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**New Technology Research & Development Program
Grant Contract 582-5-70807-0002**

Task 2 Deliverable Report

The preparation of this report is based on work funded in part
by the State of Texas through a Grant from the
Texas Commission on Environmental Quality.

El Paso County New Technology Research and Development Grant

Task 2 Report: Fabrication of the ADA Compliant Bus and Installation and of the L/CNG Engine and Fueling System

This report is submitted by El Paso County to the Texas Emission Reduction Program in fulfillment of the requirements of New Technology Research and Development Grant Contract #582-5-70807-0002 between the County of El Paso and the Texas Commission on Environmental Quality.

I. Introduction and Overview

El Paso County and its' primary subcontractor Ruby Mountain Inc. (RMI) have completed fabrication of the 33-passenger, low-floor, ADA-compliant project vehicle as well as the installation of the Cummins B Gas Plus natural gas engine. The compressed and liquefied (L/CNG) fueling system design and specifications have also been completed and are submitted with this report prior to finalization. Additionally, integration of the patented Economizer Valve into the fueling system has also been completed to allow the vehicle to operate on both liquefied and compressed forms of natural gas originating at different pressures. The Economizer Valve was developed by the Idaho National Laboratory.

As reported previously, over the first six months of the project period, the project team had assisted El Paso County in developing a comprehensive set of both body and chassis specifications which allow the vehicle to meet ADA requirements while providing for a unique rider experience. Those specs were previously submitted to TCEQ with the Task 1 Report.

Based on the NTRD scope of work, the following task has been completed:

Task 2: Fabrication of the ADA compliant bus and Installation and of the L/ CNG Engine and fueling System

2.2. Task Statement: The PERFORMING PARTY will install and fabricate the necessary components to construct the transit bus with ADA capabilities and the LNG/CNG engine.

2.2.1. The PERFORMING PARTY will install and fabricate the necessary components to construct the transit bus with ADA capabilities and the L/CNG engine and fuel system.

2.2.2. Schedule: The PERFORMING PARTY shall complete this task within 12 months of the signed Notice to Proceed Date as issued by TCEQ.

2.2.3. Deliverables: The PERFORMING PARTY shall submit a report to the TCEQ upon completion of this task. This will include but is not limited to photos and design plans of the completed transit bus.

II. Fabrication of the ADA Compliant Bus

The 33-passenger, low-floor, ADA-compliant project vehicle was fabricated by ARBOC Limited and installed onto the International 3200 Series Chassis as per the specifications previously developed and submitted to TECQ.

As originally envisioned, the project vehicle has a number of unique design features, particularly those related to the L/CNG fueling system and Hydraulic Launch Assist (HLA) device. While the NTRD project vehicle was designed specifically to accommodate the L/CNG fuel system coupled with the HLA device, the vehicle will also demonstrate the economic and technical viability of each component working separately. The demonstration will prove that the two components are integratable and adaptable to many vehicles either individually or collectively. This will accomplish TCEQ's goal of laying the groundwork for the commercialization of technologies which reduce vehicle emissions.



Photo: El Paso County Project Vehicle – Full Side View

Unlike most vehicles of its' ilk, the NTRD project vehicle is designed as a rear-wheel drive "pusher" bus which should increase vehicle durability and result in substantially lower maintenance costs.



Photo: El Paso County Project Vehicle –Side/Rear View

Americans With Disabilities Act features on the project vehicle include an interior/exterior enunciator system, visual announcement of stops/major intersections via three interior LCD screens, multiple wheelchair tie-downs, automated ramp, wide center aisle, grab bars on seatbacks, overhead and vertical stanchions as well as lap and shoulder belts on all passenger seats.



Photo: El Paso County Project Vehicle with Automated Ramp Extended

Additional interesting features include the following:

- State-of-the-art passenger entertainment and information system including multi-speaker premium sound system throughout passenger cabin, 26" LDC screen behind driver's seat and two 15" LDC flip-down screens for easy passenger viewing;
- Overhead reading lights;
- Wiring for covert security system and/or passenger surveillance;
- A coffee/drink bar; and,
- Maximum available roof-mounted air conditioning.



Photo: El Paso County Project Vehicle – Interior View

To ensure compliance with the specification developed by El Paso County, the NTRD project vehicle underwent several inspections to ensure compliance with specification. The preliminary

inspection was made by Juliet Burdelski of J.B. Planning Partners. Ms. Burdelski and Jon Lear of RMI made a secondary vehicle inspection. Additional members of the project team made “virtual” inspections with the photographs taken by Ms. Burdelski. In all, four members of the project team as well as Ms. Burdelski have looked the project vehicle over to date. The following is a summary of the items identified during the inspection process and the responses from Dick Rief, ARBOC:

- 1) Co-pilot seat was not observed. Dick confirmed there is no copilot seat, however there are three seats observed in paratransit/tie down area.
- 2) Bike rack sockets were not observed. Dick said that ARBOC has recommended a different bike rack model that could be installed with existing front grill. Bike rack model needed further discussion with transit authority.
- 3) Roll shades for top windows were not observed. Dick clarified that shades were only intended for windows in top (i.e. ceiling) of bus. Final design did not include windows in ceiling due to structural concerns. Adaptation or further modification to include a “sunroof” needed further discussion with transit authority.
- 4) Rear door, low to access CNG/LNG tanks not observed. Dick said rear door to access CNG/LNG tanks not installed due to structural concerns. Dick agreed to follow up with Bell Power Systems to review access to tank frame area without installing the tank door. (Call with Bell Power Systems held 9/15/06.)
- 5) Frame structure to support LNG tank at rear of frame not observed (or unclear). Dick confirmed that frame rails were installed to Bell Power Systems specification—with enough support to house CNG & LNG tanks.
- 6) Spec requests 215 horsepower governed speed 2800; actual (listed on engine block) shows 215 horsepower at governed speed 2600. All agreed that governed speed requirement was not critical since the diesel engine would be replaced.
- 7) Spec requests wheelbase 254” (6251.6mm); actual shows wheel base of 157” and 78” afterframe. Dick confirmed that the addition of an afterframe to lengthen the overall wheelbase is a standard practice.
- 8) Vertical side transition windows not observed. Dick explained that air conditioner cables and hoses were concealed within the areas where the side transition windows would have been.
- 9) Observed LDC unit behind driver seat completely blocks view of all seats behind driver, and rear view mirror does not enable additional views behind driver. Dick said that the existing rearview mirror should be sufficient. Additional options would include installation of surveillance cameras to monitor passenger areas allowing the driver to monitor passenger activity from a dash-mounted monitor.
- 10) Observed floor ramps down slightly to passenger door making for an odd entry into the bus. Dick said only way to make ramp ADA compliant was to ramp down slightly in the passenger entry area.
- 11) Observed aisles are wide allowing for easy access to back of bus.
- 12) Observed flip down screens are unobtrusive.
- 13) Observed stanchions are matte finish stainless steel.
- 14) Observed coffee bar next to driver.
- 15) Observed premium stereo system and interior lighting.

III. Installation of the Natural Gas Engine

As stated in previous reporting, the project team selected the Cummins Westport B Gas Plus natural gas engine to be installed into the project vehicle. The B Gas Plus engine is an excellent choice for 20,000 - 32,000 gvw short-haul applications such as pickup and delivery vehicles, shuttle buses and on/off highway applications such as refuse trucks and dump trucks. The

engine's broad power band provides excellent performance when matched to various manual and automatic transmissions. The B Gas Plus delivers optimum performance when operating in the 2,400-2,600 RPM speed range. Typical B Gas Plus overall gearing should be higher numerically than the equivalent diesel engine application. This makes good use of the higher-governed engine speed and provides excellent startability and gradeability.



Photo: Cummins B Gas Plus Engine Installation at Bell Power Systems

The Cummins B Gas Plus was installed by Bell Power Systems in Essex, Ct. and was compatible with the International 3200 Series Chassis. Preliminary performance testing of the Cummins B Gas Plus is expected in the coming month.

IV. L/CNG Fueling System

Fuel pressure control is vital to the proper operation of the B Gas Plus. In order to insure the engine operates properly, fuel pressure must be delivered to the engine fuel inlet at the pressure and flow rate listed below:

For B Gas Plus - Natural Gas must be supplied to the engine at a steady pressure +/-69 kPa (+/-10 psi) variation between 414 kPag (60 psig) minimum to 1034 kPag (150 psig) maximum for the B Gas Plus under all conditions and fuel flow rates.

Fuel temperature should be -40 C to 93 C (-40 °F to 200 °F). Fluctuating pressure may result in engine operating problems.

The El Paso County project vehicle will be operating two forms of natural gas at differing temperatures and pressures. In order to address those issues, the Idaho National Laboratory has developed a patented design – the Economizer Valve – which can be implemented as either a component or a methodology.

Put simply, when the LNG fuel is too cold, and the pressure inside the tank is too low, insufficient fuel will flow to the engine and the vehicle performs poorly or not at all. The valve, which has been installed onboard the project vehicle developed for El Paso County Rural Transit. The vehicle has a 119 gallon LNG tank onboard and four smaller CNG tanks with a capacity of just over 15 gasoline gallon equivalents (gges).

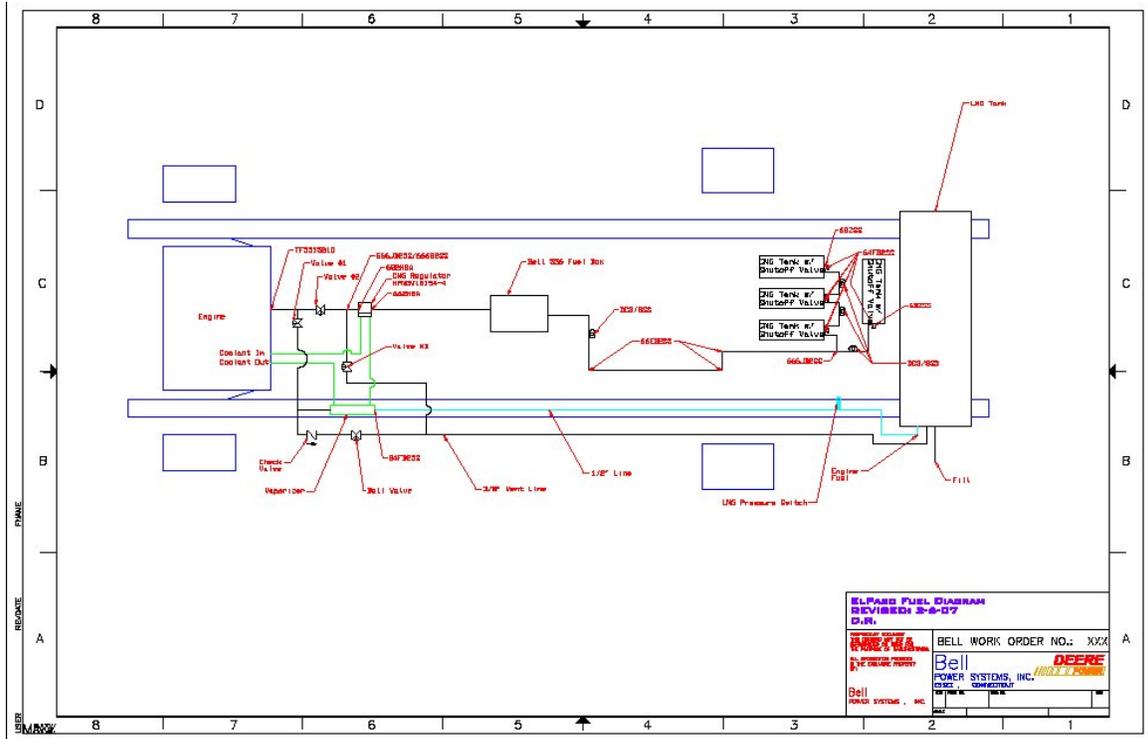


Illustration: El Paso County Project Vehicle Fuel System Schematic

The LNG tank is mounted in the back of the bus with a ½ inch line drawing liquid out of the tank and being fed toward the engine. In the front of the bus, the LNG stream is fed into a vaporizer to gasify the entire stream. The vaporizer is heated by passing engine coolant through the shell of the vaporizer/heat exchanger. This gasified stream is then fed to the engine through the valve #1 and any excess pressure in this line is being fed back in a ¼ inch line to pressurize the LNG tank. This line has a check valve to only allow pressure back into the tank through the vent line.

A second ½” line is installed in the system to allow pressurized gas to be fed from the CNG tanks. This gas is regulated to a comparable LNG pressure based on the engine configuration. Valves #1 and #2 are synchronized so that when one is open the other is closed and visa versa. A level indicator is installed on the LNG tank and the operation of valves #1 and #2 are based on this level. When the tank level is high, valve #1 is open and valve #2 is shut, and when the tank level is low valve #2 is open and valve #1 is shut.

Valve #3 has also been installed on the incoming CNG line and connected to the return line to the LNG tank. This allows for the LNG tank to be pressurized from the CNG tanks. This valve is controlled by a pressure switch that has been mounted on the LNG vent line. When the pressure is low, valve #3 is opened, and when the pressure is high the valve is closed off.

This design incorporates the design for the economizer valve approach which allows for pressure to build up in the LNG tank from either a vaporized or pressurized source. This allows operators to overcome the issue dealing with fuel that is too cold or has low pressure.

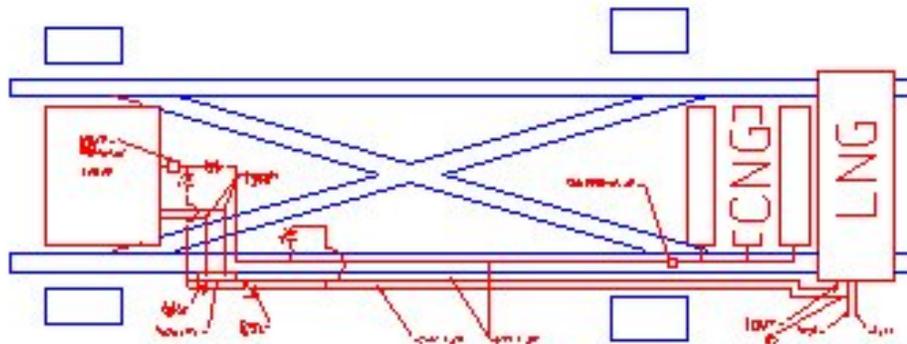
Economizer Valve

As stated previously, the project vehicle incorporates the use of both LNG and CNG. The main fuel supply comes from a 119 gallon LNG tank. A unique system developed and patented by the Idaho National Laboratory, called an economizer valve has been incorporated onto this bus. During acceleration as the engine needs fuel, this economizer valve controls the flow of LNG and in the process vaporizes the LNG forming pressurized CNG which is regulated to the engine.

During de-acceleration, when the engine does not need the fuel, the pressurized CNG is routed back to the LNG tank. This pressure build within the LNG helps to support the flow of LNG as needed. In addition, the engine can be fed from 19 gasoline gallon equivalents of CNG onboard the vehicle. If needed, the CNG supply could also be used to help pressurize the LNG tanks. This unique fueling system will advance the use of natural gas.

Natural Gas Tank Placement

The project vehicle features five natural gas tanks: one 119 gallon LNG tank manufactured by Taylor Wharton; one 5.3 gge CNG tank manufactured by Pressed Steel; and three 3.5 gge CNG tanks also manufactured by Pressed Steel.



All natural gas tanks are mounted in the rear of the vehicle, with separate fueling portals for the CNG and LNG.

Fuel Distribution Panels

The El Paso County project vehicle will be equipped with a compressed natural gas (CNG) fuel distribution panel, including the following components:

- CPI valve
- High Pressure Ball Valve
- 1/4" Shut-off Valve
- 2.5" 5000 psig Fuel Pressure Gauge

- Natural Gas Filter
- NGV II Fuel Fill Valve
- High Pressure Regulator

All components are housed in a NEMA 13 weatherproof enclosure. All CNG connections are high-pressure stainless steel tubing and fittings as per NFPA 52. The CNG fill box is located under the driver’s step near the front of the vehicle to prevent drive offs.

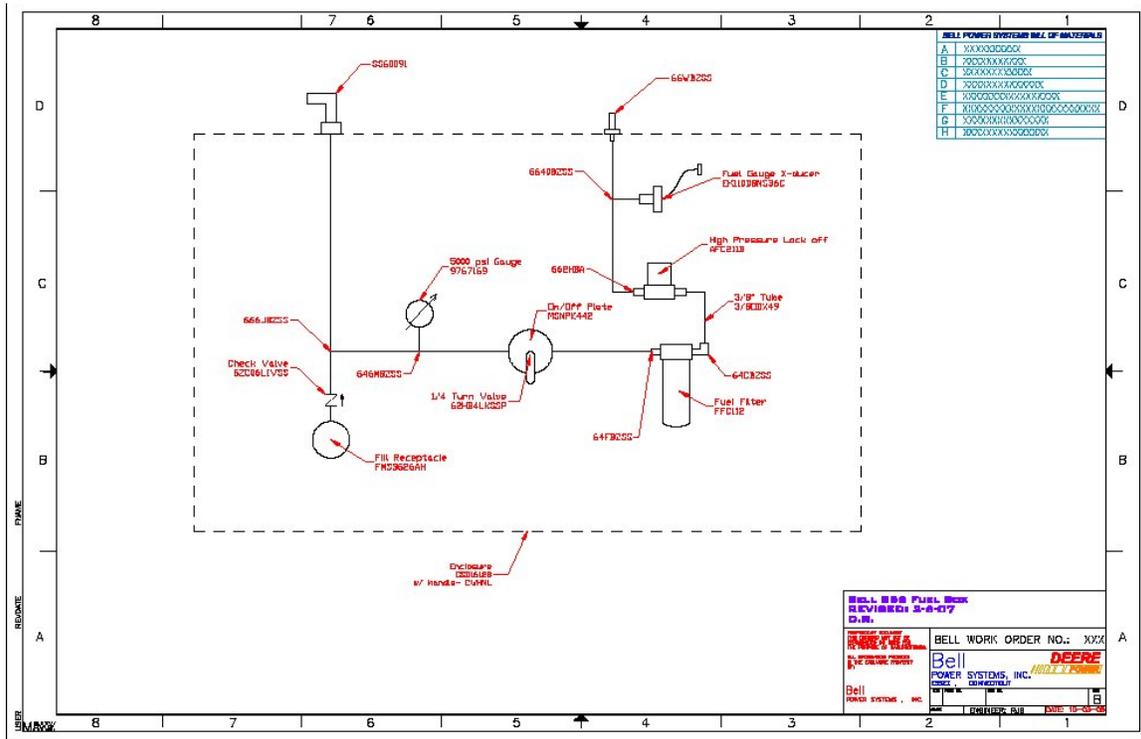


Illustration: El Paso County Project Vehicle CNG Fuel Fill Box

The LNG fill box located will be located next to the LNG tank on the back of the vehicle and consists primarily of the fueling receptacle. An LNG level gauge is mounted on the dashboard.

V. Attachments

Attached to this report is the following:

ATTACHMENT A: Additional El Paso County Project Vehicle Photos

ATTACHMENT B: El Paso County Project Vehicle Fuel System Schematic (Full View)

ATTACHMENT C: El Paso County Project Vehicle CNG Fuel Fill Box Schematic (Full View)

**Task 2 Deliverable:
Fabrication of the ADA Compliant Bus and
Installation and of the L/CNG Engine and
Fueling System**

**Attachment A:
El Paso County Project Vehicle Photos**



Photo: El Paso County Project Vehicle – Right/Front Side View



Photo: El Paso County Project Vehicle – Right/Rear Side View



Photo: El Paso County Project Vehicle – Left Side/Rear View



Photo: El Paso County Project Vehicle – Rear View



Photo: El Paso County Project Vehicle – Interior View #1



Photo: El Paso County Project Vehicle – Interior View #2

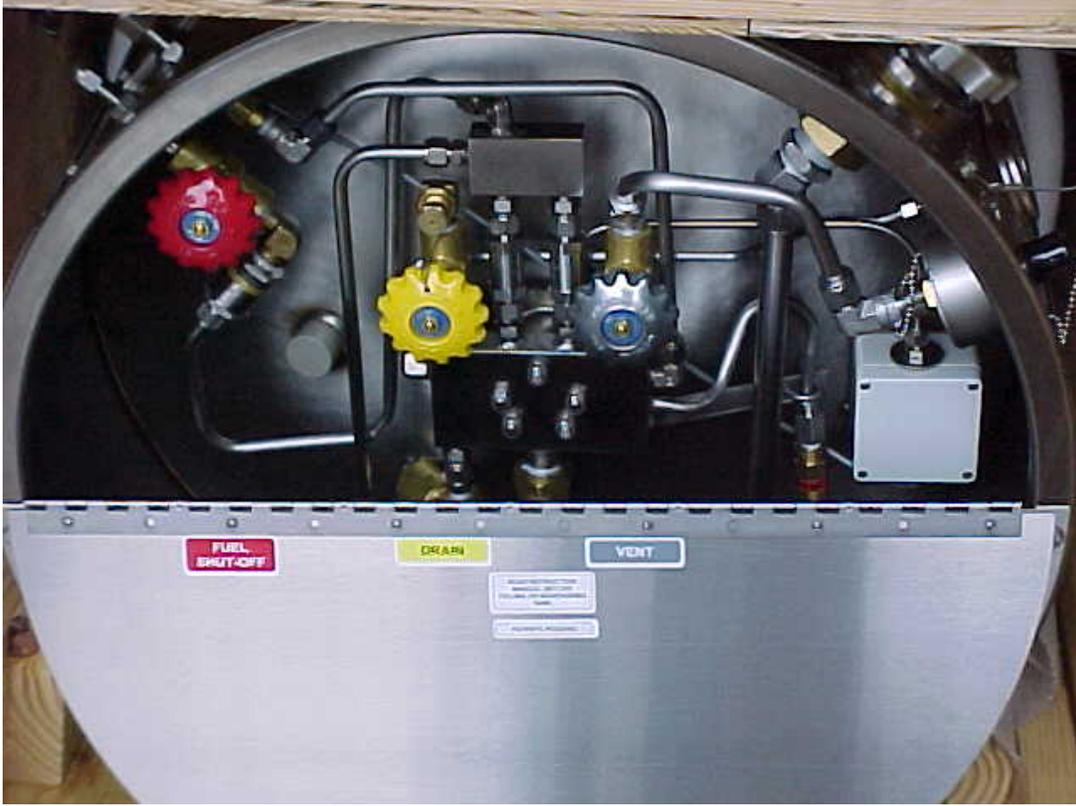


Photo: El Paso County Project Vehicle – LNG Tank View



Photo: El Paso County Project Vehicle – CNG Tank View

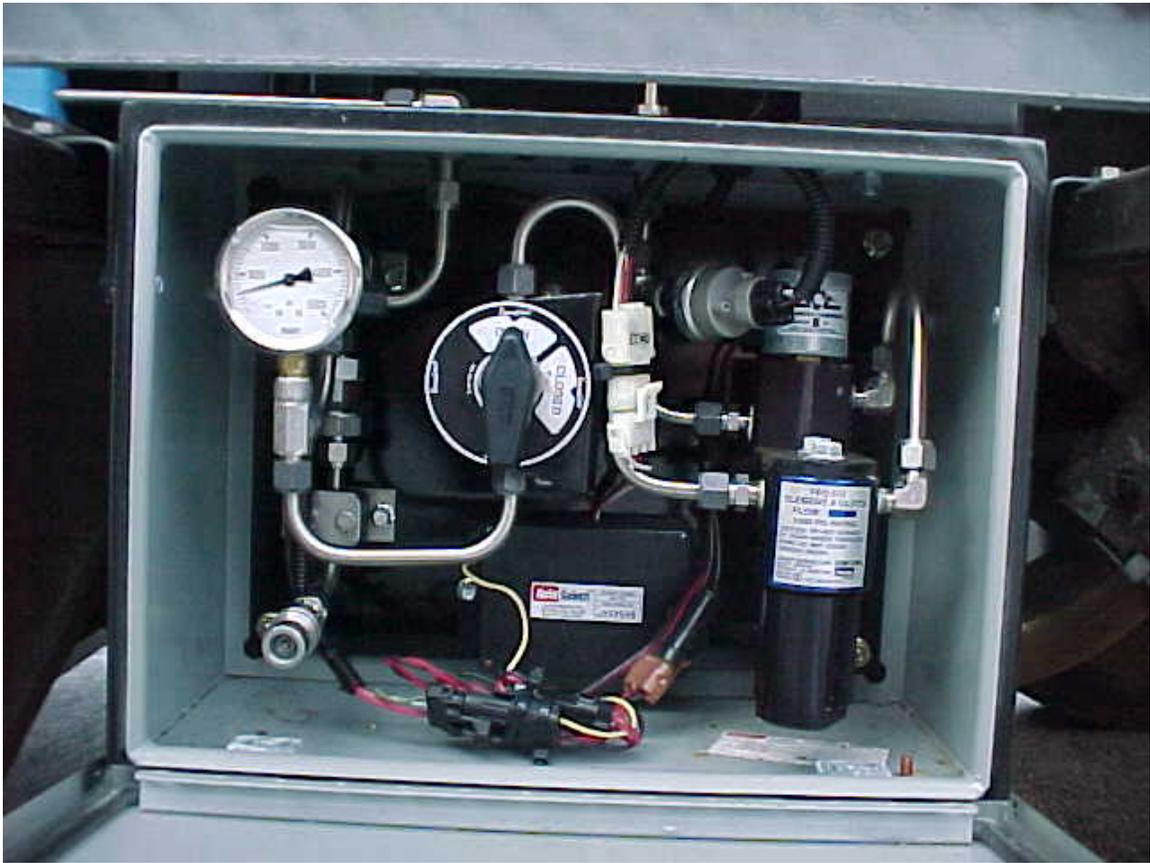


Photo: El Paso County Project Vehicle – CNG Fuel Fill Box

**Task 2 Deliverable:
Fabrication of the ADA Compliant Bus and
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**Attachment B:
El Paso County Project Vehicle Fuel System Schematic
(Full View)**

**Task 2 Deliverable:
Fabrication of the ADA Compliant Bus and
Installation and of the L/CNG Engine and
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**Attachment C:
El Paso County Project Vehicle CNG Fuel Fill Box Schematic
(Full View)**

