID				Jandakot H2
Analyte	Method	Units	Reporting Limits	Results
Oxygen	ISBT 4.0	ppm (v/v)	5	<5
Nitrogen	ISBT 4.0	ppm (v/v)	20	<20
Argon	ISBT 4.0	ppm (v/v)	5	<5
Helium	ISBT 4.0	ppm (v/v)	300	<300
Moisture	ISBT 3.0	ppm (v/v)	5	<5

All tests performed to the specifications of AS14687:2020

Note: IS indicates insufficient sample to perform test.
Note: nr indicates test not requested.
Note: Samples are analysed as received.

ACS Sample Designation	Client Sample Designation
ACS2233517-1	ATCO Western Australia Hydrogen Gas 100Bar Sampled 28/11/2022 12:45pm

5.4.1 Operational update on fuel quality

Fuel quality has been laboratory re-tested with no changes to specification or contaminants identified. The most recent hydrogen sample was taken on the 21st August 2023.

6. REGULATORY AND APPROVALS

6.1 Department of Mines, Industry Regulation and Safety

The Department of Mines, Industry Regulation and Safety (DMIRS) has a number of divisions that regulate both Dangerous Goods and the safe use of Gas. With the Hydrogen being generated and used at the CEIH and HRS installations (site), two key legislative instruments were identified;

1. Dangerous Goods Act 2004
    a) Dangerous Goods Safety (Storage and Handling of Non-Explosives) Regulations 2007
2. Gas Standards Act 1972
    a) Gas Standards (Gasfitting and Consumer Gas Installations) Regulations 1999

6.1.1 Dangerous Goods Act

The Department of Mines, Industry Regulation and Safety (DMIRS), Dangerous Goods directorate are the regulatory body for Dangerous Goods in WA as defined in the Dangerous Goods Act 2004.

The subsidiary legislation that relates to the Hydrogen as utilised in the HRS and CEIH installation is covered under the Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulations 2007.

The Dangerous Goods classification of hydrogen gas is Division 2.1 Flammable Gasses.

With the HRS storage added to the existing CEIH storage, the quantity (vessel capacity) of hydrogen storage located within the CEIH and HRS compound is approximately 6,500L which is above the 'manifest' quantity but below the 'Major Hazard Facility' level, in accordance with Schedule 1 of the Regulations.

In accordance with the legislation ATCO has completed the requirements as stipulated and received the Dangerous Goods License (DGS022830) for the facility.

6.1.1.1 Findings

In preparing and submitting the Dangerous Goods license ATCO has observed the following;

- At the time of preparation there was no 'approved standard' by DMIRS for the storage and handling of hydrogen and hence no specific standard for which there is an expectation to assess the facility against.
    - At the time of writing this report the DMIRS has since published a Dangerous Goods Safety Guide: Storage handling and production of hydrogen which now states compliance to ISO 19880 shall be assessed.
- Assessment against relevant ISO Standards (ISO 19880-1 'Gaseous Hydrogen, Fuelling Station, Part 1: General Requirements') has been undertaken to future-proof the design of the facility with regard to compliance with codes that may be potentially approved in the future.
    - It is noted at the time of writing this report the Australian Standards committee has adopted the ISO 19880.1 Hydrogen Refuelling standard with a number of amendments as detailed in the Standard.
- The consultation and approvals process within the DMIRS Dangerous Goods branch exceeded expectations especially given the novel nature of the installation being assessed.

6.1.1.2 Dangerous Goods Operational Update

DMIRS representatives have conducted an audit of the HRS facility. X minor actions were identified and have since been completed.

6.1.2 Gas Standards Act

DMIRS Building and Energy (B&E) directorate were consulted on the requirements relating to the HRS. In accordance with the Gas Standards Act 1972, the HRS is a 'Gas Installation'.

1. As per section 4 of the *Gas Standards Act 1972 (GSA)* "Gas installation" is defined as any appliance, pipes, fittings or other apparatus installed or to be installed for or for purposes incidental to the conveyance, control, supply or use of gas.
2. As per regulation 4 of *Gas Standards (Gasfitting and Consumer Gas Installations) Regulations 1999 (GSR)* "Gasfitting work" is defined as work in connection with the installation, removal, demolition, replacement, alteration, maintenance or repair of a "gas installation". A number of exemptions to what is "gasfitting work" are then listed but none appear to be applicable to the refuelling station scenario.
3. As per Schedule 5 of the *Gas Standards (Gasfitting and Consumer Gas Installations) Regulations 1999 (GSR)* Classes of gasfitting work reference Class P for "Gasfitting work on a gas installation associated with the storage and dispensing of gas for the refuelling of a motor vehicle as defined in the Road Traffic (Administration) Act 2008 section 4.
    - Note: Currently the permits issued by DMIRS B&E are restricted with the type of gas such LNG, LPG and CNG.

Considering the regulatory gaps and with the ongoing works in progress to identify the relevant Unit of competencies required for the gas fitter; as discussed and agreed with DMIRS B&E, an application was made to the Director Energy Safety for a person to receive authorisation to carry out and supervise gas fitting work associated with this installation.

6.1.2.1 Findings

- Two gasfitting authorisations were submitted.
- As advised, ATCO made the initial gasfitting application (for installation works) to the Director Energy Safety (Building and Energy). It was advised that a formal Authorisation request was required through DMIRS licensing team.
    - Due to the novel nature of this application and with respect to the current legislative instruments, the licensing team was unable to process without the approval of the Director Energy Safety.
    - The application was then passed to the Director EnergySafety and subsequently approved.
- The second gasfitting authorisation application (related to commissioning activities) was completed expediently and without issue utilising the learning from the first application.
- There is a clear gap in the legislation that does not provide for a Hydrogen Vehicle Refuelling Station to have proven gasfitting competencies.
- It is ATCOs understanding that DMIRS are working towards fixing the gaps in the legislation and subsequent competencies required for hydrogen gasfitting works.

6.1.2.2 Gas Standards Operational update

A Notice of Completion for the works was submitted to DMIRS Building & Energy as required under the legislation. There is no update or further action since commissioning.

6.2 Planning Approval

ATCO sought advice on the project from the Department of Planning, Lands and Heritage (DPLH) with respect to required approvals and received the following advice;

a) an application for approval under the Metropolitan Region Scheme (MRS) is required, as the proposed works do not meet the definition of permitted development as set out in the region scheme; and

b) no approval is required under the City of Cockburn's local planning scheme – in this regard, works on land reserved under a region planning scheme do not require approval under the local planning scheme.

6.2.1 Local Government

Notwithstanding b) above, ATCO consulted with the local government authority (LGA) - in this case the City of Cockburn, to ensure that all stakeholders were informed and due processes understood.

The required development application under the MRS is submitted via, and also assessed by the LGA.

A number of building applications associated with the works were submitted to the LGA for approval as required.

6.2.2 Department of Planning, Lands and Heritage

An application was duly made to the DPLH under the requirements of the MRS. The project was assessed by DPLH and deferred to the following government bodies for review and comment;

- Department of Biodiversity, Conservation and Attractions
  - No comment received
- Department of Water and Environmental Regulation
  - No comment received
- Department of Mines, Industry Regulation and Safety
  - refer above Section 5.1

6.2.2.1 Department of Fire and Emergency Services (DFES)

DFES was consulted early in the project initiation phase and also as a referred agency for the Development Application. A number of outcomes were provided;

- Revised bushfire management plan
- Relocation of ATCO's building fire protection system
- Updating of ATCO's building fire alarm system
- Pre-incident plan uploaded to DFES system

6.2.3 Planning approval operational update

No updates or further action.

7. CONCLUSION

ATCO is proud to have delivered Western Australia's first hydrogen vehicle refuelling station in line with the WA Renewable Hydrogen Strategy.

The below provides a summary of the challenges and positives to be taken from the HRS project post 12 months operation;

Challenges

- Spares and maintenance parts availability.
    - A number of replacement parts and spares have been required, however the lead time and availability on some of these components varies from 12 weeks to 36 weeks, in one case up to a year.
- Equipment failures.

  A number of key component failures have occurred, namely;
    - Pressure gauges
    - Compressor seals
    - Dispenser control valve
    - Chiller coolant system

  These failures were repaired without issue, however the lead time for parts and repair required either interim fixes and/or impacted HRS availability for refuelling.
- Quality control.
    - The equipment failures listed above and additional issues identified during commissioning and early operation have required rectification and a significant cost and time impact.
- Budget.
    - Due to the unplanned component failures and repairs, the original yearly budget was exceeded.
    - The initial operating budget assumptions have been identified as insufficient.

Positives

- WA has a hydrogen refuelling station capable of refuelling passenger vehicles in approximately 7 minutes.
- Ongoing maintenance is completed using ATCO employees, contractors and subcontractors based in Australia and Western Australia
- Experience and learnings that can be applied to future projects by all parties involved in project delivery and operation phases of this project.
- Socialisation of Hydrogen as a vehicle fuel.