Clean Transportation Program

FINAL PROJECT REPORT

ANAHEIM HYDROGEN

Prepared for: California Energy Commission

Prepared by: Air Liquide Advanced Technologies U.S. LLC

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California Energy Commission

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ACKNOWLEDGEMENTS

Air Liquide thanks the State of California for the opportunity to participate in this new and exciting effort. The planning, installation and operation of the hydrogen refueling station (HRS) could not have occurred without the unwavering support of the CEC Air Liquide is very appreciative and indebted to the support of the California Air Resources Board's support of its Anaheim commissioning efforts with deployment of its Hydrogen Station Equipment Performance (HyStEP) equipment and analysis team to the Anaheim HRS on two separate occasions. Additionally, Air Liquide acknowledges the efforts of many others within California's hydrogen community who worked on behalf of the project to make it a success.

PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation Program. The statute authorizes the CEC to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) reauthorizes the Clean Transportation Program through January 1, 2024, and specifies that the CEC allocate up to $20 million per year (or up to 20 percent of each fiscal year's funds) in funding for hydrogen station development until at least 100 stations are operational.

The Clean Transportation Program has an annual budget of about $100 million and provides financial support for projects that:

- Reduce California's use and dependence on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Produce sustainable alternative and renewable low-carbon fuels in California.
- Expand alternative fueling infrastructure and fueling stations.
- Improve the efficiency, performance and market viability of alternative light-, medium-, and heavy-duty vehicle technologies.
- Retrofit medium- and heavy-duty on-road and nonroad vehicle fleets to alternative technologies or fuel use.
- Expand the alternative fueling infrastructure available to existing fleets, public transit, and transportation corridors.
- Establish workforce-training programs and conduct public outreach on the benefits of alternative transportation fuels and vehicle technologies.

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual Clean Transportation Program Investment Plan Update. The CEC issued PON-12-062 to provide funding opportunities under the ARFVTP for high-performance retail hydrogen re-charging stations In response to PON-12-062, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards April 11, 2013 and the agreement was executed as ARV-12-062 on June 30, 2013.

ABSTRACT

Air Liquide Advanced Technologies U.S. LLC installed and now operates a hydrogen refueling station in Anaheim, California. This hydrogen station was awarded a capital expense grant in 2013. The hydrogen station equipment utilized a design developed by Air Liquide for European Union's Tran-Europe Network-Transport Hydrogen Infrastructure for Transport. The site was selected for its convenience to major freeways as well as containing enough unoccupied land to accommodate the hydrogen station equipment. The project milestones and major lessons learned are described in detail in the report.

Keywords: Hydrogen refueling station (HRS), Pre-Startup Safety Review (PSSR), Hydrogen Station Equipment Performance (HyStEP)

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EXECUTIVE SUMMARY

The opening of a hydrogen refueling stations at 3731 E La Palma Ave in Anaheim, CA provided a significant learning opportunity for the United States Hydrogen Energy Team at Air Liquide. This report presents the project details and some analysis on the lessons learned.

The station in Anaheim is an important part of the slowly developing hydrogen infrastructure network of Southern California. The station was awarded based on a response by Air Liquide to the CEC solicitation, PON-12-606. The award was announced in Novembers 2012. The grant, ARV-12-062 began on June 30, 2013. The station was opened for public use on November 28, 2016. During the 3 years and 5 months between initial execution of the grant and the opening of the station, several challenges were overcome, and lessons were learned.

The report identifies three project phases: site development & engineering, construction, and operation. Each phase presented unique challenges requiring creative solutions and advancing the knowledge of hydrogen fueling technology application and deployment.

The site development & engineering phase of the project faced significant challenges in the appropriate application of fire codes and compliance to those fire codes in the limited space provided at an existing gas station. While this challenge was not unique to Anaheim, the challenges were new to Air Liquide. The challenges were overcome with effort spent on internal communications and consensus interpretation of the statutory requirements.

The hydrogen equipment also presented challenges for Air Liquide. The basis of design for the station equipment was a similar project in central Europe, the European Union's Tran-Europe Network-Transport Hydrogen Infrastructure for Transport. While this project had many similar technical requirements, some aspects, particularly the point-of-sale capability were significantly different.

The construction of the station started on December 30, 2015 with the approval of the permit to construct issued by the City of Anaheim. Construction completed on July 10, 2016, approximately 40 days behind schedule. No single challenge provides clear reason for the delay in construction. The electric utility requested a larger transformer, causing several days delay in renegotiating the area specified in the lease agreement. Uncommonly frequent rainstorms caused more than expected delays during initial demolition and site work. Other aspects of the construction delays were likely due to more common issues: missing information on construction drawings, labor availability, underestimate of labor required for specific construction tasks, etc.

The operation of Anaheim has been challenged by the early issues resulting from equipment design assumptions and lack of experience to predict component reliability. The station does not meet the technical requirements of ARV-12-062. Namely, the station provides insufficient pre-cooling for the H70 pressure dispensing, not meeting the -40 degrees C pre-cooling category. Anaheim also fails to provide H35 fueling.

Despite these operational challenges, Anaheim accomplished 1000 fuelings within the first 100 days of operation.

The overall station cost $2.4M with the CEC grant providing $1.5M and Air Liquide providing $0.9M.

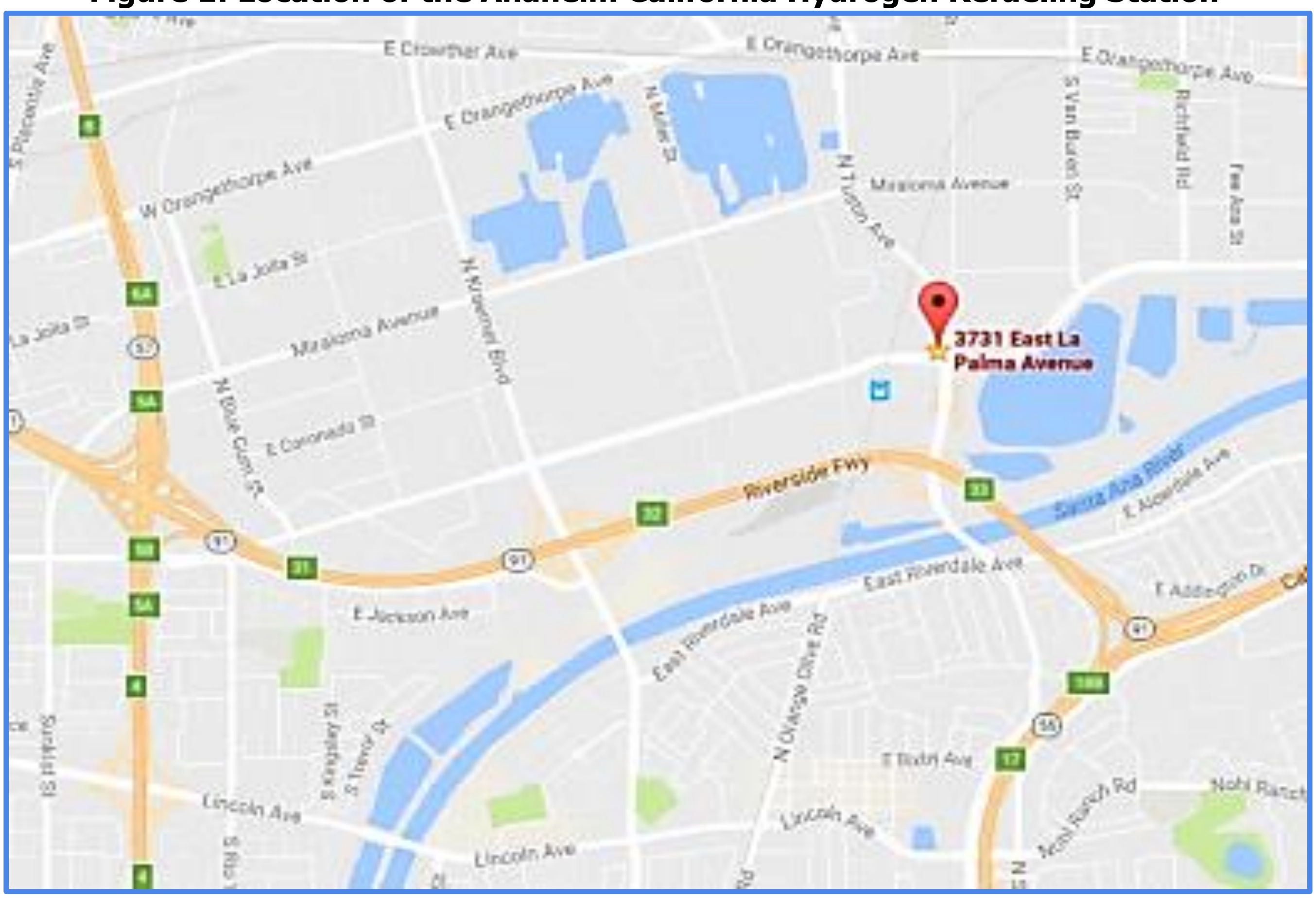
CHAPTER 1: Site Development & Engineering

This chapter provides details on the site development and engineering. The chapter is presented in chronological order of the project process with from site selection to the mobilization of construction activities. The activities often overlapped or required iterative processes. Some of this iteration and complexity is omitted from this report for the sake of clarity.

Station Site Selection & Acquisition

The Anaheim station is co-located with an existing gasoline fueling and convenience store, the La Palma 76 Station. Located at 3731 East La Palma Avenue, the site is near the Tustin Ave exit of the state highway 91 and convenient to the 91, 55 and 57 state highways, see Figure 1. The La Palma 76 Station had another critical characteristic; space to accommodate the hydrogen equipment and setback distances see Figure 2.

Figure 1: Location of the Anaheim California Hydrogen Refueling Station



Source: Google Maps

Site acquisition is the first step in the development of a hydrogen station. Site acquisition is an iterative process which begins with identification of several target sites within a geographic area. The La Palma 76 Station was one of several identified by Air Liquide[1] in November and December 2013 to develop a response to the Energy Commission solicitation PON-12-606. The La Palma 76 Station owner provided a letter of intent in support of the solicitation response; submitted to the Energy Commission before the January 24, 2013 deadline.

Site acquisition completes with the execution of a site lease or purchase. In the case of Anaheim, the site is leased from the La Palma 76 Station owner. On April 11, 2013 the Energy Commission issued the notice of proposed awards for PON-12-606 which included an announced award to Air Liquide for the La Palma 76 Station. Air Liquide executed a lease with the La Palma 76 Station on June 8, 2013. The CEC Grant ARV-12-062 was executed with Air Liquide on June 30, 2013.

Figure 2: Air Liquide site layout at the Anaheim California fueling station

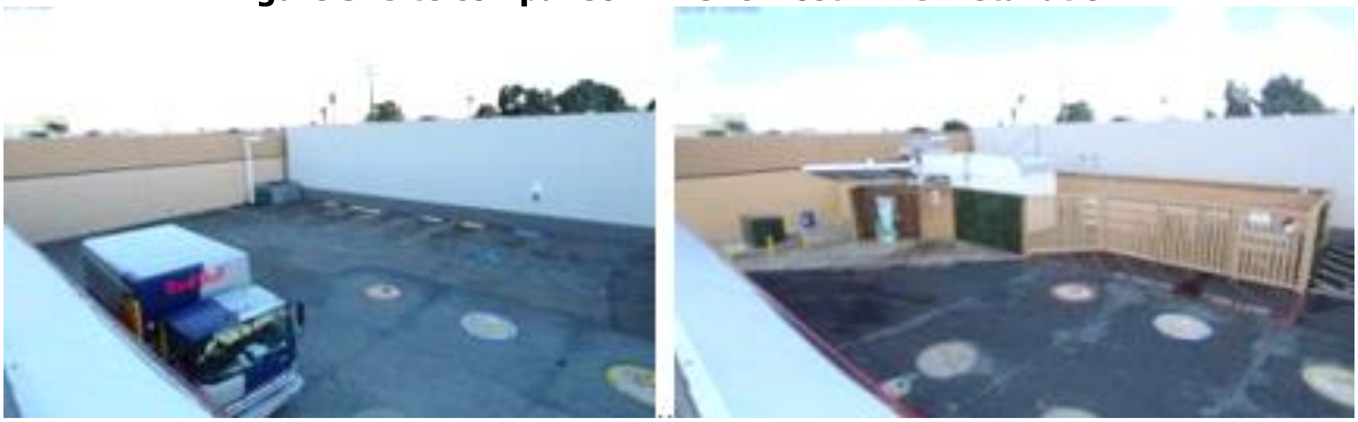
Source: Google Maps with annotation by Air Liquide Advanced Technologies. US, LLC

Site Acquisition Solution

[1] Air Liquide Website https://www.airliquide.com/

The identification of a potential hydrogen station site must initially consider several factors, namely: a willing landlord, easy access for hydrogen vehicle owners, available space for equipment including non-equipment space concerns for parking space requirements by local ordinance, delivery vehicle access and fire code compliance. In Figure 3 on the next page, we can see two photos that show the before and after site comparison of the HRS installations at the Anaheim site.

Figure 3: Site comparison: Pre- & Post- HRS installation



Source: Air Liquide Advanced Technologies U.S. LLC

Many cities use parking space ordinances based on the retail space - number of parking spaces per square foot of retail space. Many gasoline stations have maximized the retail space to parking space ratio. Therefore, hydrogen stations are best suited for gasoline stations which have yet to remodel their retail space. This was the case for Anaheim.

Figure shows the retail space of the station relative to the overall building. The rental income for the hydrogen station allows the landlord to defer any plans for the expansion of the convenience store. Thus, the station equipment was able to consume several existing parking spaces without significant variance from the city.

Figure 4: Convenience store to station site area ratio (retail space indicated by yellow box)

Source: Google Maps

Delivery vehicle access is another challenge to finding viable hydrogen sites. Hydrogen trailers, like gasoline delivery trailers, require deliberate planning to ensure easy and safe delivery of the fuel. Trailers must turn on and off the access road and should be able to pull straight through the site from entrance to exit without backing up or three-point turns. Anaheim was fortunate in that the layout of the site, shown in Figure 5 on the next page, already accommodates gasoline delivery in the approximate location that hydrogen delivery will occur.

Figure 5: Bulk gasoline and hydrogen deliveries at Anaheim

Source: Air Liquide Advanced Technologies U.S. LLC

Equipment Design, Fabrication & Delivery

The CEC solicitation PON-12-606 occurred simultaneously with a similar project development effort in central Europe, the European Union's Tran-Europe Network-Transport Hydrogen Infrastructure for Transport (HIT)[2]. Air Liquide, a partner in HIT, was developing a hydrogen fast-fil station for HIT. The HIT equipment would be installed in Rotterdam station by mid-2014. In July 2013, Air Liquide made the decision to duplicate the equipment design from HIT for Anaheim. The Anaheim station would require modifications necessary to meet U.S. equipment design standards, additional ground storage to accommodate the proposed station capacity, H35 fueling[3] capability, integrated retail point of sale (POS) and California Department of Food and Agriculture DMS compliance for weights and measures.

Air Liquide split the equipment procurement into two portions. One, the hydrogen compression and process controls would be fabricated in France based on the HIT design and modified for U.S. equipment design standards. The dispenser, bulk hydrogen storage, and utilities would be procured in the US. Only the dispenser would be sent to France for integration with the station. The bulk hydrogen storage and utilities would be delivered directly to Anaheim. The selection, shipment and integration of a U.S. based dispenser in France presented significant challenges. Eventually efforts in France were abandoned, due to challenges with the vendor, support resources and insufficient availability of testing facility. Instead, Air Liquide opted to address issues with the equipment once installed in Anaheim.

The Anaheim equipment fabrication was completed in December 2014. The equipment underwent a partial factory acceptance test in February 2015. The 19-month lead time for equipment was unanticipated and mainly due to 3 areas: lack of experience in serial production of hydrogen station equipment, use of U.S. based dispenser presenting significant challenges with controls communication and logistic challenges of multinational coordination. Based on this experience the team worked to develop U.S. dispenser vendors for future stations.

The equipment arrived in Southern California in May 2015 and was placed at the La Palma 76 Station site on May 19, 2016.

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[2] Hydrogen Infrastructure for Transport Definition https://en.wikipedia.org/wiki/Hydrogen_infrastructure

[3] H35 fueling Stations https://www.cars.com/articles/fill-er-up-refueling-the-2016-toyota-mirai-1420690448036/

Equipment Design Lesson Learned:

Gas Metering

Gas metering is employed in the TEN-T project[4]. However, California presented a unique application as there was substantially more ability for regulators to enforce International Organization of Legal Metrology[5] or National Institute of Standards and Technology[6] standards for weights and measures accuracy in California. Communication of design requirements among an international engineering team was difficult particularly without any experience with the California approach. One key difference between the European experience and California is the expectation of shared experience among infrastructure providers. This weights and measures engineering highlight this difference. While several other companies had already experienced the weights and measures review, there was no formal mechanism for sharing lessons learned, nor encouragement to cooperate on meeting requirements. In fact, the California infrastructure grant program, consistent with most U.S. public supported technology development grant programs, tends to discourage collaboration over concerns of collusion. Therefore, the project relied on feedback on user experience from vehicle spell out and budgeted additional commissioning time to address inevitable misalignments. While this additional commissioning time was necessary for Anaheim, Air Liquide has identified reduction of commissioning time as a key objective in future projects.

Equipment Design Lesson Learned: POS

POS systems are simple in theory and difficult in implementation. A POS controls the authorization and payment for retail fuel purchasing. Regardless of fuel type (gasoline, diesel, compressed natural gas or hydrogen) the POS interacts with the dispenser such that fuel is not provided unless a valid form of payment is confirmed, electronically for debit and credit cards. Unlike a retail purchase POS such as for clothing at the department store or even an item regulated by weights and measures such as apples sold per pound at the grocery store, fuel dispensers must activate a transaction, accurately count the amount of fuel dispensed then close the transaction and print the receipt. The interaction with the accuracy measurement device, a flow meter at Anaheim, is critical. Unfortunately, this is a very difficult system to test prior to site installation**.** The Anaheim station is additionally complex as the station includes a programmable logic controller (PLC) that manages station function including safety, alarms and the complex fueling protocols of SAE J2601[7]. Therefore, the POS must interact with both a dispenser controller, common to most fuel applications and a PLC, not common to other fuels. The POS to PLC interaction was a design challenge for Anaheim. Additional commissioning time was planned to address forecasted issues in the interaction particularly due to the inability to test the complete system under 'real-world' conditions. Future designs must plan POS and PLC communication prior to completing the hardware component designs.

Site Layout & Engineering

This section summarizes the construction of the Anaheim station under the CEC grant, ARV-12-062. Anaheim is the first station built for the CEC by Air Liquide and represented a

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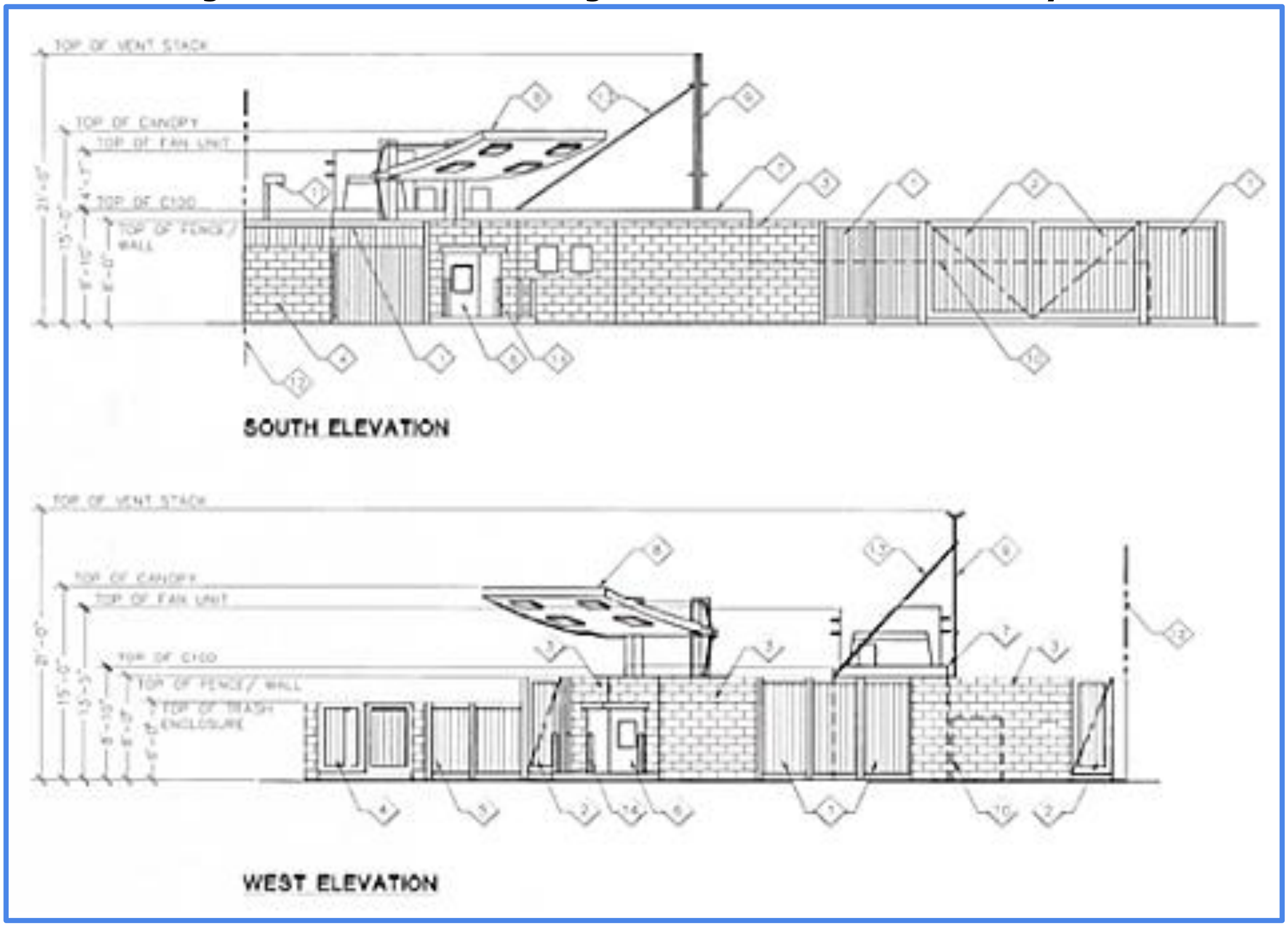
[4] Trans-European Transport Network Website https://ec.europa.eu/transport/themes/infrastructure/ten-t_en
[5] International Organization of Legal Metrology Website https://www.oiml.org/en
[6] National Institute of Standards and Technology Website https://www.nist.gov/
[7] SAE International Website https://www.sae.org/standards/content/j2601_201003/

tremendous learning opportunity for Air Liquide's Hydrogen Energy Team, particularly the U.S. based team members. The architectural rendering of the site can be seen in Figure 6 below.

Figure 6: Elevation Drawing of the Final Anaheim Site Layout

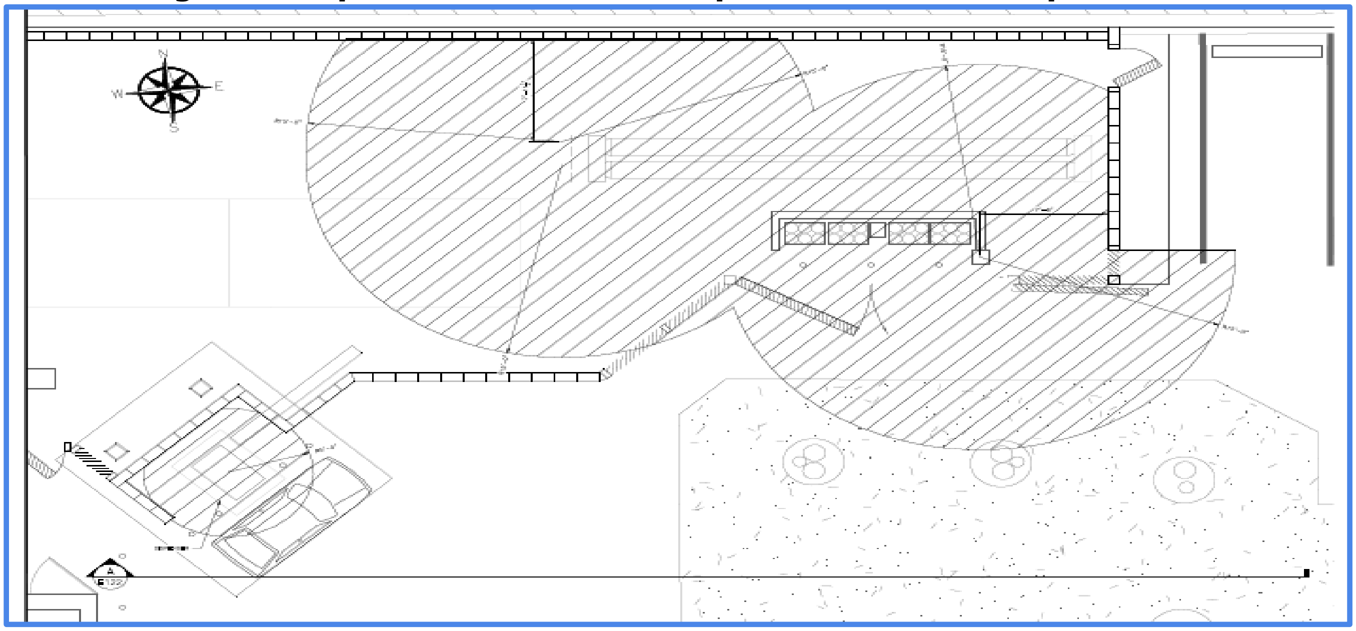


Source: Air Liquide Advanced Technologies U.S. LLC

Any HRS site must accommodate distances from exposures as required in the fire code. During the engineering period of the Anaheim station, the California Fire Code regarding hydrogen fueling installations changed from a reference to the 2009 International Fire Code to a reference to NFPA 2 - 2011[8]. This change opened a discussion within Air Liquide as to the specific requirements. Several months were spent identifying the various requirements and resolving a cohesive approach to the requirements, specifically the separation distances. Figure demonstrates some of these separation distances in the final layout. The subsequent Figure shows the 'empty space' at the site created by these separation distances, approximately 900 square feet, about one-third of the hydrogen station site.

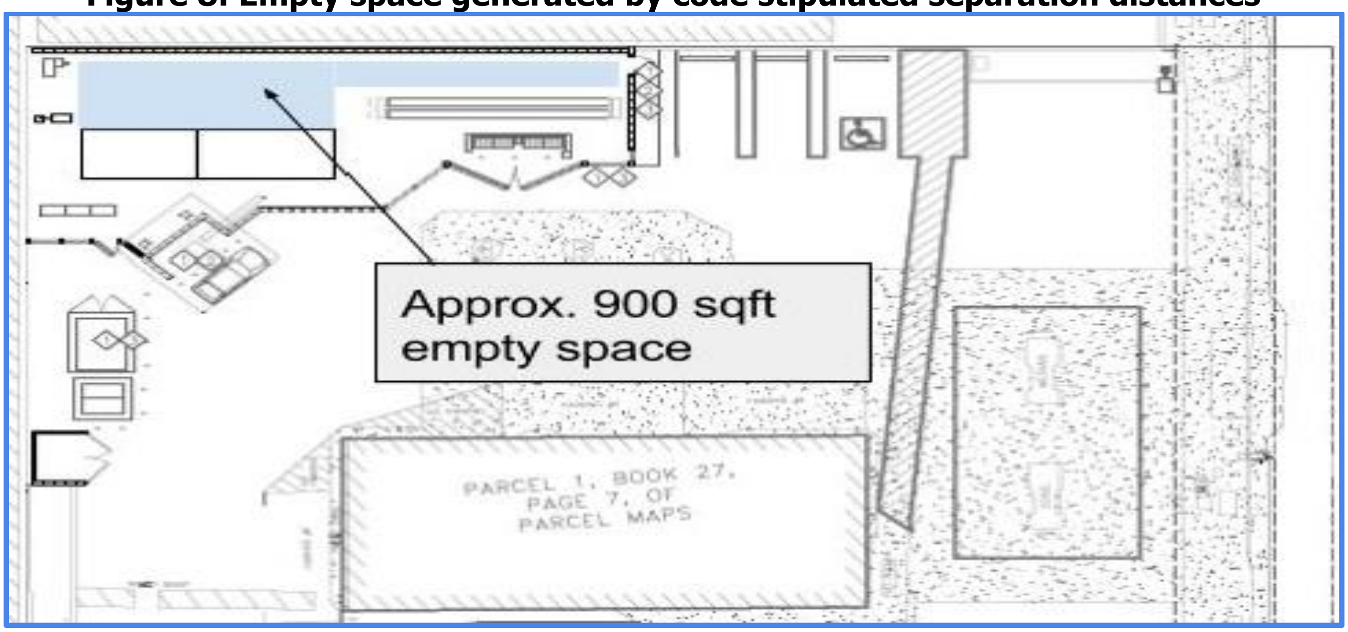
[8] National Fire Protection Association Website https://www.nfpa.org/

Figure 7: Separation distance example for Anaheim site per codes



Source: Air Liquide Advanced Technologies U.S. LLC

Figure 8: Empty space generated by code stipulated separation distances



Source: Air Liquide Advanced Technologies U.S. LLC

Safety and Risk Reduction

Safety is a critical aspect of equipment engineering and design. Key safety highlights regarding the equipment design and engineering are detailed equipment safety analysis, extensive component validation testing and 3rd Party review and certification.

Air Liquide safety processes assess and manages risks through processes known as an Accident Risk Assessment for specific project designs and a Generic Risk Assessment which is applicable to all hydrogen installations.

Summary of the Accident Risk Assessment for Hydrogen Stations
The Accident Risk Assessment for hydrogen stations used 8 nodes to identify 24 hazard scenarios called "feared events" in the evaluation:

The most frequent 'feared event' is the development of a hydrogen enriched environment during the venting and purging process portion of gas delivery. The analysis predicts the frequency for this event to occur once every 43.8 attempts. Since every delivery requires the operator to vent and purge the connection prior to fuel transfer, this frequency is appropriate given the delivery frequency assumed in the analysis.

The initial system criticality for the venting and purging event is unacceptable. The risk associated with a hydrogen rich atmosphere is the risk of fire or explosion. The risk is reduced to an acceptable level when mitigations are applied. The mitigations for this feared event are the use of a vent stack complying National Fire Protection Association 2 for design and installation. NFPA 2 references CGA G 5.5 Vent System Design, a commonly practiced design standard developed by CGA, the Compressed Gas Association. Air Liquide's own internal standard provides further guidance for vent stack design and installation at Air Liquide facilities. Design of vent systems includes several requirements:

- Conveyance of gas from release valves (purge or relief valves) without unacceptable restriction, prevent pressures to develop in the vent system and thus determines the size of the vent
- Appropriate design of release point for gas from the vent system. Direction of flow and weather prediction is critical. Since hydrogen is extremely buoyant and diffuses quickly in open air, the vent stack must direct the flow of release gas upwards. This upward release point must include some form of weather protection to prevent blockage from ice or other environmental conditions.
- Appropriate location of the release point at the facility. This includes both the height and physical location at the site. Hydrogen stations are particularly challenging as the site is intended for retail sale of fuel in a convenient location. Both CGA 5.5 and NFPA 2 provide guidance regarding location of the vent system.

The second most frequent 'feared event' is the rupture or leakage of the transfer hose between the customer vehicle and the customer connection point. The analysis predicts a frequency of this feared event to occur every 192.8 hours. Experience from the hydrogen community, including US, Japan and European stations, suggests hoses fail leak tests at a frequency of every 500 hours or 200 fills. In the case of automatic detection the station stops the fuel transfer, conducts a soft shutdown which includes reducing pressure in the piping between the high pressure storage and the dispenser, isolating the dispenser from high pressure storage and sends an automatically generated maintenance request to replace the hose. There are many failure modes associated with the transfer hose; however, the most common occurring failure mode for the fueling hose leak is the failure of the hose material or hose to fitting connection. The risk is reduced through the following mitigations:

- Automatic leak checks - both immediately prior to each fueling and an automatic daily leak check which occurs when fueling is not anticipated (i.e. middle of the night). Automatic leak checks pressurize the dispensing system, including the hose, then isolate the dispensing system and monitor the pressure drop. The acceptable pressure decay varies from site to site due to the distance between the dispenser and the isolation valves as well as the ambient temperature. The automatic controller is pre-programmed to calculate an acceptable pressure drop under a variety of conditions.

- Hoses are replaced on a frequency of once every 500 fills or every 6 months whichever occurs first.
- The hose leakage is an industry wide issue as the replacement frequency is unacceptable. New vendors, improved fabrication techniques and different materials are the subject of private and public partnerships as well as characterization testing at national laboratories such as National Renewable Energy Lab.

The next most common failure mode related to hose failure is vehicle drive-off, occurring approximately every 20,000 fuelings in forklift installations. Light duty vehicles don't yet have the demand frequency of the forklifts; however, drive-offs are expected to occur with hydrogen at a frequency no greater than forklifts. Many light duty vehicles include a feature which disables the vehicle when the fuel door is opened, which is not a current feature on forklifts.

Summary of the Generic Risk Assessment for Hydrogen Supply Chain

The Hydrogen Supply Chain Assessment outlines the feared events and predicted frequencies common to any Air Liquide hydrogen installation. The Assessment applies common practices and company policy requirements to determine the resulting risk for those common feared events. This system establishes a basis for site specific evaluation. Air Liquide's approach to GRA, when completed, becomes a standalone Assessment for a specific location uses an analysis tool established by the central safety team which is then provided to qualified users in each region. The subsequent Assessment performed for each site by the regional team is therefore a site-specific version of the original Assessment. Individuals qualified to perform the Assessment are also responsible for providing feedback and corrections on the Assessment to the central risk team. The Assessment system including feedback is not unique to hydrogen stations within Air Liquide; this process is practiced for all product lines and all installations.

Use Permit / Entitlement

The permit process began September 2013. As discussed in the Engineering and Design Fabrication report, the development of the layout was complicated by the adoption of NFPA 2 by the State of California in January 2014. While Air Liquide agrees with the use of NFPA 2, this project had proceeded for several months using the International Fire Code rather than NFPA 2, thus the change required Air Liquide to re-evaluate and better understand the specific requirements. The net impact of the changes and the Air Liquide evaluation was a one-year delay and an increase in the overall station size by about 500 square feet.

The delay and new layout required restarting the permitting process the city departments prior to beginning the official permit application. After several informal discussions the City determined that the installation required approval from the zoning commission. The "entitlement" application, used by planning and zoning groups to approve the concept of new construction, was submitted March 2015. A public hearing approved the station on July 13, 2015.

Critical Project Review (July 23, 2015)

On July 23, 2015 the CEC and Air Liquide conducted a Critical Project Review for the Anaheim station. The review resulted in CEC approval for Air Liquide to proceed with the project. The cover page of the review is shown in Figure below.

Figure 9: Critical Project Review (July 23, 2015) (cover page only).

Source: Air Liquide Advanced Technologies U.S. LLC

Building Permit (September 4, 2015 - December 30, 2015)

On September 4, 2015 Air Liquide applied for a construction permit to the City of Anaheim. On December 30, 2015 Air Liquide received the construction permit. During the period between submission and approval, the City of Anaheim made several requests for additional information. For example, the City requested details on storm water management during site construction. The City of Anaheim also requested a larger power transformer. Requests such as the larger transformer created additional delays as the larger transformer required a increase in the site layout, which then required a change to the land lease agreement, thereby requiring re-negotiation of the land lease.

CHAPTER 2: Construction

On January 25, 2016, Air Liquide mobilized the construction contractor, Hydrogen Frontiers. A time-lapse camera was installed at the site to capture the progress of the construction. Selected images are presented below in

Figure to demonstrate the progress of the site construction. The initial planned end of construction was early May 2016. Actual ending of construction occurred around July 10, 2016. The construction of the site was challenged with several minor delays which amounted to approximately one month. Minor delays included 15 days delay due to rain and adding storm water abatement. Other delays included complexity of on-site fabrication for the fencing and canopy installation.

Figure 10: Eighteen Photos of the Time Lapse series of Site Construction

17 May - Prepared for equipment foundations

18 May - Equipment foundations

19 May - Prepared for equipment delivery

19 May - Equipment arrives

19 May - Prepared for equipment delivery

20 May - Excavation of fueling area

20 May - fueling area prepared

30 May - fueling area finished

25 July - Pressure testing

8 Aug -Complete, hydrogen delivered

21 Nov 2016 - Prepared to Open

Architectural rendering submitted to City

Source: Air Liquide Advanced Technologies U.S. LLC

Pre-Startup Safety Review

A PSSR transfers responsibility for the site from the contractor to Air Liquide. The PSSR is used by Air Liquide for all plants and bulk gas applications. The PSSR ensures a comprehensive review for site safety, security, and equipment functionality. The PSSR was completed on August 8, 2016 with the introduction of hydrogen to the storage system. The PSSR at Anaheim was longer than will be required for future sites as many of the equipment aspects including controls and POS were first of their kind and required significant rework to correct initial errors.

CHAPTER 3:
Operational Requirements Phase

In support of ongoing efforts to complete hydrogen stations and keep those stations operational, the CEC solicited proposals under PON-13-607. These so-called, "Operation and Maintenance Grants" provided operational and maintenance funding for new as well as previously awarded stations. Air Liquide proposed and was awarded funds under grant ARV-15-031. The award included additional technical requirements considered critical for the station to achieve "operational status". These requirements included:

- All required operational and safety permits.
- Documentation that the station's hydrogen purity test results demonstrate that the station is in compliance with SAE International J2719:2011 "Hydrogen Fuel Quality for Fuel Cell Vehicles."
- Description of the process and results of fueling one fuel cell electric vehicle, and
- A written statement that the station is open to the public meaning no physical barriers exist that would preclude the public from entering.

Operational and Safety Permits from Local Jurisdiction and Agency

The required operational and safety permits included:

- From the City of Anaheim - Construction Permit and Permit to Operate
- The construction permit was received on December 30, 2015
- The permit to operate was received on August 10, 2016
- Division of Measurement Standards – Temporary Use Permit.

  The DMS is responsible for enforcing merchant transaction involving weights and measures, laws, and regulation. As required for all fuel purchases, the DMS certifies any device used for metering quantities. On August 25, 2016, the Air Liquide Anaheim HRS satisfied all DMS criteria with detailed and was issued its temporary approval as shown in Figure 11. The permanent DMS approval was received on August 25, 2016.

Figure 11: DMS Meter Calibration Approval & Temporary Use Permit (Aug 25, 2016)

Source: Air Liquide Advanced Technologies U.S. LLC

Hydrogen Purity Test

The successful hydrogen quality test (3) was performed by Smart Chemistry on August 15, 2015.

Figure shows the test results from Anaheim.

Figure 12: SAE-J2719 Hydrogen Fuel Quality Sampling Data

SmartChemistry

AIR LIQUIDE — ANAHEIM HYDROGEN STATION

SAE J2719 [illegible]	[illegible]	[illegible]	[illegible]
H_2O	[illegible]	[illegible]	0.65
Total Hydrocarbons [illegible]	2		0.043
[illegible]			0.038
[illegible]			0.0033
[illegible]			0.0017
O_2	5	1	< 1
He	300	7	7.1
N_2 & Ar	100		
N_2		5	< 5
Ar		0.4	< 0.4
CO_2	2	0.1	< 0.1
CO	0.2	[illegible]	0.0014
Total S	0.004		0.00030
[illegible]		0.00001	0.00027
[illegible]		0.00001	0.000018
[illegible]		0.00001	< 0.00001
[illegible]		0.00001	< 0.00001
[illegible]		0.00001	< 0.00001
[illegible]		[illegible]	0.0000076
[illegible]		0.00001	< 0.00001
[illegible]		0.00001	< 0.00001
[illegible]		0.00001	< 0.00001
[illegible]		0.00001	< 0.00001
[illegible]		0.00001	< 0.00001
[illegible]		0.00001	< 0.00001
Formaldehyde	0.01	0.001	< 0.001
Formic Acid	0.2	0.001	< 0.001
Ammonia	0.1	0.01	< 0.01
Total Halogenates	0.05		0.00098
Cl_2		0.001	< 0.001
HCl		0.001	< 0.001
HBr		0.001	< 0.001
Total Organic Halides [illegible]			0.00098
[illegible]			0.00098
Particulate Concentration	1 mg/kg		0.042 mg/kg
Particulates Found & Size			[illegible]
Hydrogen Fuel Index	> 99.97%		99.99922%

Source: Air Liquide Advanced Technologies U.S. LLC

Fueling One Fuel Cell Electric Vehicle at Anaheim

The first vehicle was filled at Anaheim on August 31, 2016. Figure are photos of the event. Figure shows the notification sent to the CEC documenting the completion of "Operational" status requirements.

Figure 13: Station completes "Operational" status (August 31, 2016)

Source: Air Liquide Advanced Technologies U.S. LLC

Figure 14: Anaheim "Operational" Status Notice (August 31, 2016)

ZUCK, Dwight <dwight.zuck@airliquide.com> 8/31/16

to Sarah K Willia., Phil Cazel, Aaron, Samuel, bcc: BobO

Hi Sarah,

As discussed this morning, below are pictures of an FCV being fueled at Air Liquide's Anaheim station earlier today. This station/dispenser is open to the public. These pictures along with the J2719 H2 Fuel Quality Report which was previously forwarded to you under separate cover, satisfy the definition requirements of the O&M portion of PON-13-607 for "Operational" effective as of today.

Please advise of any questions.

Thanks again for your support.

Dwight

4 Attachments

Source: Air Liquide Advanced Technologies U.S. LLC

CHAPTER 4: Operational to Open (September 1, 2016 - November 28, 2016)

In the nascent industry of hydrogen infrastructure there still exists some gaps around the process and definition of "completion." A coordinated effort by the Energy Commission, California Governor's Office of Business and Economic Development and the California Fuel Cell Partnership helped define a process for a station to proceed from completing the grant requirements, i.e., become "operational" to the station being confirmed for reliable, daily, public, retail use, so-called "open".

Air Liquide spent about 3 months completing the process of "operational to open". This section describes some of the key milestones and highlights key lessons learned. The key milestones are POS, HyStEP testing and OEM confirmation. The "open" process is complete when the station is listed on the California Fuel Cell Partnership Station Operating Status System (SOSS).

POS

As discussed in Chapter 1, the POS for Anaheim was not part of the equipment design as the equipment design was based on the requirements of the HIT project in central Europe which did not require POS. Also, testing the POS was not feasible during the factory acceptance testing in France. Therefore, the project faced a significant challenge in the selection, installation and programming the POS after installation in Anaheim.

A study of available suppliers resulted in the selection of Orange Coast Petroleum as the distributor and installation vendor, and OPW[9] as the POS equipment supplier. Much of this selection resulted from the previous selection of a Kraus Global dispenser for use at Anaheim. Kraus Global offers hydrogen and compressed natural gas dispensers which are modified from a standard Gilbarco gasoline housing. It is the Gilbarco system with which the POS must interface. Orange Coast was able to supply and support a system from OPW which interfaced with the Gilbarco dispenser components.

An additional challenge in the system integration is the interaction of the POS, the dispenser embedded controls and the station PLC. All three systems must interact to allow for the processing of payment and control of fueling without causing faults in system timeout or other communication glitches. Faults and glitches are difficult to predict with most resulting in the now infamous, "zero receipt" where the vehicle does not receive fuel and the transaction closes with the printing of a receipt for $0.00. Many of these issues are result of timing and other detailed aspects of the fueling which are beyond the scope of this report. It is sufficient to state that Anaheim benefited greatly from public workshops which exchanged best practices related to POS.

A further issue about POS is the establishment of appropriate 'back office' systems. This can include selecting the appropriate processing bank and establishing merchant identification. This is non-trivial and includes complexities in banking and fraud protection which are also beyond the scope of this report.

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[9] PPW Website https://www.opwglobal.com/

If not for the delays associated with HYSTEP testing and original equipment manufacturer confirmation, the integration of the POS would have created a 2-month gap between "operational" and "open".

HYSTEP Testing

The Air Resources Board and H2FIRST initiative[10] from the U.S. Department of Energy Fuel Cell Technologies Office worked in coordination to develop and deploy a station testing device called HYSTEP. Air Liquide served on the technical advisory committee for the design of HTSTEP.

The HYSTEP device tested Anaheim on two occasions, the week of August 19, 2016 and the week of November 1, 2016. On the next page, Figure shows the HyStEP device parked at the Anaheim station.

The first round of testing starting August 19, 2016 revealed significant discrepancies in the design and implementation of the cooling system with respect to performance to the SAE J2601-2014 T40 fueling category. The station was unable to maintain the required gas temperature.

Air Liquide instituted and aggressive campaign to modify the station to meet the requirements. By late October the station modifications were complete. Unfortunately, without significant changes, the station would not reach the T40 category, and it was decided to proceed as a T30 station.

Note: Under SAE J2601 the T30 category represents a longer fill time, for example T40 fills completed in 3-5 minutes while T30 fills take 7-12 minutes.

HYSTEP returned to Anaheim the week of November 1, 2016. Testing results were discussed and evaluated 1 week later in a meeting hosted by the Air Resources Board to which representatives from all vehicles original equipment manufacturers with vehicles for sale or lease in the California market were invited. Representatives from Toyota, Honda and Hyundai attended. This group affirmed the performance allowing Anaheim to proceed to the 3rd and final stage of "operational to open" – original equipment manufacturer confirmation tests.

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10 H2FIRST Initiative Website http://h2first.com/

Figure 15: HyStEP System at Anaheim.

Source: Air Liquide Advanced Technologies U.S. LLC

Original Equipment Manufacturer Confirmation

The Fuel Cell Electric Vehicle Original Equipment Manufacturers support the process of "operational to open" through the confirmation of stations. This is the final step by the original equipment manufacturer technical teams to ensure their vehicle customers will experience safe, reliable, understandable, and consistent fueling. The feedback provided to Air Liquide regarding Anaheim is invaluable in the further development of hydrogen station equipment as well as immediate improvements implemented at Anaheim prior to 'opening' the station.

The original equipment manufacturer representatives visited Anaheim several times during the "operational to open" process. Some of the official dates where fuel cell electric vehicles were used to confirm the station function were:

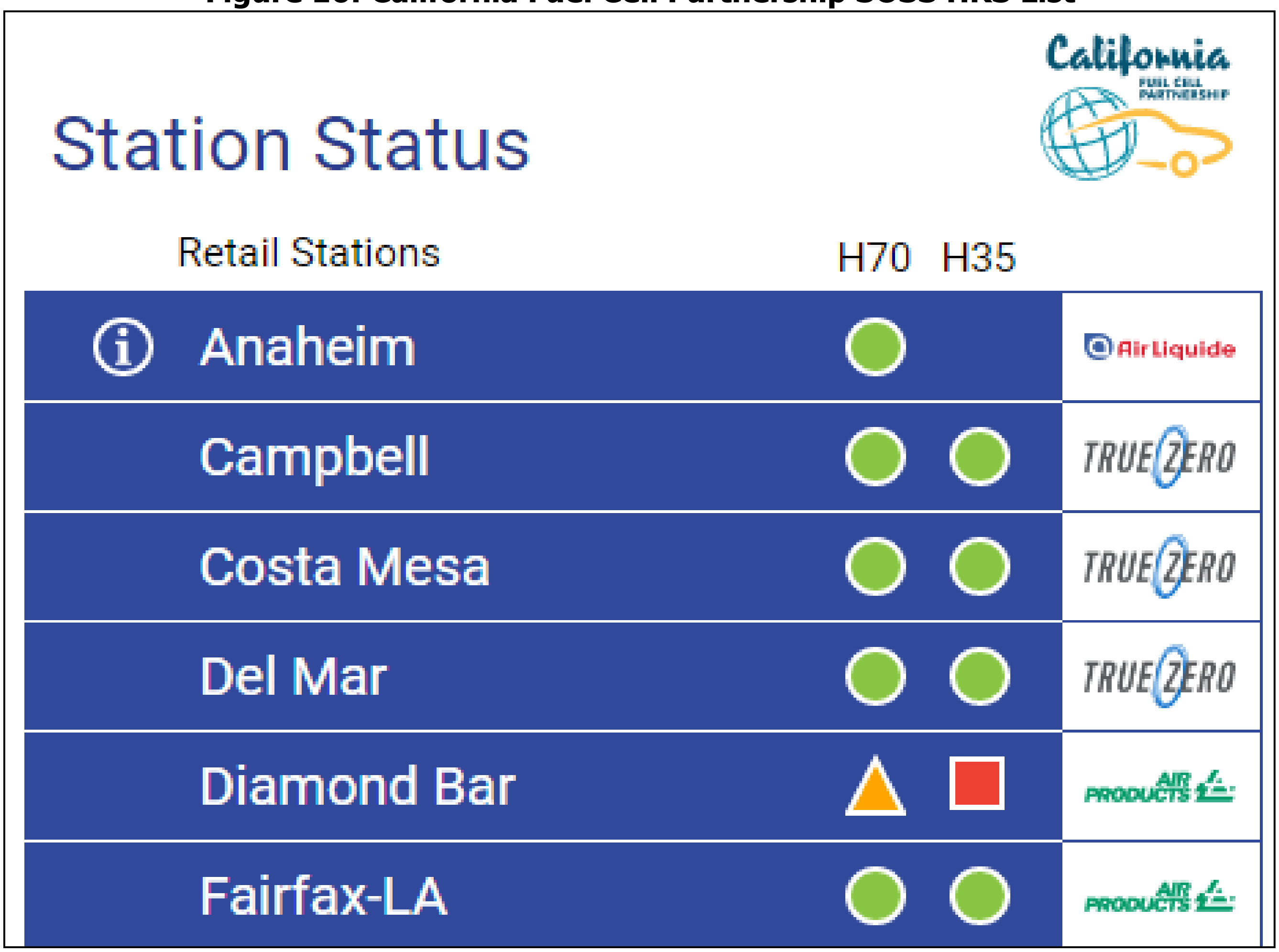
- Toyota provided three fuel cell electric vehicles on October 7, 2016 and five on November 14, 2016
- Honda provided one fuel cell electric vehicle on October 3, 20216 and November 22, 2016
- Hyundai provided five fuel cell electric vehicles on November 22, 2016 and two on November 28, 2016

Station Operational Status System Activation (November 30, 2016)

The California Fuel Cell Partnership operates a website providing near 'real time' status of hydrogen stations, the SOSS. Participation in SOSS is optional, and Air Liquide opted to participate. To prevent confusion for vehicle users, the California Fuel Cell Partnership created criteria and other useful informational notes in the SOSS website. Stations must complete the "operational to open" process prior to being listed on SOSS. The Anaheim station began appearing on SOSS on November 20, 2016.

Figure shows Anaheim on the SOSS website. There are some noteworthy aspects of the display of Anaheim. First, since H35 is not currently offered, there is no symbol shown in the H35 column. Also, since the station does not perform T40 temperature category fills an informational note is added. This is noted with a small informational tag ***(i)*** that, when clicked displays, "Fueling times vary and may take up to 10 minutes." as shown in Figure 16 below.

Figure 16: California Fuel Cell Partnership SOSS HRS List



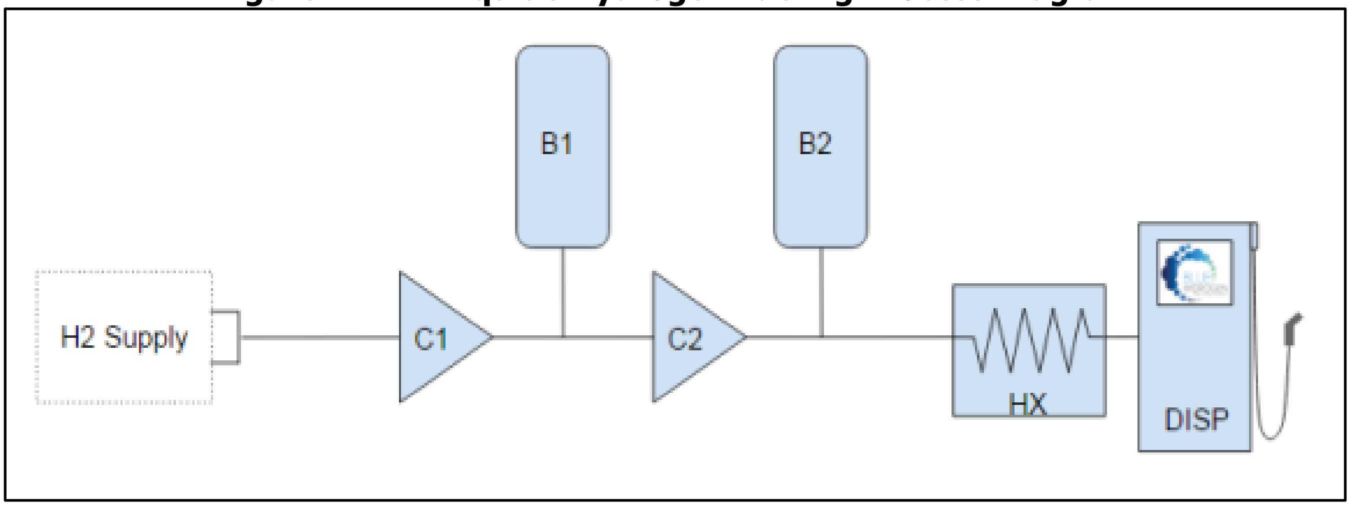
Source: CA Fuel Cell Partnership Website

CHAPTER 5: Ongoing Operations

Overview of the Hydrogen Fueling Process at Anaheim

Figure below depicts an overview of the process flow for the hydrogen fueling process at the Anaheim Station. Hydrogen gas is supplied as delivered or fixed storage tubes (H2 Supply), then compressed (C1) to a buffer storage (B1), compressed to buffer storage (B2). As requested, hydrogen flows through a cooling system (HX) and is then dispensed (DISP) into each car.

Figure 17: Air Liquide Hydrogen Fueling Process Diagram



Source: Air Liquide Advanced Technologies U.S. LLC

Data Collection & Reporting

The CEC grant requires the routine, ongoing collection and quarterly submission of operational data, which is also shared and evaluated by the National Renewable Energy Lab National Renewable Energy Lab. The quarterly submission is to be made to the CEC on the 15th of the month following the end of each calendar-year quarter. Since the Anaheim station commenced commercial "Open" operation status during the last week of November 2016, the first Data Collection Report was prepared and submitted January 15, 2017 and covered Nov 28, 2016 through December 31, 2016.

Air Liquide Anaheim Monitoring Systems

Air Liquide aspires to provide safe, full fills whenever requested by a driver at Anaheim; 24 hours per day, 7 days per week, 365 days per year. In addition, Air Liquide ensures that in the event the station is unavailable, that the operations team responds immediately, the user community knows immediately, that the expected return to service time and date are broadcast quickly and that the promised time and date are met.

Air Liquide uses a plethora of monitoring methods to achieve the availability goals. These methods also provide long term trend or product improvement insights, particularly with respect to the needs and requests of the user community. Some methods are direct such as video monitoring and supervisory control and data acquisition systems. Other methods are indirect through business processes such as routine preventive maintenance schedules and weekly performance metrics. Finally, anecdotal feedback comes from the delivery drivers, the original equipment manufacturer contract durability testing drivers and social media posts from the general public.

Video Monitoring

One of the direct monitoring methods at the Anaheim station is a live video feed Figure shows the four different camera angles. This video system is web-based allowing multiple users to access the video at any time.

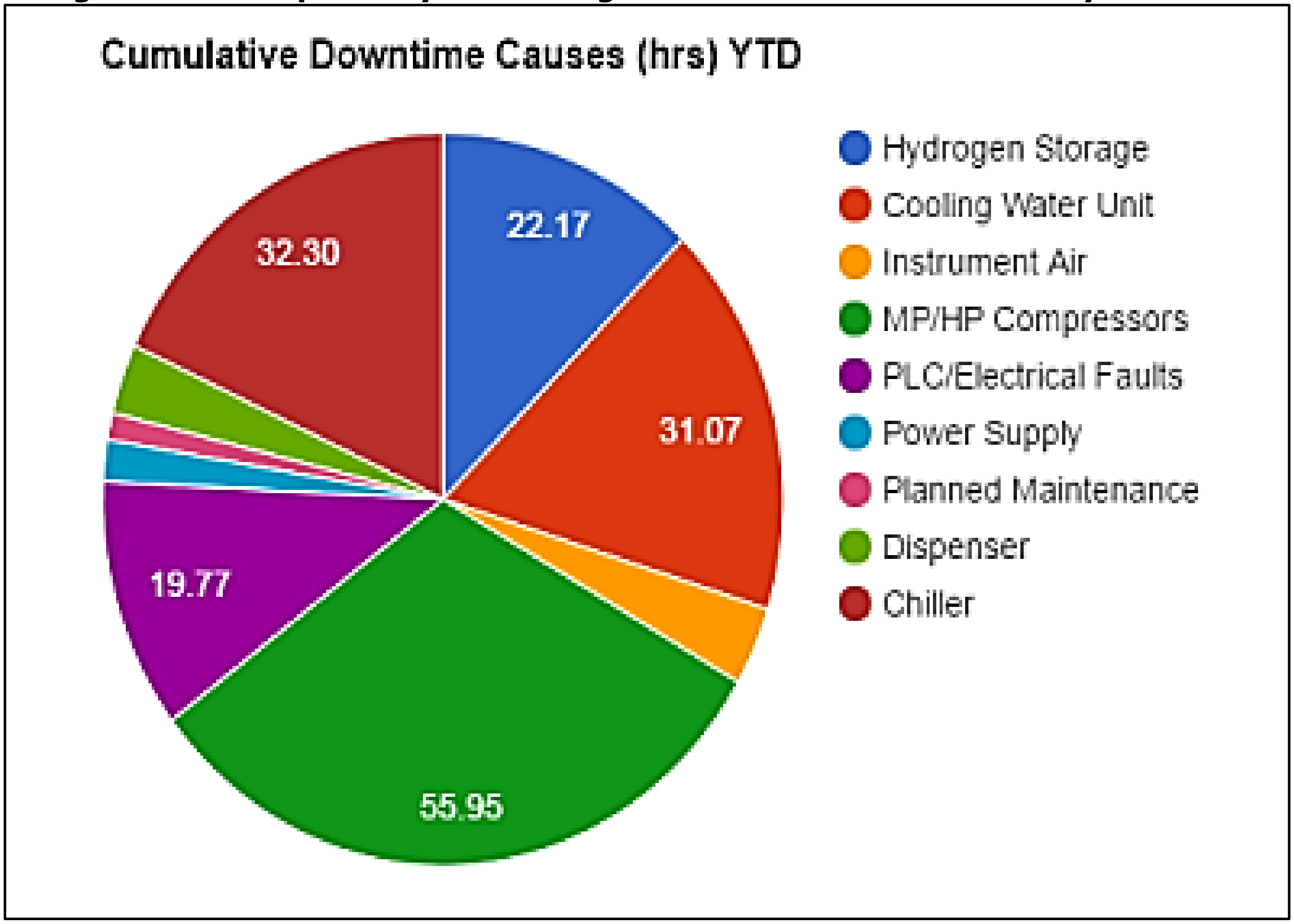
Figure 18: Air Liquide's Live Camera Monitoring System.

Source: Air Liquide Advanced Technologies U.S. LLC

Weekly Customer Experience and Incident Reporting

Air Liquide tracks the customer experience through various reports. Figure shows an example of one report, the causes of downtime. This type of detailed analysis allows Air Liquide to focus maintenance and prioritize efforts to improve availability.

Figure 19: Example analysis showing cumulative downtime causes year to date



Source: Air Liquide Advanced Technologies U.S. LLC

Preventive Maintenance Program

Air Liquide implements a preventive maintenance program for each station. This program is based on Air Liquide's extensive experience operating equipment and plants. Also, hydrogen energy operations teams in Germany, Japan, Korea and the U.S. coordinate efforts and exchange ideas to constantly improve availability.

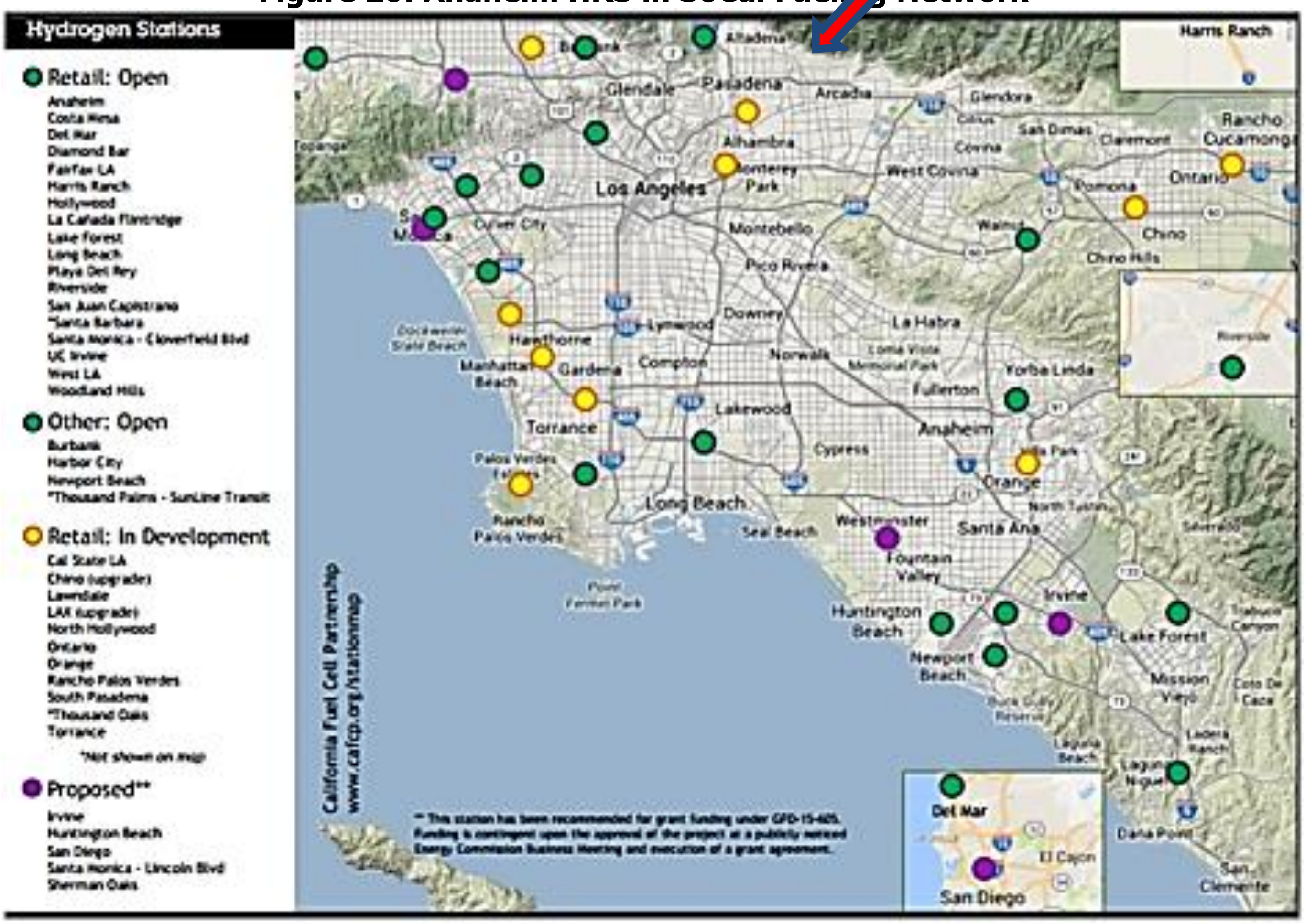
CHAPTER 6: Further Projects and Improvements to the Fuels and Transportation Project Management Processes

This chapter provides miscellaneous notes on project execution and discussion on future projects.

Demonstration of Demand

Air Liquide has been surprised by the demand at the Anaheim station. On March 7, 2017, the 100th day that Anaheim was 'open', Anaheim also performed it's 1000th fueling. Anaheim is uniquely located on the southeast side of the greater Los Angeles area, which can be seen Figure 20 below.

Figure 20: Anaheim HRS in SoCal Fueling Network



Source: California Fuel Cell Website

Summary of Costs

Table 1, on the next page, provides a summary of costs by equipment or service category. While the costs are comparable to similar station installations for Europe and Japan when corrected for local real estate and equipment design requirement differences, these costs are neither acceptable to Air Liquide nor capable of providing a profitable business case.

Table 1: Summary of Project Costs

Vendor	Equipment or Service	Cost
Air Liquide Advanced Technologies HRS Equipment	Hydrogen Equipment	$1,667,159
Hydrogen Frontier	Site Preparation and Construction	$485,688
Hydrogen Frontier	Ongoing Operations	$90,000
Various Vendors	Utility Connection Equipment	$27,295
Various Vendors	Permitting, Design, and Planning	$125,978
Various Vendors	Commissioning, Startup, and Testing	$48,182
Total Vendor Costs		$2,444,302
CEC Grant		$1,500,000
Match Share by Air Liquide Advanced Technologies		$944,302
Total CEC Cost Share (excluding no ALATUS internal costs)		61.4 percent

Source: Air Liquide Advanced Technologies U.S. LLC

Path Forward and Statement of Future Intent

Air Liquide intends to operate the Anaheim HRS longer than required by ARV-12-062 or ARV-15-031 grants. Air Liquide signed a 9-year lease for the site with options to extend the lease beyond the 9 years. As part of this effort Air Liquide intends to upgrade the Anaheim station to fully comply with the technical requirements of both grant ARV-12-062 and ARV-15-031.

Upgrade Plans - J2601-2014 T40 and H35

Per a recent request of the CEC, on March 14, 2016 a meeting was held with the CEC, California Air Resources Board, The Governor's Office of Business and Economic Development, and Air Liquide parties to provide preliminary plans to upgrade to T40 chilling and to add the H35 dispenser capabilities as required by the grant. Air Liquide is submitting a separate J2601-2014 T40 and H35 Upgrade Plan Report[11] on, or about, March 30, 2017.

Minimizing Delays for Future Sites

[11] SAE Website https://www.sae.org/standards/content/j2601_201407/

Anaheim provided substantial lessons for Air Liquide. Improvements are possible in all aspects of hydrogen station projects. A few key improvement areas include, equipment requirements communication, site layout planning and equipment controls coordination.

The inability for the Anaheim station to meet the technical requirements of either grant ARV-12-062 and ARV-15-031 was avoidable. A lack of communication on the project objectives, the equipment performance capabilities and the differences between similar projects occurring in two different early adoption areas lead to the current performance. Two major changes at Air Liquide will affect change regarding these issues. First, Air Liquide has transitioned the hydrogen energy responsibilities from the industrial merchant business to a newly developed advanced technologies U.S. LLC business in the U.S. This transition was due in part to the acquisition of Airgas and the merging of Airgas with the U.S. industrial merchant business for Air Liquide. Second, various advanced business and technology units were scattered across regions and countries within various business units of Air Liquide. In 2016 Air Liquide reorganized these groups under a single global business unit called Global Markets and Technologies. Formation of this new business unit creates visibility of growth markets to Air Liquide’s shareholders, and it centralizes the responsibility for performance of new business groups such as hydrogen energy. This centralized effort is developed for other businesses within Air Liquide and facilitates improved communication and sharing of technical resources. This change is already impacting both new projects in California and the U.S. Northeast but also in the planning and preparation of upgrades at Anaheim.

With regard to site layout planning, the separation distance requirements of the fire codes will continue to challenge hydrogen station planning for many years to come. The industry will naturally develop acceptable best practices. This shared learning based on experience and close coordination with fire officials and safety experts will ensure station layout requirements are more predictable and consistently applied. With this consistency station developers will reduce costs through standardization of design. Already cost projections for site layout planning and permitting durations are decreasing. Air Liquide expects to benefit from this industry-wide trend.

Finally, equipment controls coordination is critical to shorter commissioning times and reduced complexity of embedded controls systems. The lack of coordination and planning for the POS and PLC interface presented unique challenges. Future stations will benefit from early vendor selection for dispenser, POS and PLC. Additionally, Air Liquide has implemented a factory testing process which includes POS. The goal being station equipment which arrives at the site ready to operate immediately following the PSSR.

GLOSSARY

CALIFORNIA ENERGY COMMISSION (CEC)—The state agency established by the Warren-Alquist State Energy Resources Conservation and Development Act in 1974 (Public Resources Code, Sections 25000 et seq.) responsible for energy policy. The Energy Commission's five major areas of responsibilities are:

1. Forecasting future statewide energy needs
2. Licensing power plants sufficient to meet those needs
3. Promoting energy conservation and efficiency measures
4. Developing renewable and alternative energy resources, including providing assistance to develop clean transportation fuels
5. Planning for and directing state response to energy emergencies.

HYDROGEN REFUELING STATION (HRS)—is a turnkey solution, which comes fully interconnected, automated and is easy to install. The process is quiet, reliable and safe; and it provides zero emission fuel from production to consumption, eliminating the dependency on carbon fuels.

HYDROGEN STATION EQUIPMENT PERFORMANCE (HyStEP) Device — The primary purpose of the HyStEP Device is to be used by a certification agency to measure the performance of hydrogen dispensers with respect to the required fueling protocol standard. Specifically, the device has been designed to carry out the test methods of CSA HGV 4.3 to measure that stations follow the fueling protocols standard SAE J2601-2014 including IrDA communications per SAE J2799.[12]

POINT OF SALE (POS)— Is the point at which a customer makes a payment to the merchant in exchange for goods or after provision of a service.[13]

PRE-STARTUP SAFETY REVIEW (PSSR)—The fundamental purpose of a prestart up safety review is to ensure that any changes that are made to a facility or item of equipment meet the original design or operating intent.[14]

PROGRAMABLE LOGIC COMPUTER (PLC)—An industrial digital computer which has been ruggedized and adapted for the control of manufacturing processes, such as assembly lines, or robotic devices, or any activity that requires high reliability control and ease of programming and process fault diagnosis.

STATION OPERATING STATUS SYSTEM (SOSS)— A machine or piece of equipment that is operational is in use or is ready for use.[15]

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[12] Hydrogen fueling infrastructure research and technology https://h2tools.org/hystep-hydrogen-station-equipment-performance-device
[13] Point of Sale Definition https://en.wikipedia.org/wiki/Point_of_sale
[14] Pre-startup safety review definition https://www.aiche.org/ccps/resources/glossary/process-safety-glossary/pre-startup-safety-review-pssr
[15] Station Operating Status System https://dictionary.reverso.net/english-cobuild/operational+status