CALIFORNIA ENERGY COMMISSION

California Energy Commission

Clean Transportation Program

FINAL PROJECT REPORT

San Diego Metropolitan Transit System: South Bay Maintenance Facility Compressed Natural Gas Station Improvements

Prepared for: California Energy Commission

Prepared by: San Diego Metropolitan Transit System

Gavin Newsom, Governor

November 2019 | CEC-600-2019-073

California Energy Commission

Frank Doucette
Primary Author

San Diego Metropolitan Transit System
1255 Imperial Avenue, Suite 1000
San Diego, CA 92101
Sandiego Transportation (www.sdcommute.com)

Agreement Number: ARV-10-018

Donald Coe, P.E.
Project Manager

Elizabeth John
Office Manager
ADVANCED FUELS & VEHICLE TECHNOLOGIES OFFICE

Kevin Barker
Deputy Director
FUELS AND TRANSPORTATION

Drew Bohan
Executive Director

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-09-006 to provide funding for alternative fueling infrastructure projects, including compressed natural gas fueling stations. In response to PON-09-006, the recipient submitted an application which was proposed for funding in the Energy Commission's notice of proposed awards May 17, 2010 and the agreement was executed as ARV-10-018 on January 28, 2011 in the amount of $186,150.

ABSTRACT

This report describes installation of natural gas compression and fueling equipment at the San Diego Metropolitan Transit System's South Bay Maintenance Facility. This equipment is used to fuel urban transit buses. The project was partially funded through a grant from the California Energy Commission.

In July 2010 San Diego Metropolitan Transit System contracted with Trillium USA for the installation of two natural gas compressors and one inlet gas dryer at the South Bay Maintenance Facility. The scope of work included providing all skilled labor, tools, equipment, transportation, and supervision needed to properly install and operate the two compressors (up to and including integrating the new equipment with the existing fueling facility). The anticipated budget for all improvements provided for San Diego Metropolitan Transit System was $5,688,920.

Since completion of the installation in October 2011, San Diego Metropolitan Transit System has achieved greater fueling efficiency, gained a better perspective of the role that the local utility has on the construction schedule for a natural gas fuel station, and recognized the benefits of combining equipment installation and maintenance contracts.

Keywords: San Diego Metropolitan Transit System, South Bay Maintenance Facility, compressed natural gas, CNG fueling, CNG buses.

Please use the following citation for this report:

Doucette, Frank. San Diego Metropolitan Transit System. 2019. San Diego Metropolitan Transit System: South Bay Maintenance Facility CNG Station Improvements. California Energy Commission. Publication Number: CEC-600-2019-073.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

Page

EXECUTIVE SUMMARY

This project included the procurement, installation and operational maintenance of compressed natural gas fueling equipment at San Diego Metropolitan Transit Systems' South Bay Bus Maintenance Facility in Chula Vista, California. The primary purpose of the expanded compressed natural gas fueling station is to increase its speed and capacity in fueling a larger fleet of compressed natural gas transit buses.

A combination of federal and state funding sources, including the California Energy Commission grant, funded this project. Energy Commission funds in the amount of $186,150 were used to purchase the natural gas compressors and inlet gas dryer. The remaining budget of $5,502,780 was composed of Federal 5307 Federal Transit Administration Transportation Clean Fuels funding from the U.S. Department of Transportation.

The scope of work included the installation of two natural gas compressors, one inlet gas dryer, and all of the associated plumbing, electrical, and civil improvements required to make the equipment operational. The two new natural gas compressors total 3,360 standard cubic feet per minute capacity, which increased overall capacity of the station from 1,900 standard cubic feet per minute to 5,260 standard cubic feet per minute. More than 250 buses can now be filled with compressed natural gas in a seven-hour period. This will enable the San Diego Metropolitan Transit System to add 40 new compressed natural gas transit buses and 20 new articulated compressed natural gas transit buses to the existing compressed natural gas bus fleet of 158 buses.

The original construction contract required that all work be completed by July 13, 2011. This completion date was extended to November 10, 2011, with a contract amendment to perform electrical supply improvements required by the local utility, San Diego Gas & Electric. Initial operation and in-servicing of the compressed natural gas fueling equipment were delayed for four months while electrical improvements were made to the utility grid. Lack of coordination with utility inspectors and scheduling delays to perform the final electrical connection caused some schedule slippage; however, all equipment was installed in place by the completion date.

The benefits of the station's increased fueling capacity was evident after the first month of operating the new compression equipment. Using the contractor installed monitoring software, the research team was able to track fueling statistics and equipment operational data to better understand fueling capabilities. Based on the researchers' ability to fuel more buses in less time, while using less labor and energy, they believe that the project was a complete success.

During first six months of operation, the expanded South Bay Facility compressed natural gas bus fleet accumulated 3,251,160 miles and displaced 1.3 million gallons of diesel fuel. Extrapolating the initial results, the expanded facility avoided the use of 2.7 million diesel-gallon equivalents in the first year of operation.

CHAPTER 1:
Project Planning and Construction Approach

Project Purpose

This project supplemented the existing compressed natural gas (CNG) compressors and fueling equipment with two additional compressors, controls, and support equipment that substantially increased the station's fueling capacity. The original compressors have a rated output of 1,900 standard cubic feet per minute (SCFM) and were installed to support a fleet of 50 CNG buses. The two new CNG compressors have a rated output of more than 3,360 SCFM for a new combined fueling capacity if more than 225 buses per night.

While the additional compressors have dramatically increased the station's fueling capacity, the contractor's efforts to improve the overall station operation have resulted in even greater fueling efficiencies. During construction, all storage vessel inlets were enlarged, the valve panel was replaced and an advanced equipment monitoring system was installed to allow 24-hour off site control of the fuel station.

Allow for Expansion of CNG Bus Fleet

Currently there are 158 CNG buses garaged at the South Bay Maintenance facility, with a future anticipated growth of 40 urban transit buses. In addition, there are plans to increase the fleet with 20 new articulated CNG buses as described in the proposed Bus Rapid Transit project. Without the installation of the new compression equipment, these increases would not be possible.

Reduce Fleet Fueling to Once per Day

Another goal of this project was to create sufficient fueling capacity to eliminate the practice of "top-off fueling" during the day whereby buses were fueled during the day to reduce the fueling requirement at night. Due to slow evening fueling and short fills (partially fueling a bus to speed the fueling process), daytime fueling became a standard practice.

During the first month of operating the new CNG equipment, the need to fuel during the day was eliminated. All buses could be completely fueled at night - in less time than it used to take to achieve partial fills. It is difficult to calculate the peak-usage electricity savings and the reduced labor costs, but the operational impact has been impressive.

Project Planning and Construction Approach

San Diego Metropolitan Transit System (SDMTS) had installed natural gas fueling facilities at three bus maintenance yards prior to this project using a variety of procurement approaches. After reviewing the results of similar construction projects nationwide, SDMTS decided to combine a 10-year operating and maintenance contract with this equipment installation project. This strategy was intended to ensure that only firms qualified to operate and manage the compression equipment would bid on the installation. Also, by requiring 10 years of turn-

key operation and maintenance at a fixed cost, SDMTS essentially negotiated a 10-year warranty for any failures – regardless of the cause or circumstances.

After the completion of a major construction project it is common to deliver the finished product to a custodian for maintenance and upkeep. These custodians often have maintenance issues related to equipment quality, construction flaws, and/or design defects. By combining the operations and maintenance contract with the equipment installation, these issues were avoided.

Provide Performance Requirements Rather Than Design Specifications

The development of the researchers' technical specifications for this project began with an assessment of the fleet capacity at the South Bay Maintenance Facility. It was determined that a maximum bus complement of 225 buses could be supported on the property. With this in mind, SDMTS decided to structure the equipment specifications as a performance requirement instead of following the traditional method of hiring a consultant to create a complete set of civil and mechanical design drawings and specifications.

Rather than provide a rigid design for contractors to bid on, SDMTS set performance requirements and allowed all bidders to propose equipment and designs that they felt would most efficiently meet the requirements. Two qualified contractors were identified early in the procurement process, and they were encouraged to submit a bid that would represent the highest value to SDMTS. Cost was a factor in the evaluation process; however, cost was weighted with other factors such as energy efficiency, projected fueling speed, and the quality of equipment. The proposal offered by Trillium was determined to be the best value for SDMTS after all proposal submittals were reviewed by the SDMTS Evaluation Panel.

Use In-House Project Management and Hire Design Review Consultants

SDMTS managed the installation of all new compression equipment with in-house staff members. As a result, less than one percent of the entire project budget was spent on engineering, design, or construction management services. The contractor designed and installed the equipment in compliance with their bid proposal, greatly reducing the construction management effort required to complete this project.

To help in-house project managers maintain a responsible level of oversight regarding the equipment design and installation, SDMTS hired Fuel Solutions for expert CNG fuel station consulting services. Fuel Solutions' scope of work included a review of the construction drawings submitted by the contractor, review and approval of all submittals, a review of all in-service documentation and a top to bottom inspection of the equipment after installation. These services provided the quality assurance and technical assistance that SDMTS project managers needed to efficiently manage the project, while sticking to a minimal administration and professional services budget.

CHAPTER 2:
Construction and Commissioning

Construction Activities Performed

Due to their modular design, the compressor and gas dryer assemblies were easily craned into place. After bolting these units into place and making the necessary gas and electrical connections, the real work of integrating the station's control and monitoring system into the new equipment began. Sensors that collect temperature, pressure and vibration data were installed to monitor each stage of compression. Parameters for automatic shutdown including excessive heat and pressure, vibration, and low oil pressure and/or flow were programmed into the station monitoring computer. Every process from the point that the gas enters the station to when it is dispensed into the vehicle is monitored. Data is sent to the monitoring system via programmable logic computers installed throughout the station.

Figure 1: Installation of Compressor and Gas Dryer

Source: SDMTS Staff

Figure 2 shows the housing for the compressor & dryer being lowered

Figure 2: The Housing for the Compressor & Dryer

Source: SDMTS Staff

Completed Utility Upgrade to Support New Equipment

For several months after all of the monitoring equipment and controls were installed and tested, the researchers were unable to operate the compressors and gas dryer. The local electrical utility was very slow in providing designs and detailed instructions on how the contractor would be required to connect the new equipment to the electrical supply. Additionally, SDMTS project managers needed time to process a change order to compete the work. While the researchers anticipated having to upgrade the existing electrical utility connection, they were unable to estimate the scope of this work prior to the contract award. As a result, the utility upgrades were handled through the change order process. This resulted in about a three-month delay in the installation schedule.

Provided As-Built Construction Drawings, OEM Manuals, and Training

In late 2011 a draft set of as-built drawings were delivered to SDMTS project managers for plan-check and review. These drawings were sent back to the contractor with a request for additional information and corrections. In March 2012 a final copy of the as-built drawings were accepted by SDMTS. (Two full size, four quarter-size, and 2 CDs with PDF and AutoCad versions were included in the package.) Original equipment manufacturer manuals for the

compressors and gas dryer were included in the submittal packages prior to installation and digital versions were supplied with the as-built drawings.

All SDMTS employees involved with the fueling effort were trained on the new dispensing equipment installed during the project. As a result, instances of short fills and operator error defects have been greatly reduced. There have been no instances of buses running out of fuel since the installation of the new equipment.

Additionally, Trillium provided training to SDMTS operating and maintenance contract managers so they could utilize the online fuel station monitoring application. Managers were provided access to the online monitoring website and trained to download operating statistics. The Web-based monitoring system allows SDMTS managers to remotely monitor compressor functions and see up to the minute compressor fault status. Select managers can also view the station via the installed video monitoring system.

Commissioning

Schedule and Budget Impacts for Project

The primary impact to both the schedule and budget on this project was the electrical utility upgrade. While SDMTS was aware of the requirement to upgrade the electrical service feed, researchers were unable to determine the scope of the improvement since much of the equipment design detail work was accomplished after the contract award. Once the equipment submittals were approved by SDMTS the electrical requirements were forwarded to the local utility, San Diego Gas & Electric (SDG&E).

After months of delays, SDG&E provided SDMTS with detailed specifications and approved drawings to complete the work using the researchers' contractor. SDG&E would make the final connections inside the main electrical service panel but required SDMTS to complete all other work – including trench work to connect a transformer located across a busy four-lane road to the new station.

SDMTS required the contractor to obtain three bids for the electrical utility upgrade work, and the low bid was approved during the change order process. The resulting change order increased the original project bid price by $191,040 and extended the construction schedule by 120 days. All work was completed by September 27, 2011, (on time) and to the satisfaction of SDMTS and SDG&E.

Equipment Downtime and Monitoring Effects

Since the equipment was placed into service, there have been no equipment downtime issues. The station is remotely monitored 24-hours a day, and any equipment failures are usually resolved without any indication of failure at the fuel dispenser. Operators monitor the station at all times and can shut down one compressor and start another compressor from their remote control center.

The result of operating more efficient equipment and monitoring that equipment remotely has been a dramatic decrease in unscheduled maintenance. The majority of work orders generated by the station technicians are for preventative maintenance, and there have been no

catastrophic failures since the new equipment was installed. This seems like an obvious goal, but it should be understood that researchers had four catastrophic compressor failures in the year before the new equipment was installed.

Fueling Speed and Operational Impacts

One of the most significant improvements made during the equipment installation project was the replacement of the valve panel assembly. The existing valve panel is shown below on the left. The new valve panel is shown on the right. Note the considerably larger diameter of the new valve panel's piping. The ¾-inch lines were replaced with a 2-inch inlet lines. The old 5/8-inch air-operated valve was replaced with a 2-inch valve.

Figure 3: Control Valves for the CNG System

Source: SDMTS Staff

The effect of this improvement was known well before the new compressors were installed. The contractor made this improvement prior to installing the new compressors to help compensate for the loss of two of the research team's existing compressors during the new compressor installation. Researchers were forced to cut power to two of the existing natural gas compressors during the installation of the new compressors due to a utility conflict. Even though researchers were short two compressors, they were able to fuel the same number of buses each night. Researchers were essentially fueling the same number of buses using half the energy.

Now that all compressors are up and running, researchers have the luxury of setting two compressors as the "lead" and "lag" machines while the others sit idle in standby. These

compressors will run during periods of peak operation and remain in standby mode when demand falls – ready to pick up the slack if either the "lead" or "lag" compressor fails to operate properly.

Performance gains in terms of reduced fueling times have been spectacular. Our baseline average fueling time before the new compressors were installed was 10 minutes per bus. The current average fueling time is a little more than four minutes per bus. This reduction in fueling time made it unnecessary to "top off" buses during the day and eliminated a major consumer of electrical energy during the peak demand period of the day. Now buses are fueled at night (between 6:00 p.m. and 2:00 a.m.) when electrical energy demand is statistically lower, and MTS is not subject to demand charges.

CHAPTER 3:
Results and Benefits

Performance and Technology Advances

Off-Site Monitoring Capabilities

The improvements SDMTS has gained through the off-site monitoring system technology cannot be underestimated. The remote station operators have complete control of the station at all times and have virtually eliminated CNG fuel station downtime through the use of redundant equipment. No transit property should consider a proposal to install or maintain CNG fuel station equipment without this technology. It is available, it is cost-effective compared to full-time employees, and it works.

A secondary benefit to off-site constant monitoring is the ability to remotely lock-out compression equipment according to a schedule or to meet an external request. SDMTS has the ability to lock out all compressors during peak energy demand periods (when electricity costs are excessive) and upon request when the local utility experiences higher than normal demand periods. This level of control is both economical for SDMTS and beneficial to the region.

Sound Mitigation through Vibration Dampening

The pictures in Figure 4 show that the vibration levels are so low a coin can stay balanced on its edge.

Figure 4: Substantially Reduced Vibration Levels

Source: SDMTS Staff

The level of sound mitigation and vibration dampening that is built into JW Operating compressors was one of the main reasons the contract was awarded to Trillium. SDMTS sent a project manager to the JW Operating manufacturing facility to inspect the equipment at the factory and to monitor the quality assurance process. The researcher team's project manager had detailed discussions with the compressor designers that covered skid structural stiffening, gas pulsation dampening technique, and crankshaft load balancing.

The result of JW Operating's advanced design is a 500 horsepower compressor that is so quiet you can have a normal conversation standing right next to it while it runs. Their engineering efforts are focused on reducing vibrations through a process of balancing and pulsation dampening. The pictures above show a coin balanced on its side while the compressor is running. This was a truly amazing demonstration. While the noise reductions are appreciated by all who work around the compressor, the vibration and noise reduction efforts are not just for human comfort. Noise and vibrations waste energy that should be used to compress gas – and vibrations cause equipment failures.

Paced Fueling to Reduce Starts

The new station control system determines the actual pace of bus fueling to help eliminate dips and spikes in fuel capacity demands. It limits the number of compressors running to match the fuel demand. It also utilizes a "first bus in" prioritization program to ensure that bus output remains constant throughout the evening. By reducing the number of compressor starts and stops, this upgrade allows the equipment to run more efficiently, use less energy, and last longer.

While the new compressors fuel much faster than the existing equipment, they also fuel smarter. Rather than rely on the employees to set the fueling pace, the station monitoring and control system established the pace of buses that leave the fuel station. This benefit was a difficult sell to the on-site employees, but after a few evenings, it was clearly better than random fueling.

The pace fueling system keeps tract of bus fueling times and assigns a priority to the first two buses that are fueling. The third or fourth bus to "hook up" to a dispenser is put on hold while the first two finish fueling. Rather than have four buses finish fueling at the same time, the paced fueling system ensures that there is always a bus finishing up the fueling process – and another bus is ready to start fueling as soon as the first bus is completely filled.

The result is a more constant flow of fueled buses out of the service lanes and less wasted time waiting for buses to fuel. Additionally, because the lag time between fueling is eliminated (there is always a bus waiting to fuel during the evening hours), the compressors do not run unloaded or shut down between fills. The reduction of unloaded run time and "stops and starts" saves energy and reduces wear on the compressors.

Reduced Fueling from Twice Daily to Once Daily

Of all the efficiencies realized after the new compressors were installed, terminating daytime fueling has had the greatest impact to operations. Maintenance managers no longer have to supply personnel to move and fuel buses during the day, and peak energy costs are totally avoided by not running the 500 HP compressor motors during the day.

Using Off-Site Monitoring for Better Control and Energy Savings

The off-site monitoring system has eliminated the need for maintenance managers to conform their evening operations around the CNG fuel station's capacity. Since the installation of the new compressors, equipment failures are mitigated with no impact to bus operations. Maintenance managers now focus on servicing and cleaning buses – mission accomplished.

By installing the remote monitoring and control system, researchers have improved their ability to control fuel station energy consumption. The economical and energy conservation benefits to locking out the equipment during the daytime (and other periods of high energy demand) were unachievable without this technology. What was impossible before is now made simple with a few keystrokes.

Operational Benefits

Workforce Effort Reduced with Less Frequent Fueling

By reducing fueling frequency from twice daily to only once per day, researchers have reduced the labor required to fuel the natural gas fleet by one-third. As a result, personnel have been reassigned to perform work such as vehicle deep-cleaning, vehicle exterior detailing, and facility maintenance. The added labor availability helps to keep operational costs down while continuing to improve the service provided.

Zero Down Time Due to Extra Capacity

The new compressors have added an unprecedented a level of fueling capacity to the South Bay Maintenance Facility CNG fuel station. During a typical fueling shift (6:00 p.m. to 2:00 a.m.), at least one compressor will remain in standby mode. This compressor can be started remotely if any of the lead compressors experience a failure during the fueling shift. This compressor redundancy makes it possible to mitigate equipment failures such that the employees who are fueling the bus fleet experience no change in fueling capacity. While it is not possible to prevent all equipment failures, the new equipment has made it possible to prevent equipment failures from affecting operations.

Ten-Year Follow up Maintenance Agreement Ensures Quality and Reliability

SDMTS had a specific strategy in mind when researchers created the requirements for this project. Only firms with the experience and capacity to install and maintain the equipment for a period of 10 years were deemed qualified to bid on the contract. As a result, researchers received two highly competitive bids for equipment that met or exceeded our requirements – with cost proposals below the engineers cost estimate.

After the contract was awarded, SDMTS realized additional benefits during the construction and installation phase of the project. The contractor never hesitated to correct issues during the construction or to make a change that would improve equipment maintainability. Researchers believe that this was a direct result of the requirement that the contractor maintain the equipment after construction.

The construction contract expired in January 2012, and only the operations and maintenance contract remains in effect. As expected, no issues related to equipment quality, construction

techniques, or design defects have been raised by the contractor. In fact, the contractor has been exceptionally successful at maintaining the station under the terms of the contract. The contractor has implemented a planned maintenance system for all equipment and initiated a plan to improve the aesthetics of the existing equipment and facilities with new paint and decals. This project has proven the effectiveness of the researchers' "construction improvements with follow on maintenance" strategy, and this approach will be used as a model for all future CNG fuel station capital improvement projects.

Remote Monitoring Allows for Effective Administration of Maintenance Contract

The operations and maintenance contract administrator is an SDMTS employee located at the Imperial Avenue Division Bus Maintenance Facility. The remote monitoring technology installed with the new compressors provides real-time data at three SDMTS-owned CNG fuel stations including the South Bay Bus Maintenance Facility site. Daily fuel statistics such as the number of fuel transactions, average fill time and number or fills per hour are accessible via the Internet. The compressor status is provided along with a daily alarm log that lists all alarms and/or equipment failures that have occurred in the last 24 hours. If any repair work was performed overnight, the administrator can see the technician's repair notes on the repair log. Access to the installed video camera system is also provided on this secure website.

The availability of real-time equipment monitoring has been a valuable contract management tool. The contract administrators (and select maintenance managers) use it to better understand the station's operating characteristics and to help the maintenance department to get the most performance out of the fueling equipment. Performance issues are no longer subjective or based on word-of-mouth reporting. The researchers now look to real-time fueling data to see where efficiency improvements can be made. Their access to actual real-time data (combined with the equipment improvements) has virtually eliminated performance complaints.

Petroleum Displacement

Table 1 shows total CNG fuel use at the South Bay station during the first six months of operations. Total CNG bus mileage was over 3.2 million miles and over 1.8 million therms were used. Total petroleum fuel displacement was over 1.3 million diesel gallon equivalents (DGE).

Multiplying by two to indicate 12 months, total annual petroleum displacement from the initial year of operations was 2.7 million DGE. Carbon reduction benefits from CNG fuel use can range from 10 to 20 percent lower than diesel fuel.

Table 1: First Six Months' Mileage and CNG Fuel Use Statistics

Operational Month	Total Bus Mileage	Therms Used	Miles Per Therm	Diesel Gallon Equivalent (DGE)	Miles Per DGE
January 2012	541,210	309,260	1.75	229,080	2.36
February 2012	511,400	291,700	1.75	216,080	2.37
March 2012	564,110	310,840	1.81	230,250	2.45
April 2012	525,910	301,410	1.74	223,270	2.36
May 2012	550,850	308,080	1.79	228,210	2.41
June 2012	557,680	304,180	1.83	225,320	2.48
Totals	**3,251,160**	**1,825,470**		**1,352,210**	

Source: SDMTS

Summary

The researchers' goal was to increase the fueling capacity at the South Bay Maintenance Facility. Rather than detail what equipment was required, they specified how the equipment needed to perform. In addition, they specified that only those firms who were willing to maintain the equipment under a long-term maintenance contract.

The resulting proposals were highly competitive and the winning proposal offered significant value added components including exceptional equipment, advanced monitoring, and process control improvements to the existing equipment.

The schedule and budget were maintained except for the change order to upgrade the electrical utility connection. While this work took longer than expected and cost more than anticipated, all work was completed successfully, and the project was completed within the original budget.

After installing the new equipment, the researchers have experienced added capacity in excess of their performance specifications along with significant energy- and labor-saving improvements. There have been no maintenance issues related to the construction, and many existing maintenance issues were resolved during the integration of the new equipment. After eight months of operation, all equipment functions perfectly, and the operations and maintenance contractor is under contract to maintain the fuel station in top condition until July 25, 2020.

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:

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

COMPRESSED NATURAL GAS (CNG) - Natural gas that has been compressed under high pressure, typically between 2,000 and 3,600 pounds per square inch, held in a container. The gas expands when released for use as a fuel.

DIESEL GALLON-EQUIVALENT (DGE) - is the amount of alternative fuel it takes to equal the energy content of one liquid gallon of diesel gasoline.

SAN DIEGO GAS & ELECTRIC (SDG&E) - SDG&E is a regulated public utility that provides natural gas and electricity to San Diego County and southern Orange County in southwestern California, United States. It is owned by Sempra Energy, a Fortune 500 energy services holding company based in San Diego.[1]

SAN DIEGO METROPOLITAN TRANSIT SYSTEMS (SDMTS) - is the public transit service provider for Central, South, Northeast and Southeast San Diego County, in the United States.[2]

STANDARD CUBIC FEET PER MINUTE (SCFM) - the molar flow rate of a gas corrected to standardized conditions of temperature and pressure thus representing a fixed number of moles of gas regardless of composition and actual flow conditions.

---

1 San Diego Gas and Electric Website https://www.sdge.com/

2 San Diego Metropolitan Transport System https://www.sdmts.com/