CALIFORNIA ENERGY COMMISSION

California Energy Commission

Clean Transportation Program

FINAL PROJECT REPORT

Riverside Hydrogen Station

Prepared for: California Energy Commission

Prepared by: ITM Power, Inc.

Gavin Newsom, Governor

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California Energy Commission

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- PowerTech Labs Inc.
- Engineering Procurement and Construction LLC.
- The City of Riverside.

PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation Program, formerly known as the Alternative and Renewable Fuel and Vehicle Technology Program. The statute authorizes the California Energy Commission (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-13-607 to provide funding opportunities under the ARFVTP for high-performance hydrogen retail refueling stations. In response to PON-13-607, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards on May 1, 2014. The agreement was executed as ARV-14-012 on July 22, 2014 in the amount of $2.1 million.

ABSTRACT

Per the terms of funding agreement ARV-14-012 with the California Energy Commission, ITM Power Inc. designed, engineered, permitted, constructed, and commissioned a hydrogen refueling station at 8095 Lincoln Avenue, Riverside, in Riverside County. ITM Power Inc. will own and operate the station for the foreseeable future. The station consists of an onsite electrolyzer, tube-trailer delivery area, and a compression, storage and dispensing system. The single dispenser houses 350 and 700 bar hoses and nozzles.

Keywords: California Energy Commission, hydrogen, Riverside, ITM Power Inc., electrolyzer, fuel cell

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EXECUTIVE SUMMARY

Hydrogen fuel cell vehicles offer zero emission travel without compromising the short refueling times and long-ranges between refueling events that motorists are accustomed to with today's gasoline and diesel vehicles. The State of California has shown great support to the hydrogen community and is leading a world class effort to bring zero- emission vehicles here. The vehicles are produced in increasing numbers from original equipment manufacturers such as Toyota, Honda and Hyundai, and these vehicles need a filling station support network.

The California Energy Commission contributed $2.1 million in grant funding as part of the Clean Transportation Program to allow the design, construction, permitting, and commissioning of the hydrogen refueling station in Riverside.

This particular site is home to the Riverside alternative fuel station, which offers public fueling for natural gas, propane and electric vehicles alongside the new hydrogen system. The system also uses a combination of on-site hydrogen generated via electrolysis and gas delivered via a tube trailer. This allows the station flexibility in the hydrogen supply and the fluctuating demand for fuel.

The system incorporates an ITM Power Inc. electrolyzer with 100 kilograms (kg) daily capacity of hydrogen (35 kg produced by the electrolyzer and the other 65 kg from trucked-in sources); connected to a compression and storage and a dispensing system provided by PowerTech Labs Inc. The site design, permitting and construction were carried out by Engineering, Procurement and Construction LLC.

The system supports the Inland Empire region of California making it part of California's hydrogen network as well as providing a link to the San Diego, Palm Springs, and Las Vegas region.

CHAPTER 1:
Station Design and Construction

The project timeline for the Riverside hydrogen project involved various phases. The station achieved operational status in eleven weeks after receiving the local permit.

Site Acquisition–Station Construction (August 2014–September 2015)

ITM Power Inc. has a license agreement with the City of Riverside to occupy the land where the Riverside station is located. ITM Power Inc. negotiated a zero cost lease/license agreement for this site. The cost of the land is considered as cost-share to the project from the City of Riverside. The acquisition process was long, due mainly to legal counsel timelines. The agreement was put in place in parallel to the procurement and design of the station because ITM Power Inc. was confident of the city staff was committed to the project.

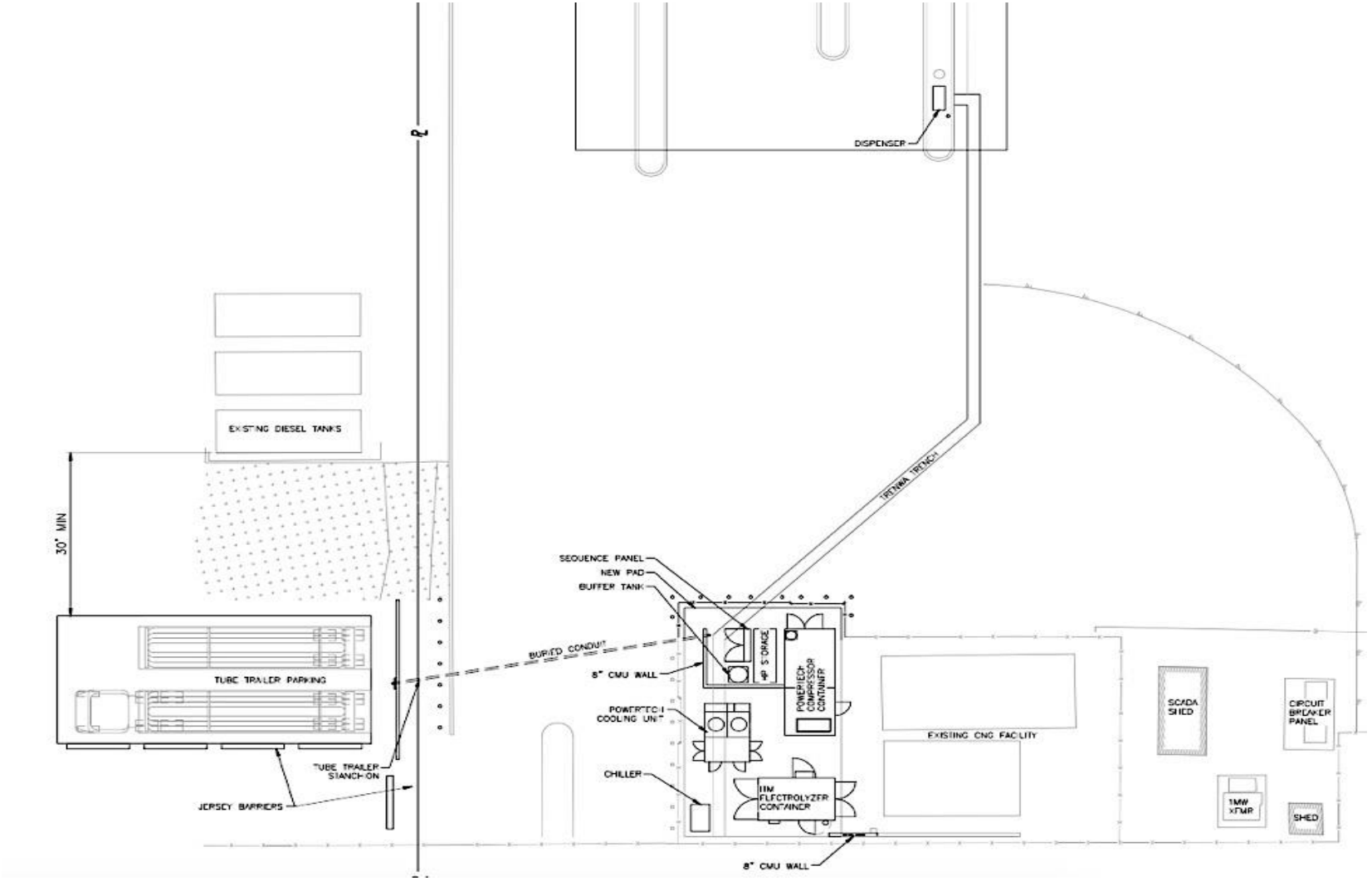
April 2015 saw ITM Power Inc. and Engineering, Procurement and Construction LLC (EPC LLC) undertake the full site survey, prepare detailed engineering illustrations and submit these to the city for permitting.

Examples of the permitting illustrations are included in this report (Figures 1, 2, and 3). The illustration plans were returned to the engineering team for amendments and were finally accepted by the city planning department in June 2015.

The fact that the site was already a retail fuel site and that it was in an industrial area with minimal existing aesthetic features helped ITM Power Inc. streamline the process and plan for a lean and efficient construction phase. The National Fire Protection Association (NFPA) – Hydrogen Technologies Code was a critical reference for the team to use during planning and construction.

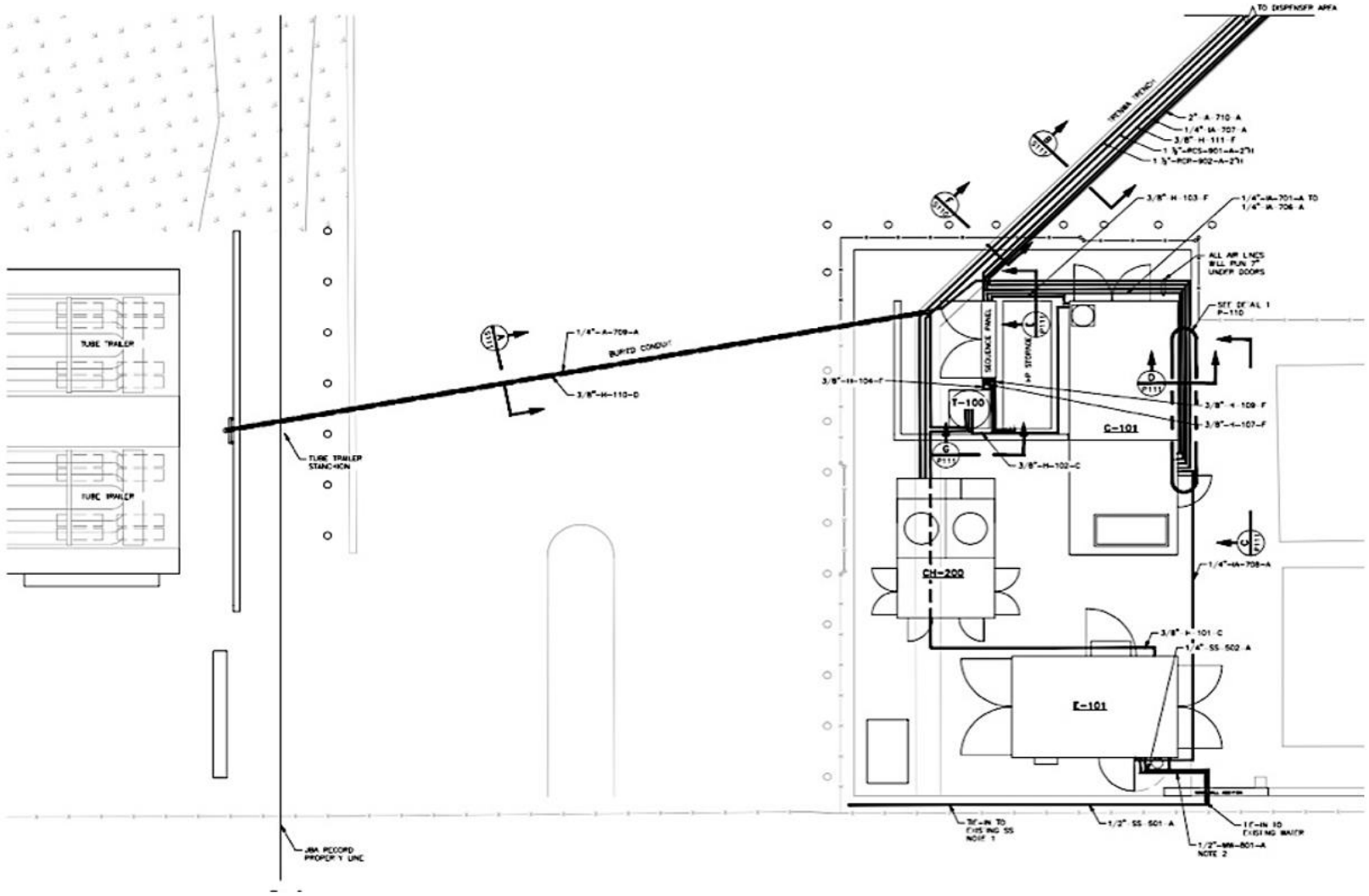
The equipment procurement phase was straightforward; ITM Power Inc. supplied the electrolysis unit, while the project partners PowerTech Labs Inc. provided the compression, storage and dispensing equipment. The project saw a change in the engineering, procurement and construction contractor when the original partner, Hydrogen Frontier, left the project. It was replaced by EPC LLC in April 2015, who was responsible for all design, permitting and construction of the site including the utility hook up and cabling/pipework on site. The electricity connection was complex, even though the City of Riverside had direct links to the local Riverside utility.

Figure 1: Final Layout Plan Submitted to City of Riverside for Permitting



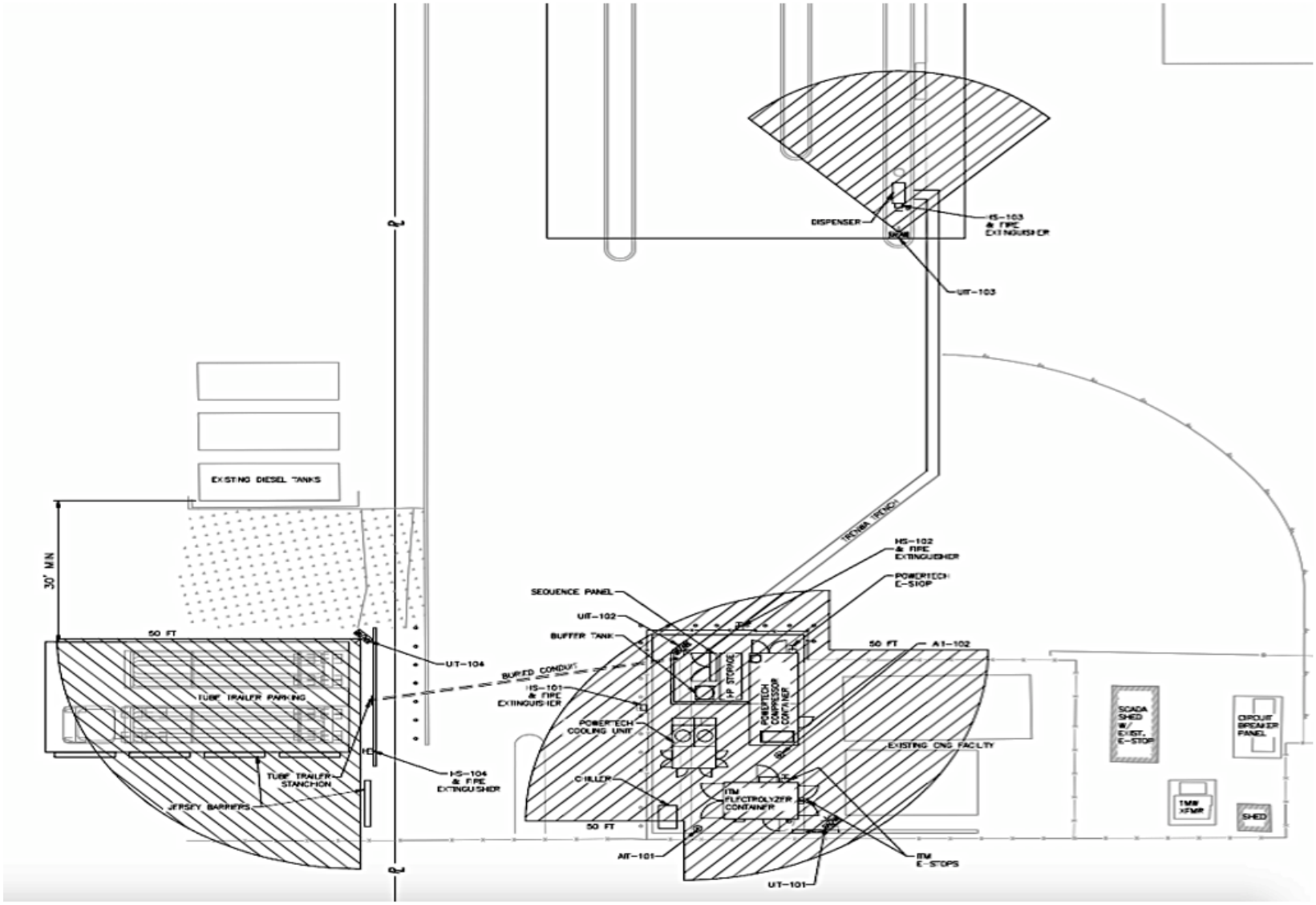
Source: ITM Power, Inc.

Figure 2: Piping Plan Illustration Submitted to City of Riverside for Permitting



Source: ITM Power, Inc.

Figure 3: Fire Detection Plan Submitted to City of Riverside for Permitting



Source: ITM Power, Inc.

The project team submitted all materials required for the permits in May 2015; the permit was received in July 2015. The equipment was delivered to the site in late September 2015.

Because of delays associated with substituting the project team's EPC LLC contractor, construction was compressed into an 11-week period following receipt of the permit. The process was well planned and executed and resulted in a well-built station.

The groundwork and prep took place in August and early September 2015. The equipment was delivered late September and installed as shown in Figures 4 and 5.

Figure 4: Crane Setting Cylinders into Position

Source: ITM Power, Inc.

Figure 5: Crane Lifting Equipment into Position

Source: ITM Power, Inc.

Commissioning Process (October 2015)

The commissioning process was quick and involved hooking up the equipment, purging the vessels and pipework, pressure testing the system, and installing and testing all components of the system. The electrolyzer was run for 48 hours initially to fill the hydrogen storage vessels on site before a fueling test was done using a test tank setup. Finally, a gas test and vehicle fill were undertaken.

Station Declared Operational (October 30, 2015)

The station met the definition of operational in PON-13-607, including:

- Completing installation of all station/dispenser components.
- Obtaining all required permits from the local jurisdiction.
- Filling the station storage tubes with pressurized hydrogen gas.
- Successfully fueling one fuel cell vehicle with hydrogen (Figure 6).
- Being on a site that was open to the public.
- Successfully passing a hydrogen quality test in conformance with SAE J2719 (Figure 7).

Figure 6: Completed Dispenser Installation Filling a FCEV

Source: ITM Power, Inc.

Figure 7: Summary of Purity Tests Performed at the Riverside Hydrogen Station

ITM POWER

RIVERSIDE H70 H_2

@Nozzle sampled on 10/26/2015

SAE J2719 Report

	SAE J2719 Limits (µmol/mol)	Smart Chemistry Detection Limits (µmol/mol)	Concentration (µmol/mol)	Analytical Method
Water	5	1	< 1	ASTM D7649
Total Hydrocarbons (C_1 Basis)	2	1	**1.28**	ASTM D7892
Methane		0.001	0.069	
Acetone			1.2	
Oxygen	5	1	< 1	ASTM D7649
Helium	300	10	< 10	ASTM D1946
Nitrogen, Argon	100			
Nitrogen		2	**< 2**	ASTM D7649
Argon		0.4	Not Required	ASTM D7649
Carbon Dioxide	2	0.5	< 0.5	ASTM D7649
Carbon Monoxide	0.2	0.0005	**0.010**	ASTM D5466
Total Sulfur	0.004	0.000001	**0.000027**	ASTM D7652
Hydrogen Sulfide		0.000001	0.0000098	ASTM D7652
Carbonyl Sulfide		0.000001	0.0000088	ASTM D7652
Methyl Mercaptan (MTM)		0.00001	< 0.00001	ASTM D7652
Ethyl Mercaptan (ETM)		0.00002	< 0.00002	ASTM D7652
Dimethyl Sulfide (DMS)		0.00002	< 0.00002	ASTM D7652
Carbon Disulfide		0.000001	0.0000089	ASTM D7652
Isopropyl Mercaptan (IPM)		0.00002	< 0.00002	ASTM D7652
Tert-Butyl Mercaptan (TBM)		0.00002	< 0.00002	ASTM D7652
n-Propyl Mercaptan		0.00002	< 0.00002	ASTM D7652
n-Butyl Mercaptan		0.00002	< 0.00002	ASTM D7652
Tetrahydrothiophene (THT)		0.00002	< 0.00002	ASTM D7652
Formaldehyde	0.01	0.001	< 0.001	ASTM D7892
Formic Acid	0.2	0.005	< 0.005	ASTM D5466
Ammonia	0.1	0.01	< 0.01	ASTM D5466
Total halogenates	0.05		< 0.02	
Chlorine		0.001	< 0.001	ASTM D5466
Hydrogen Chloride		0.007	< 0.007	ASTM D5466
Hydrogen Bromide		0.007	< 0.007	ASTM D5466
Organic Halides (32 compounds in red and bold listed in "Other Hydrocarbons"). Smart Chemistry limit is for each individual organic halide.		0.001	< 0.001	ASTM D7892

Source: ITM Power, Inc.

Station Testing and Certification

California Department of Food and Agriculture, Division of Measurements Standards (CDFA/DMS) performed testing and also certified correct operation of the dispensing system, per *SAE J2601 Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles* (Figure 8). Automaker testing was also conducted (Figure 9) to verify appropriate hydrogen refueling from the dispenser. The test processes involved more than 100 kilograms of hydrogen filling.

The station now has Division of Measurement Standards certification and passed Hydrogen Station Equipment Performance device testing in addition to automaker testing in December 2016, with the station opening to the public soon thereafter.

The station suffered delays associated with the pre-cooling system and conformance with back-to-back fuel testing. ITM Power Inc. worked with the equipment provider, PowerTech Labs Inc., to resolve these issues, which was an involved and meticulous process.

Figure 8: CDFA/DMS Certification

Source: ITM Power, Inc.

Figure 9: Automaker Testing

Source: ITM Power, Inc.

Environmental Impacts

Hydrogen will be stored as a compressed gas in above-ground tanks protected by a wall and fence. Hydrogen is nontoxic and disperses in air rapidly when a leak occurs; it also has no color or odor so it poses no environmental issues if loss of containment occurs. Sensors are present at the station to detect leaks and alert staff to any problems. No solid or liquid waste will be produced at this site.

No landscaping or irrigation was required for this project. The electrolyzer consumes around 2.5 gallons of purified water for each kilogram of hydrogen produced. This figure is lower than the water required to produce the equivalent 2.5 gallons of gasoline, so water impact is considered negligible. Hydrogen vehicles also produce the exact same 2.5 gallons of water when the kilogram of hydrogen is used for transportation.

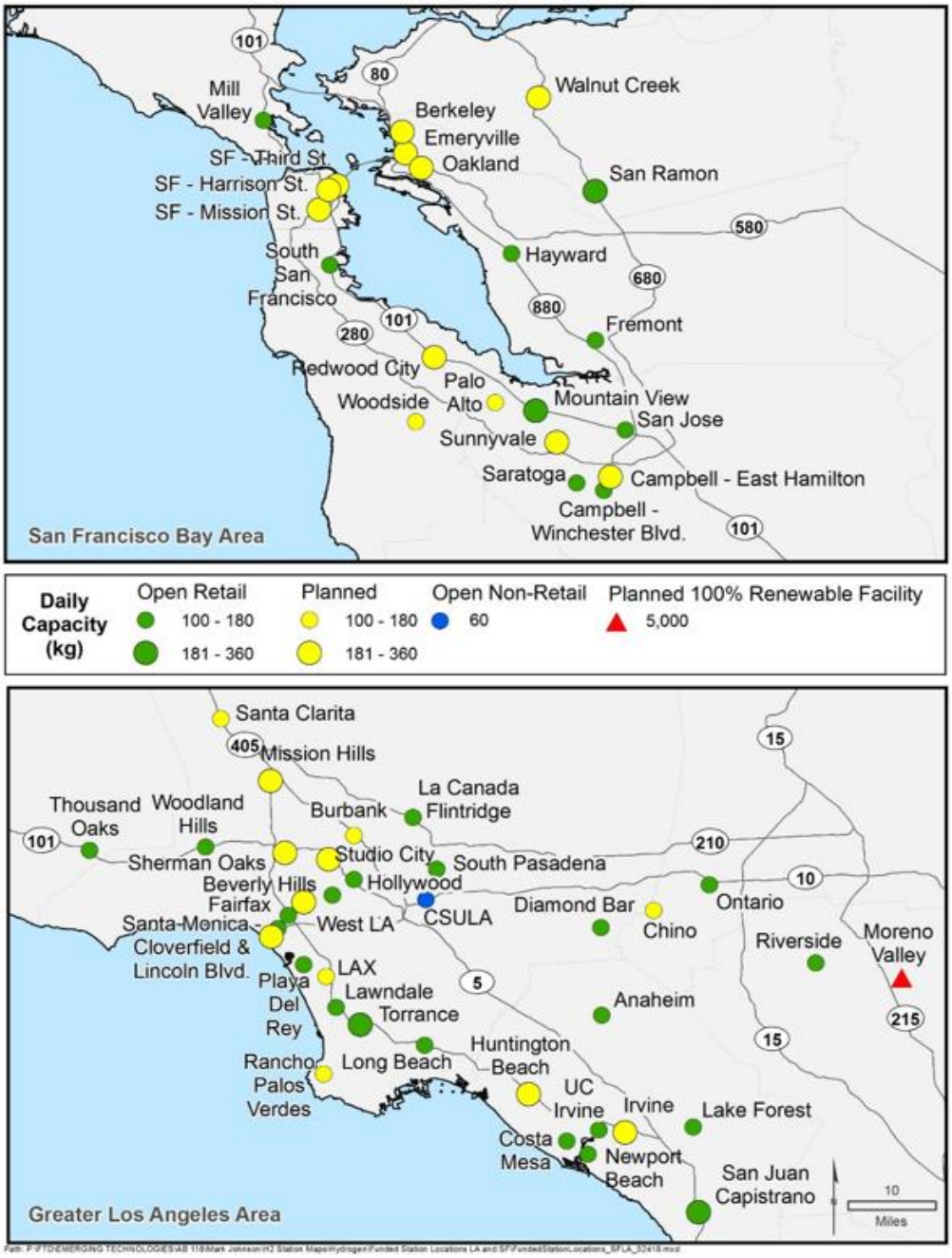
The system will not impact any other environmental factors such as noise, dust or aesthetics on the site.

Riverside Hydrogen Station in the Network

The station will provide an expansion to the east side of the network. Riverside will be the closest station to Las Vegas and Palm Springs and will provide a good link to the North San Diego area via Temecula.

Figure 10 shows the greater San Francisco and Los Angeles area maps. The lower map indicates where the Riverside station is situated in relationship to other stations in the southern part of the state.

Figure 10: San Francisco and Los Angeles Area Maps

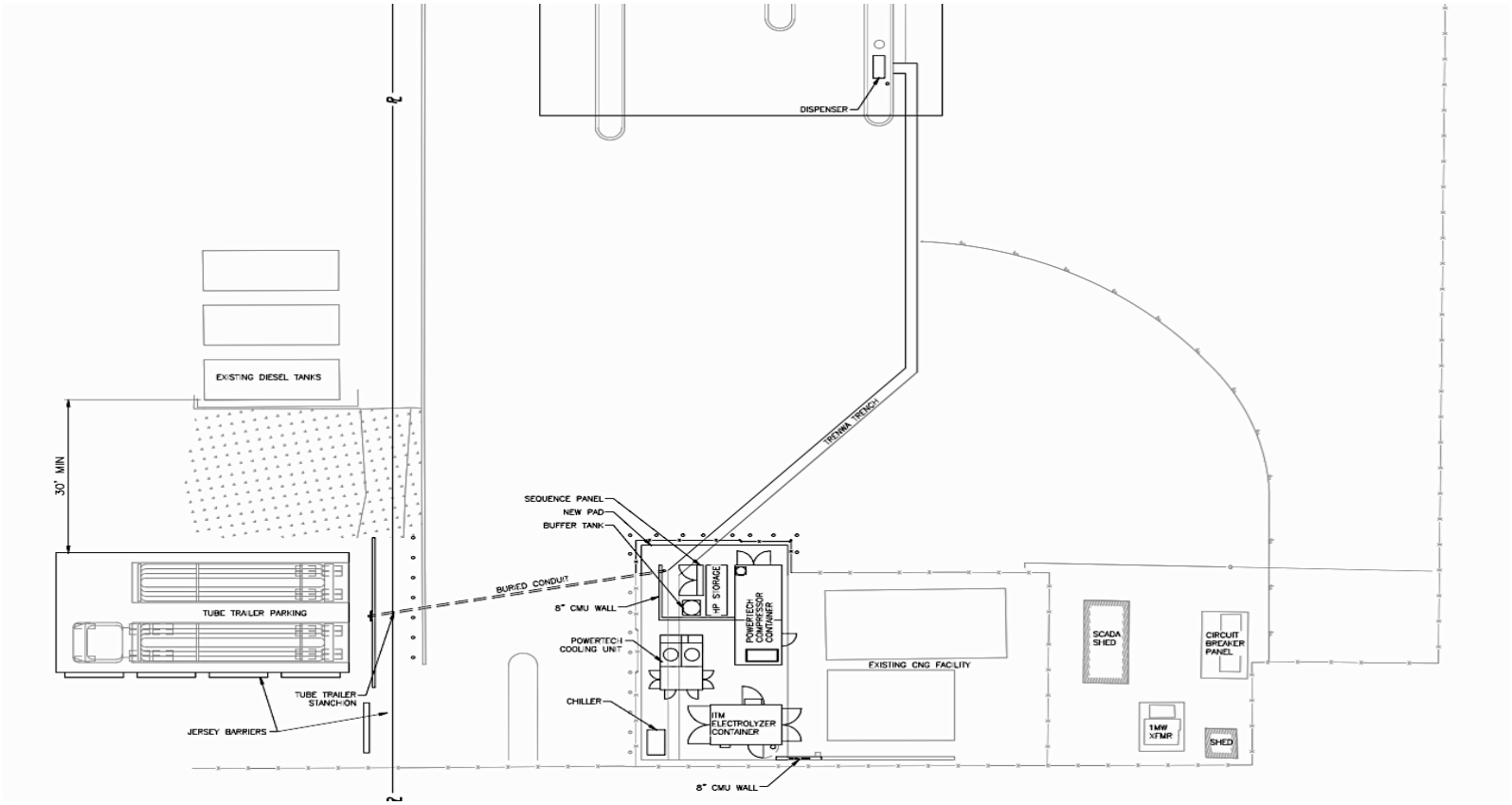


Source: California Energy Commission Staff

Final Configuration and Budget

The final layout drawing of the Riverside Hydrogen Station is shown in Figure 11.

Figure 11: Final Layout of the Riverside Hydrogen Station



Source: ITM Power, Inc.

Table 1 shows a detailed view of the budget to construct the Riverside hydrogen station.

Table 1: The Grant Recipient, Subcontractors, and Budget

ITM Power Inc.	
Administration	$108,540.00
Engineering, Procurement, and Site Installation	$351,638.00
Commissioning and Start-up	$18,000.00
Data Collection and Analysis	$3,500.00
PowerTech Labs Inc.	
Administration	$66,000.00
Engineering, Procurement, and Site Installation	$1,442,059.00
Commissioning and Start-up	$39,000.00
EPC, LLC.	
Engineering, Procurement, and Site Installation	$548,947.00
City of Riverside	
Administration	$50,000.00
Engineering, Procurement, and Site Installation	$90,000.00
Commissioning and Start-up	$20,000.00
Total Budget	$2,734,184.00
California Energy Commission Grant	$2,125,000.00
Match Funding	$609,184.00
Total Energy Commission cost share	77.7%

Source: ITM Power, Inc.

CHAPTER 2:
Energy Analysis

The Riverside station uses a combination of gas generated on-site via electrolysis and gas delivered via tube trailer. The delivered gas comes from a steam methane reformation process that converts natural gas into hydrogen. The electrolyzer is capable of producing up to 35 kilograms of hydrogen per day with any additional gas supplied from the tube trailer. This enables ITM Power Inc. to keep the number of tube trailer deliveries to a minimum.

Per Senate Bill 1505 (Lowenthal, Chapter 877, Statutes of 2006), a minimum of one-third of the hydrogen fuel sold to vehicles needs to be produced from renewable energy sources. The hydrogen station, at Riverside, achieves this by the fact that the electrolysis unit uses electricity that is linked to Renewable Energy Credits (RECs) that are traced through the Western Renewable Energy Generation Information System. This process is managed by the Riverside Public Utilities Company which provides the electricity to the site.

As the site is rated at a capacity of 100 kilograms per day and the electrolyzer produces 35 kilograms per day, the station satisfies the minimum 33 percent requirement. The reality is that when the station dispenses less than 100 kilograms per day the renewable component of the gas will be higher than 33 percent, because the electrolyzer is being prioritized in terms of gas generation over the tube trailer supply.

All energy and fuel data will be reported to the California Energy Commission throughout the term of the operations and maintenance grant. The data collected will be sent via the National Renewable Energy Laboratory data collection tool.

CHAPTER 3:
Statement of Future Intent

ITM Power Inc. intends to operate the station in Riverside for at least five years. It is probable that the station will be operated by ITM Power Inc. for longer than this, with systems being upgraded to cope with increasing demand, as required. ITM Power Inc. invested substantial funds to build the station and this investment will require many years of operation to recover the initial costs.

ITM Power Inc. has a willing and supportive land owner in the City of Riverside. The city has operated the "renewable fuel station" at this site which includes electric vehicle charging, compressed natural gas fueling, and propane fueling. The City of Riverside has operated this station for many years and city officials are thrilled that hydrogen is a part of the fuel mix.

ITM Power Inc. has a maintenance agreement in place with EPC LLC, who is using remote diagnostic tools to monitor and respond to maintenance events to ensure the long-term viability and performance of the equipment.

ITM Power Inc. plans to continue to expand the number and size of electrolyzer-based fueling stations in California and to support these stations fully with staff and expertise.

CHAPTER 4:
Findings, Conclusions, and Recommendations

The Riverside station was an important project for ITM Power Inc. to secure a position within California's hydrogen fuel future. There were a several important findings:

1. The station incorporates a novel on-site and delivered gas model. This has proven to be valuable for ensuring a hydrogen supply is always available on site.
2. The early engagement of the City of Riverside was valuable in securing the site permit in a short time window. The National Fire Protection Association – Hydrogen Technologies Code was a critical reference for the team to use during planning and construction.
3. Despite the City of Riverside having direct links to the local Riverside utility, electricity connection was complex, and this should not be overlooked for future station builds.
4. Adding the hydrogen system into an existing point-of-sale system was an efficient way for dealing with the situation, saving cost and complexity.
5. Delays to the project were encountered that were associated with verifying back- to-back fueling performance of the station. The main reason for the length of delay was that ITM Power Inc. does not possess a 700 bar test tank with Infrared communication, nor does ITM Power Inc. own any hydrogen vehicles to use for testing. Future projects should plan for the availability of multiple vehicles to provide load to the station and enable performance to be tuned.

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.

FUEL CELL ELECTRIC VEHICLE (FCEV) -- A zero-emission vehicle that runs on compressed hydrogen fed into a fuel cell "stack" that produces electricity to power the vehicle.

RENEWABLE ENERGY CERTIFICATE/CREDIT (REC) -- A market-based instrument that represents the property rights to the environmental, social and other non-power attributes of renewable electricity generation. RECs are issued when one megawatt-hour (MWh) of electricity is generated and delivered to the electricity grid from a renewable energy resource. (US EPA).

WESTERN RENEWABLE ENERGY GENERATION INFORMATION SYSTEM (WREGIS) issues and tracks Renewable Energy Certificates (RECs) for generation of renewable-source electricity in the geographic area covered by the Western Electricity Coordinating Council (WECC). WREGIS also facilitates REC transfers, enables permanent retirement of RECs, assists regulators with the implementation of their renewable energy programs, and brings transparency to REC markets.[1]

[1] Western Energy Coordinating Council – WREGIS Webpage: Frequently Asked Questions (https://www.wecc.org/Administrative/WREGIS%20Frequently%20Asked%20Questions.pdf)