Hybrid Yard Hostler Demonstration and Commercialization Project

Final Report

March 2011

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The Port of Long Beach
The Port of Los Angeles

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Three diesel-battery-electric hybrid yard hostlers were developed, demonstrated and compared to conventional diesel yard hostlers. Both in-use and chassis dynamometer testing was conducted. The hybrid yard hostlers were able to perform all the tasks required of a yard hostler in real world use, and were well accepted by the drivers. Fuel economy and emissions benefits were evaluated, but a difference in the mechanical specifications of the vehicles limited comparability. Based on all the evaluations and analyses conducted, the hybrid system is estimated to deliver 12% to 18% improvement in fuel economy. Further development of the hybrid drive system could potentially improve fuel economy and emissions reductions. The business case analysis for large-scale use of hybrid yard hostlers showed that incentives of approximately $18,000 per vehicle would be needed to ensure payback of the hybrid system.

This report was prepared by CALSTART staff for the Port of Long Beach (POLB). The primary authors were Patrick Chen and Michael Ippoliti with Allyson Teramoto of The Port of Long Beach providing oversight and editorial review.

CALSTART would also like to thank the following individuals for providing assistance during the project and/or information which contributed to the final report.

Port of Long Beach
- Ms. Allyson Teramoto
- Ms. Heather Tomley
- Mr. Jonard Talamayan

Port of Los Angeles
- Mr. Kevin Maggay

Kalmar Industries
- Mr. Mikko Vuojolainen
- Mr. Jay Hayes
- Mr. Dean Newton

Long Beach Container Terminal, Inc.
- Mr. Kevin Hayes
- Mr. Hal Burkey
- Mr. Robert Nuthall

Tetra Tech
- Dr. Eddy Huang
- Ms. Tunisia Hardy

TIAX, LLC
- Mr. Patrick Couch
- Mr. Jon Leonard

US Hybrid
- Dr. Abas Goodarzi
- Dr. Don Kang
- Mr. Jeff Kohne
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University of California, Riverside
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TABLE OF CONTENTS

APPENDICES

TABLES

FIGURES

ACRONYMS AND ABBREVIATIONS

AB118	California Assembly Bill 118
AC	alternating current
A/C	air conditioning
AQIP	Air Quality Improvement Program
avg	average
CAAP	Clean Air Action Plan
CAN	controller area network
CARB	California Air Resources Board
CHE	cargo handling equipment
CO	carbon monoxide
CO_2	carbon dioxide
DC	direct current
DERA	Diesel Emissions Reduction Act
DPM	diesel particulate matter
ECM	electronic control module
EGR	exhaust gas recirculation
EPA	United States Environmental Protection Agency
F	Fahrenheit
g	grams
g/bhp-hr	grams per break horsepower-hour
g/cycle	grams per cycle
gal/hr	gallons per hour
GPS	global positioning system
HCU	hybrid control unit
hp	horsepower
HVAC	heating, ventilating, air conditioning
HVIP	Hybrid Truck and Bus Voucher Program
HYH	hybrid yard hostler
IGBT	Insulated gate bipolar transistor
kg	kilograms
kPa	kilopascal
kW	kilowatt
LBCT	Long Beach Container Terminal, Inc.
L	liter
lbs	pounds
Li-ion	lithium-ion
LCA	lifecycle cost analysis
NO_x	nitrogen oxides
Nm	Newton-meter (Torque)
mi	mile
mph	miles per hour
OEM	original equipment manufacturer
PM	particulate matter
POLA	Port of Los Angeles
POLB	Port of Long Beach
PTHS	post transmission hybrid system
SO_x	sulfur oxides
SOC	state of charge
stdev	standard deviation

ACRONYMS AND ABBREVIATIONS (cont.)

RFI	request for information
RFP	request for proposals
RPM	revolutions per minute
THC	total hydrocarbons
UTR	utility tractor rig
UCR	University of California, Bourns College of Engineering, Center for Environmental Research and Technology
WVU	West Virginia University Center for Alternative Fuels, Engines, and Emissions

EXECUTIVE SUMMARY

Yard hostlers (also referred to as terminal tractors, yard trucks, utility tractor rigs, yard goats, yard hustlers and yard tractors) are off-road truck tractors designed for moving cargo containers. Yard hostlers are the most common type of cargo handling equipment used at container terminals, and comprise 50% of the total CHE population at the ports of Long Beach (POLB) and Los Angeles (POLA)[1,2].The ports' 2009 air emissions inventories also showed that yard hostlers were responsible for approximately 40% of NO_x emissions and about 50% of particulate matter (PM) emissions from all CHE at container terminals at the two ports.

While hybrid technology has been successfully demonstrated in on-road applications, off-road terminal tractors operating in demanding marine terminal environments are subject to different performance requirements. It was anticipated that the hybrid drive systems would at least partially offset the increased vehicle cost via reduced fuel consumption, paving the way for widespread acceptance of hybrid technology for port applications.

On September 2006 the United States Environmental Protection Agency's (EPA) West Coast Diesel Collaborative presented a grant to the Port of Long Beach to fund the design and development of diesel-electric hybrid technology for the yard hostlers. The project team, lead by POLB, includes POLA, Long Beach Container Terminal Inc. (LBCT), Kalmar Industries, and US Hybrid. U.S. Hybrid was selected from a competitive bid process to design and develop the hybrid drive system. West Virginia University developed the duty cycle for yard hostlers at ports to be used during emissions testing. CALSTART was contracted by POLB to provide technical management of the project.

The goals of the demonstration project were to assess the performance and emissions of hybrid yard hostlers during in-use operations at a port container terminal. Three hybrid yard hostlers were put into service at LBCT at POLB for a period of 6 months performing ship, rail, and dock work. Emissions testing on a hybrid yard hostler and a baseline conventional diesel yard hostler were performed by the University of California, Riverside, Bourns College of Engineering Center for Environmental Research and Testing (UCR). In conjunction with performance and emissions testing, a high-level analysis of the hybrid yard hostler business case was also performed.

Table ES-1 summarizes the specifications of the test vehicles and the container terminal operation each vehicle was assigned during the performance test.

[1] Port of Long Beach 2009 Air Emissions Inventory (Hwww.polb.com/environment/airH/emissions.asp)
[2] Port of Los Angeles 2009 Air Emissions Inventory (www.portoflosangeles.org/environment/studies_reports.asp)

Table ES-1. Yard Hostler Test Fleet

Vehicle ID	Engine Model Year	Engine Certification Standard	Engine Make/Model	Aftertreatment Device	Operation (Ship, Rail, or Yard Work)
Hybrid					
HYH 01	2009	ISB07 (On-Road)	Cummins 6.7L 6CT, 200 hp	Diesel Particulate Filter	Ship
HYH 02	2009	ISB07 (On-Road)	Cummins 6.7L 6CT, 200 hp	Diesel Particulate Filter	Rail
HYH 03	2009	ISB07 (On-Road)	Cummins 6.7L 6CT, 200 hp	Diesel Particulate Filter	Yard
Diesel					
UTR 180	2008	ISB07 (On-Road)	Cummins 6.7L 6CT, 240 hp	Diesel Particulate Filter	Ship
UTR 159	2008	ISB07 (On-Road)	Cummins 6.7L 6CT, 240 hp	Diesel Particulate Filter	Rail
UTR 172	2008	ISB07 (On-Road)	Cummins 6.7L 6CT, 240 hp	Diesel Particulate Filter	Yard

The hybrid yard hostlers' fuel economy was evaluated by comparing the average fuel economy for the hybrid yard hostler and the diesel yard hostlers during in-use operations during the six-month performance testing period. Fueling log sheets were manually completed each day by LBCT refueling staff. For the hybrid yard hostlers performing ship work, the vehicles showed no change in fuel consumption. The hybrid yard hostlers performing rail work consumed approximately 0.28 gallons more diesel fuel per hour compared to the diesel yard hostler working the same duty cycle, equating to a 14% increase in fuel use over the diesel yard hostler. The hybrid yard hostlers performing dock work showed a slight improvement over its diesel-fueled counterpart, demonstrating a fuel economy of 2.31 gallons per hour (gal/hr) compared to 2.40 gal/hr for the baseline diesel vehicles.

As a result of the low fuel economy performance of the hybrid yard hostlers, an investigation of potential causes of the low fuel economy revealed a difference in the rear axle differential ratios between the hybrid and diesel vehicles. The higher rear differential ratio on the hybrid yard hostler requires the engine to operate at about 20% increased revolutions per minute (RPM) and at lower torque for the same amount of work performed by the diesel yard hostlers. Based on a modeling analysis performed by US Hybrid, the hybrid's increased fuel consumption was likely due to their higher rear differential ratio.

Operator Acceptance was evaluated during in-use operations by using surveys completed by drivers. The survey questions covered key vehicle performance areas and other characteristics of the vehicle that would directly affect the driver. Due to the subjective nature of driver impressions, a rating scheme of "better," "same" or "worse" was used. Based on the driver surveys, 100% of the drivers found the hybrid yard hostlers to have the same or better performance than traditional diesel yard hostlers with 74.5% rating them as superior in general. A majority of the additional comments provided by the drivers of the hybrid yard hostlers were positive.

The only feature of the hybrid yard hostlers frequently rated as worse than diesel yard hostlers was acceleration, with 30.4% of respondents rating it as "worse." However, this is a deliberate design function implemented by US Hybrid. In conversations with US Hybrid, it was found that the limiting of

the acceleration was done to provide the driver with a safe and smoother ride only when the vehicle is operating without a load.

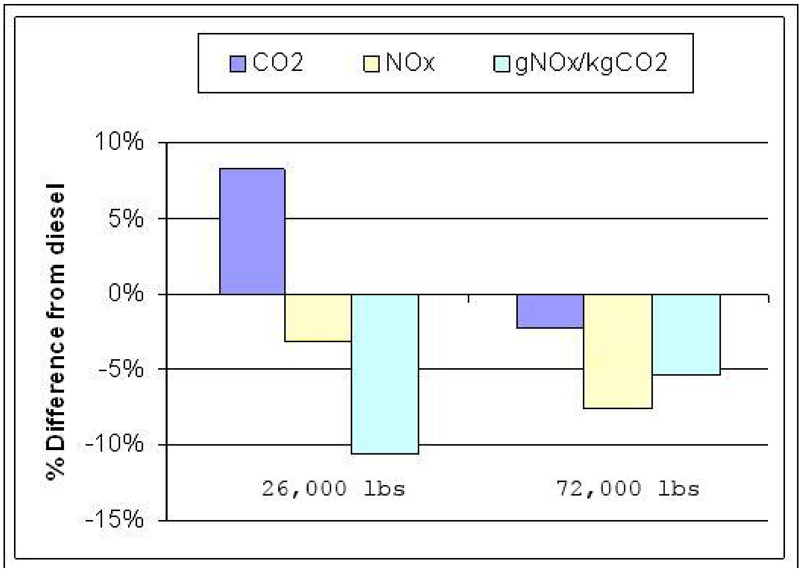
To assess the reliability, maintainability and serviceability of the hybrid yard hostlers compared to typical diesel yard hostlers, LBCT maintenance staff tracked vehicle availability as well as maintenance and service events. During the six-month performance test period, the three hybrid yard hostlers were available on average 88% of the time, whereas the average availability of the three diesel yard hostlers over the six-month performance testing period was 100% as no maintenance was required during the testing period (see Table 6). Although the hybrid drive system is designed to allow full operation in diesel mode in case of hybrid system failure, hybrid yard hostler availability refers to hybrid yard hostlers operating in hybrid mode only.

LBCT mechanics were also asked to provide subjective feedback on various service and maintenance aspects of the hybrid yard hostlers compared to diesel yard hostlers. While no maintenance or service was performed by LBCT maintenance staff, the survey was completed based on their experience and understanding of the new hybrid yard hostlers. LBCT maintenance staff felt their experience with the vehicles was good but due to the prototype nature of the vehicles, addressing issues associated with the hybrid system required U.S. Hybrid's dedicated response.

A transient duty cycle, specifically developed for yard hostlers by West Virginia University, was used to conduct emissions testing on UCR's heavy-duty chassis dynamometer. Emissions were measured with UCR's Mobile Emission Lab and state of battery charge monitored while the vehicle followed the transient cycle. Analysis compared the results for both the case of a light load (26,000 lbs) and a heavy load (72,000 lbs) for hybrid and diesel yard tractors.

During preparation of the hybrid yard hostlers for testing on the chassis dynamometer, UCR learned that the prototype hybrid yard hostlers were limited by U.S. Hybrid to a maximum speed of 18.5 miles per hour (mph), while the peak speed for medium-heavy and heavy-heavy loads were 27 mph and 23 mph, respectively. Therefore, testing the supplied transient cycle developed by West Virginia University for the project had to be modified at a peak speed of 18.5 mph. Both the hybrid and diesel vehicles were tested on the same modified cycle and the results at two different loads are shown in the figure below. The results indicate that at low loads the hybrid consumed about 7% more fuel and at high loads the hybrid saved about 3% fuel. NOx emissions were reduced 3% and 8% at the low and high loads, respectively. State of battery charge did not change significantly during the testing.

Figure ES-1. Comparative Emissions Factors for Various Yard Tractor Engines



The chassis dynamometer testing indicated that emission rates generated by the hybrid yard hostler using the modified transient cycle were similar to the emission rates generated using the original transient cycle developed by West Virginia University. The fuel economy of the hybrid yard hostler was only better than the conventional diesel at higher loads. The hybrid failed to achieve the expected fuel savings of about 30%, which can potentially be attributed to the difference in rear-end gear ratio, or to the small state-of-charge changes during the test cycle.

After the initial emissions test showed the hybrid yard hostler not meeting original estimates for fuel economy and emissions, a second chassis dynamometer test to evaluate the hybrid vehicle's fuel economy was commissioned by US Hybrid after additional changes were made to the vehicles. TableES-2 summarizes the comparison of fuel economy results from the initial and second chassis dynamometer tests. Table ES-3 summarizes the comparison of fuel economy results for the hybrid vehicle operated in hybrid mode and full diesel mode during the second chassis dynamometer test.

Table ES-2. Comparison of Fuel Economy – Hybrid Yard Hostler Operating in Hybrid Mode (Initial and Second Chassis Dynamometer Test)

Load	Fuel Consumed		Improvement from Initial Test
	Initial Test	Second Test	
	(liters)		
26,000 lbs.	1.667	1.370	**17.8%**
72, 000 lbs.	2.497	2.323	**7%**

Table ES-3. Comparison of Fuel Economy - Hybrid Yard Hostler Operating in Diesel and Hybrid Mode (Second Chassis Dynamometer Test)

Load	Hybrid Yard Hostler Operation Mode	Fuel Consumed (liters)	Improvement between Diesel and Hybrid modes
26,000 lbs.	Diesel	1.665	**17.7%**
	Hybrid	1.370	
72, 000 lbs.	Diesel	2.650	**12.3%**
	Hybrid	2.323	

A business case analysis for large-scale use of hybrid yard hostlers was performed based on data collected during the demonstration period. The business case analysis was based on the chassis dynamometer testing results rather than the in-use fuel economy data due to the difference in rear axle differential ratios between the hybrid and diesel vehicles. With the current pricing and assumptions used in the life cycle cost analysis, incentives are necessary to make the business case viable, given the levels of performance delivered by the prototypes. At production volumes of 1,000 units, about $18,000 per vehicle in incentives or buy-down would be needed to make the business case, based on the assumptions used in the analysis. However, other systems have come to market with very similar performance and costs, so the assumptions used in this report may be overly conservative.

1 INTRODUCTION

Yard hostlers (also referred to as terminal tractors, yard trucks, utility tractor rigs, yard goats, yard hustlers and yard tractors) are off-road truck tractors designed for moving cargo containers. In a typical operation, a container is loaded from an ocean-going vessel onto the yard hostler's trailer by a ship-to-shore crane. The yard hostler then drives (tows) the trailer with the container to a destination within the terminal where the container is unloaded by another piece of cargo handling equipment (CHE) such as a top-pick, side-pick or rubber-tired gantry (RTG) crane. Yard hostlers are the most common type of cargo handling equipment used at container terminals, and comprise 50% of the total CHE population at the ports of Long Beach and Los Angeles[3,4]. The ports' 2009 air emissions inventories also showed that yard hostlers were responsible for approximately 40% of NO_x emissions and about 50% of particulate matter (PM) emissions from all CHE at container terminals at the two ports.

The unique duty cycle, or "stop and go" operation of yard hostlers in port container terminals makes them ideal candidates for a hybrid system coupled with the cleanest available diesel engine to potentially achieve an even higher level of emissions and fuel economy benefits.

In a conventional diesel yard hostler configuration, idling involves the sustained inefficient operation of the internal combustion engine. In a vehicle equipped with a diesel-electric hybrid drive system, the internal combustion engine can potentially be shut down during normal vehicle idling times with the vehicle operated in an all-electric mode of operation. Regenerative braking is an additional feature of hybrid systems that allows energy normally lost during mechanical braking to be captured by the hybrid drive system and used to recharge the on-board energy storage device, thereby increasing fuel efficiency and lower emissions.

1.1 Background

On November 20, 2006, the Boards of Harbor Commissioners of the Port of Long Beach (POLB) and Port of Los Angeles (POLA) adopted the Final 2006 San Pedro Bay Ports Clean Air Action Plan (CAAP)[5]. The CAAP is a joint planning document for the two ports, developed in cooperation with the United States Environmental Protection Agency Region 9 (EPA), the California Air Resources Board (CARB), and the South Coast Air Quality Management District (SCAQMD). The CAAP is intended to be a "living" document that is periodically reviewed and updated. The original CAAP focused on the near-term, five-year planning window between 2006 and 2011, and targeted significant reductions in diesel particulate matter (DPM), nitrogen oxides (NO_x), and sulfur oxides (SO_x). DPM is of particular concern as it is linked to cancer and other serious health effects. NO_x and SO_x emissions contribute to the region's ozone smog and fine particulate matter levels, and are also important health concerns.

Since the CAAP was adopted in November 2006, significant achievements have been made by the ports, consistent with the goals of the original plan. An update to the CAAP (CAAP Update) was approved by the ports of Long Beach and Los Angeles on November 22, 2010. The CAAP Update identifies near-term planning goals through 2014, a health risk reduction goal for 2020, and emissions reduction goals for the years 2014 and 2023.[6]

A significant initiative of the CAAP is the Technology Advancement Program (TAP). The ports have allocated $1.5 million a year to support the development and demonstration of new technologies and strategies that will ultimately reduce DPM, NO_x, and SO_x. The Hybrid Yard Hostler Demonstration and

[3] Port of Long Beach 2009 Air Emissions Inventory (Hwww.polb.com/environment/airH/emissions.asp)

[4] Port of Los Angeles 2009 Air Emissions Inventory (www.portoflosangeles.org/environment/studies_reports.asp)

[5] San Pedro Bay Ports – Clean Air Action Plan (http://www.cleanairactionplan.org)

[6] 2010 San Pedro Bay Ports Clean Air Action Plan Update (www.cleanairactionplan.org/reports/documents.asp)

Commercialization Project is one of several projects funded under the TAP, and supports CAAP goals to significantly reduce air pollutants from port-related operations and health risk to surrounding communities.

2 PROJECT OVERVIEW

While hybrid technology has been successfully demonstrated in on-road applications, off-road terminal tractors operating in demanding marine terminal environments are subject to different performance requirements. It was anticipated that the hybrid drive systems would at least partially offset the increased vehicle cost via reduced fuel consumption, thus paving the way to widespread acceptance of hybrid technology for this application.

On September 2, 2006, the EPA's West Coast Diesel Collaborative presented a $300,000 grant to the Port of Long Beach to fund the design and development of the diesel-electric hybrid technology for the yard hostlers. The project team, lead by POLB, includes POLA, Long Beach Container Terminal Inc. (LBCT), Kalmar Industries, and US Hybrid. LBCT volunteered to test the hybrid yard hostlers in the container terminal operations during the six-month performance test period. The yard hostlers used in the demonstration were leased by the ports from original equipment manufacturer (OEM) Kalmar Industries, who provided their technical expertise to assist with the specification and integration of the hybrid drive systems into Kalmar's existing Ottawa 4x2 Terminal Tractor product line. US Hybrid was selected from a competitive bid process to design and develop the hybrid drive system, and integrate the hybrid drive systems into three Kalmar Ottawa 4x2 yard hostlers. CALSTART was contracted by POLB to provide technical management of the project.

The goals of the demonstrations were to:

- Evaluate the in-use performance of the hybrid terminal tractor compared to baseline diesel terminal tractors in a marine terminal environment. This evaluation included fuel consumption, vehicle performance, operator acceptance, reliability, maintenance and service;

- Quantify and compare the emissions of hybrid vs. baseline diesel yard hostlers using a port terminal tractor duty cycle, and

- Assess the business case for large-scale fleet use of hybrid terminal tractors including life-cycle cost analysis (LCA), potential market size, identification of any issues for commercialization and general recommendations.

3 PROJECT IMPLEMENTATION

The Hybrid Yard Hostler Demonstration and Commercialization Project is a technology demonstration and evaluation program aimed at reducing emissions in marine terminal environments. The project was divided into three phases:

- Phase I - Hybrid vehicle specification development, hybrid drive system supplier selection, vehicle procurement and vehicle prototype integration were performed.
- Phase 2 - The prototype hybrid yard hostlers were put into service at a container terminal for a total of six months. Data were collected on the performance of the hybrid yard hostlers compared to a group of baseline diesel yard hostlers. Emissions tests were also performed during Phase 2.
- Phase 3 - A high-level analysis of the hybrid yard hostler business case was performed.

3.1 Vehicle Prototype Development

Yard hostlers presented a new application for a proven technology that could potentially provide a higher level of emissions and fuel economy benefits due to the unique characteristics of the yard hostler duty cycle.

3.1.1 Hybrid Yard Hostler Vehicle Specifications

At the time the project was initiated, there were no hybrid yard hostlers commercially available. The project team, led by Calstart, developed the hybrid yard hostler vehicle specifications based on performance requirements, such as fuel economy improvement and emissions reductions. The project did not specify particular types of hybrid technology or configuration, which allowed for a range of hybrid options to be considered. A key component of the specification was the ability to integrate potential hybrid drive systems with the existing Kalmar terminal tractor chassis. The project team ensured that all requirements for interfacing between the hybrid drive system and the yard hostler were specified.

The vehicle specifications for the hybrid yard hostlers were designed on a Kalmar Ottawa 4X2 Terminal Tractor platform, and included the following:

- Cummins ISB07, 200 horsepower engine
- Allison MY09 3000RDS (1-4 speed) electronic transmission
- Meritor FF-961 front axle with 16.5” brakes
- Sisu SRDP 12.28:1 ratio, rated at 66,150 lbs at under 15 mph.
- 17” lift height, with 5” hydraulic cylinders, 60,000 lb. lift rating
- Holland FW-35 fifth wheel plate rated at 70,000 lbs.

The hybrid yard hostler specifications were included in the Port of Long Beach’s Request for Information to potential hybrid drive system suppliers.

3.1.2 Hybrid Drive System Suppliers Request for Information/Request for Proposals

In August 2007, the Port of Long Beach released a Request for Information (RFI) soliciting interest from potential hybrid drive system suppliers to supply and integrate hybrid drive systems into Kalmar’s Ottawa 4X2 line of terminal tractors. The RFI included specifications for the prototype hybrid yard hostlers as developed by Kalmar and the project team. The RFI was sent to 41 companies known to develop hybrid drive systems through their participation in CALSTART’s Hybrid Truck Users Forum. The Port received 16 responses to the RFI. Responses to the RFI included various questions and comments from potential hybrid drive system suppliers which were used to develop the subsequent Request for Proposals (RFP) issued to hybrid drive system suppliers. The RFI is provided in Appendix A.

The Port of Long Beach’s grant agreement with the EPA required that a hybrid drive system supplier be selected through a competitive bid process. A Request for Proposals (RFP) was developed by the project team based on the needs for the demonstration project and the responses to the RFI. In February 2008, the Port of Long Beach released the RFP to hybrid drive system suppliers. The RFP included detailed project information, vehicle specifications, and bidding instructions. The RFP for the project was technology and fuel neutral, and all proposals were considered regardless of the hybrid architecture, technology or supporting infrastructure proposed. A total of 4 responses were received. Hybrid technologies proposed included hydraulic hybrid, series electric hybrid, and parallel electric hybrid, and all battery/full electric. The RFP is provided in Appendix B.

A committee consisting of representatives from the ports, CALSTART, and Kalmar reviewed the proposals received and rated them based on the technology's estimated emissions reductions and fuel reductions, business case proposal, as well as the schedule and cost to design and develop the hybrid drive system. The qualifications of the proposed supplier's team were also considered.

After an extensive proposal review process, US Hybrid Corporation, based in Torrance, California was selected in June 2008 as the hybrid drive system supplier for the project.

3.2 US Hybrid Post Transmission Hybrid System

The selected hybrid drive system supplier, US Hybrid, designed and developed a diesel-electric parallel hybrid, post transmission configuration with electric accessories and engine shut down for the hybrid yard hostler application. US Hybrid's post transmission system integrates the electric drive system behind the vehicle's transmission and is designed to be installed as a "drop-in" component to an OEM production line, or retrofitted in post-production vehicles. US Hybrid's Post Transmission Hybrid System "PTHS" utilizes most of the existing OEM components and does not require re-certification. In addition, it was hypothesized that the post transmission offers a fuel efficient hybrid configuration for the port application, while being applicable to support other port vehicles and applications such as the distribution trucks with much higher average load power demand.

The hybrid powertrain utilizes a high performance permanent magnet (1150 Nm, 110kW), insulated gate bipolar transistor (IGBT) inverter with Digital Controllers, CAN diagnostic capabilities, Li-Ion Batteries, and safety protection system. The powertrain also includes electric driven OEM hydraulic pump and air-compressor as well as the existing Cummins 2007 OEM engine and after treatment with the OEM Allison 3000 transmission. US Hybrid also integrated their proprietary hybrid control unit (HCU) vehicle controller based on the J1939 CAN interface. The controller was designed to contain all the components necessary to control the powering of a vehicle in a single package. The main component is an inverter, which converts DC electricity to AC electricity. US Hybrid developed controllers for the hydraulic and air system, 12V DC-to-DC converter for vehicle auxiliary loads. This approach simplifies the vehicle wiring harness and increases system reliability. Using US Hybrid's proprietary software package, vehicle interfaces and control parameters can be programmed in-vehicle, which was used throughout the test phase to alter vehicle configuration for optimization of vehicle operations. Real-time vehicle performance parameters can also be monitored and collected. The complete drive system is air cooled to minimize the vehicle packaging and maintenance. Specifications of the hybrid yard hostler vehicles are provided in Appendix C.

3.3 Yard Hostler Duty Cycle Development

Yard Hostler activities in marine container terminals generally fall into three main categories: ship work, rail work, and dock work. Ship work involves loading and unloading of containers onto and from cargo ships. Rail work entails loading and unloading containers to and from cargo trains, while dock work (also called yard work) consists of moving containers within a terminal yard (e.g., consolidation of containers).

At any given time during the operation of a yard hostler, the physical load being pulled by the vehicle can vary depending on the weights of the trailer and container connected to the tractor. For the purposes of this project, it is necessary to know both the vehicle speed and physical load (i.e., weight) of the trailer and container being pulled by the yard hostler, which has an effect on how "hard" the engine has to work, and in turn, affects emissions and fuel consumption.

In order to compare the relative emissions and fuel economy of hybrid yard hostlers and diesel yard hostlers on a chassis dynamometer, researchers from the Center for Alternative Fuels, Engines, and Emissions at West Virginia University (WVU) developed a duty cycle representative of actual in-use

activity of yard hostlers working in terminal operations using data logging equipment installed on yard hostlers at LBCT. Data from the yard hostlers was collected in 2008 over a period of five days.

The three hybrid yard hostlers were equipped with Race Technologies DL1 electronic logging devices that recorded the vehicles 'positional data using a global positioning system (GPS). In parallel with the GPS data, external inputs included a driveshaft speed sensor and a sensor to record the state of the ignition system (on/off). Vehicle, trailer and average container load were manually recorded. Manual logs identified the activity, vehicle, trailer type, and container presence and load status. For this effort, data were logged for a total duration of 54 hours and 4 minutes during which time the vehicles traveled a distance of 288 miles.

WVU utilized a technique to generate representative driving cycles from in-use activity data where the driving cycles are constructed using actual vehicle speed-time data. This technique involved logging speed-time and idling data from yard hostlers as they carried out their daily activities. As a result of the significant variability in physical load, or weight of the yard hostlers during operation and the constraints of typical heavy-duty chassis dynamometers, the yard hostler duty cycle was divided into two sub-cycles that corresponded to the portion of the duty cycle associated with the operation of the yard hostler in one of two weight categories: "medium-heavy duty" and "heavy-heavy duty". Based on an analysis of the combined vehicle, trailer and container weights of all potential tractor/trailer combinations, average weights for each category were calculated based on the actual data as the number of weighted trips (in pounds [lbs.]) in each category divided by the total number of trips in each category. As a result, the average weight for a yard hostler in the medium-heavy duty category is 26,209 lbs (11,888 kilograms [kg]), and the in heavy-heavy duty category is 72,393 lbs (32,837 kg).

Driving cycles were constructed using data from actual percentage of time spent in each weight, category, and actual speed-time data gathered from the data loggers on the vehicles. The data were then broken into microtrips with each microtrip composed of a period of idle followed by the vehicle travelling some distance and returning to idle. Each microtrip was then classified according to the type of activity the vehicle was performing (eg. ship work, dock work, or rail work) and the vehicle loading. Groups of driving cycles representing ship related activity at light-medium and medium-heavy loading and rail related activity at light-medium and medium-heavy loading were then generated by randomly combining microtrips from respective data sets. These individual driving cycles were then compared to their parent datasets using statistical metrics and a minimization function to choose the most representative driving cycle from each group.

The yard hostler duty cycle study conducted by WVU is provided in Appendix D.

3.4 Performance Test

An important element of the demonstration project was to determine the capability and reliability of the hybrid terminal tractors in real-life settings and duty cycles at port terminals. A test program was developed to evaluate the vehicles' fuel economy, operator acceptance, reliability, and maintainability.

Evaluations of the fuel consumption and operational characteristics of the hybrid vehicles are necessary to understand the business case for expanded use of hybrid terminal tractors in marine terminals and other terminal tractor applications such as intermodal rail yards and distribution centers. Performance testing was conducted between June and November 2010. Details of the performance test program are described below.

3.4.1 Test Vehicles and Operations

The test vehicles used for the performance testing and evaluation were comprised of three prototype diesel-electric hybrid yard hostlers and three conventional diesel-fuel yard hostlers from LBCT's fleet that served as the baseline comparison group.

The baseline diesel yard hostlers consisted of Kalmar Ottawa Commando 4x2 terminal tractors with 2008 Cummins ISB-07 on-road engines. The diesel-fueled engines were also equipped with after treatment devices to control particulate matter emissions. The diesel yard hostlers were selected because they are representative of the most common engine configurations in LBCT's yard hostler fleet.

The hybrid drive systems designed and developed by US Hybrid were integrated into three Kalmar Ottawa 4x2 yard hostlers leased by the ports at US Hybrid's facility in Torrance, California. As integration of the hybrid drive systems into the vehicles was completed, they were transported to LBCT, where the maintenance staff prepared the vehicles for terminal operations. The first hybrid yard hostler was delivered to LBCT on May 28, 2010, the second on July 7, 2010, and the third on July 27, 2010. Each of the three yard hostlers was assigned to a specific operation, or duty (i.e., ship work, dock work, or rail work).

Yard hostlers at the ports are typically driven by International Longshoreman Worker Union (ILWU) personnel contracted by the terminal operators. Yard hostlers typically work two eight-hour shifts per day, seven days a week; though not all yard hostler operations (ship, dock, rail) are performed each day or each shift. ILWU drivers that regularly work at LBCT were assigned to operate the hybrid yard hostlers.

Table 1 summarizes the test vehicle specifications and the operation each vehicle was assigned during the performance test.

Table 1: Yard Hostler Test Fleet

Vehicle ID	Engine Model Year	Engine Certification Standard	Engine Make/Model	Aftertreatment Device	Operation (Ship, Rail, or Yard Work)
Hybrid					
HYH 01	2009	ISB07 (On-Road)	Cummins 6.7L 6CT, 200 hp	Diesel Particulate Filter	Ship
HYH 02	2009	ISB07 (On-Road)	Cummins 6.7L 6CT, 200 hp	Diesel Particulate Filter	Rail
HYH 03	2009	ISB07 (On-Road)	Cummins 6.7L 6CT, 200 hp	Diesel Particulate Filter	Yard
Diesel					
UTR 180	2008	ISB07 (On-Road)	Cummins 6.7L 6CT, 240 hp	Diesel Particulate Filter	Ship
UTR 159	2008	ISB07 (On-Road)	Cummins 6.7L 6CT, 240 hp	Diesel Particulate Filter	Rail
UTR 172	2008	ISB07 (On-Road)	Cummins 6.7L 6CT, 240 hp	Diesel Particulate Filter	Yard

Fuel Economy Testing

To compare the average fuel economy for the hybrid yard hostler to diesel yard hostlers during in-use operations, daily fuel usage and hours of engine operation for the hybrid yard hostlers and the baseline diesel yard hostlers were evaluated during the six-month performance testing period using fueling log

sheets manually completed each day by LBCT refueling staff. The amount of fuel used to fill up the fuel tank and the operating hours were recorded from an on-board readout display on the vehicle. CALSTART performed the analysis of all raw data collected by LBCT with assistance from US Hybrid.

Operator Acceptance

To assess the drivers' impressions of the performance of the hybrid yard hostlers during in-use operations compared to typical diesel yard hostlers, written surveys were distributed to and completed by drivers of the hybrid yard hostlers. The surveys were given to the LBCT drivers each time they operated the hybrid vehicles.

The one-page hybrid yard hostler driver survey used for this demonstration was similar to the driver survey previously developed for the liquefied natural gas yard hostler project conducted by the Port of Long Beach at LBCT in 2007. The survey questions covered key vehicle performance areas and other vehicle characteristics that would directly affect the driver. The survey contained a total of 14 questions and a section for drivers to record additional comments. Due to the subjective nature of driver impressions, a simple, relative rating scheme of "better," "same" or "worse" was used to compare hybrid yard hostler performance characteristics to those of a typical diesel yard hostler. The driver survey is included in Appendix E.

The specific areas covered by the Hybrid Yard Hostler Driver Survey questions included:

- Maneuverability
- Pulling power
- Acceleration
- Shifting
- Steering
- In-cab visibility
- Ride comfort
- In-cab controls
- Braking
- Interior noise level
- Exterior noise level
- HVAC system
- Cab entry and exit
- Overall vehicle rating
- Additional comments

Maintenance and Serviceability

To assess the reliability, service and maintenance of the hybrid yard hostlers compared to typical diesel yard hostlers, LBCT mechanics were asked to provide subjective feedback on various service and maintenance aspects of the hybrid yard hostlers compared to diesel yard hostlers. Vehicle availability served as the primary metric to evaluate hybrid yard hostler reliability. Vehicle availability refers to the percentage of days that a vehicle was potentially available for use during the performance testing period, regardless of whether the vehicle was actually used on a particular day. LBCT maintenance staff tracked vehicle availability as well as maintenance and service events for the hybrid and baseline diesel yard hostlers.

Vehicle Availability

Vehicle availability was defined as the percentage of full days each month that a particular vehicle was available for operations. Vehicles undergoing routine maintenance or being repaired were considered "unavailable" until they were put back into service. Please note that yard hostlers, both hybrid and

diesel, which were removed from service for emissions testing at CE-CERT were not included in the availability data for the specific days it was out of service for testing. Vehicle availability was tracked via a combination of methods including:

- Notes in the hybrid and diesel fueling logs;
- US Hybrid service records;
- LBCT vehicle maintenance and service records; and
- E-mails and discussions with LBCT maintenance and US Hybrid staff.

Vehicle availability was determined by cross-referencing the above information for each vehicle in the test group on a monthly basis.

Mechanics Survey

To evaluate the maintainability and serviceability of the hybrid vehicles compared to typical diesel yard hostlers, a survey was given to LBCT mechanics assigned to the yard hostlers at the end of the demonstration period. The survey contained a total of seven questions and a space for mechanics to record additional comments. For subjective questions, a rating scheme of 1 to 5 was used, 1 being "unacceptable" and 5 being "excellent". A copy of the survey form distributed to mechanics is provided in Appendix F.

In addition, LBCT mechanics assigned to the hybrid yard hostlers were interviewed at the end of the performance testing period to solicit their feedback regarding maintainability and serviceability of the hybrid yard hostlers compared to diesel yard hostlers. The specific areas covered by the survey included:

- Start-up problems (i.e. problems noted during the early phases of deployment)
- Hybrid systems and component training
- Design for maintainability
- Design for serviceability
- Quality of manufacturer support (OEM and Hybrid Drive System)
- Trends in service actions over the performance testing period
- Additional comments

3.5 Emissions Testing

Emissions testing and analysis was performed at the University of California, Riverside's Bourns College of Engineering, Center for Environmental Research and Technology (UCR) in Riverside, California and was based on the transient cycle developed for port yard hostlers by WVU and used on the UCR heavy-duty chassis dynamometer. Emissions were measured with UCR's Mobile Emission Lab and state of battery charge monitored while the vehicle followed the transient cycle. Analysis compared the results for both the low load and heavy load tests. A summary of the emissions test results are provided in Section 5.

4 PERFORMANCE TEST RESULTS

This section describes the outcome from individual elements of the test program as stated above. A summary of test results and any conclusions that may be reasonably drawn from the data are presented in this section.

4.1 Fuel Economy

Fuel economy calculations were based on the assumption that all average monthly fuel economies are weighted equally. In practice, the engine hours and fuel consumption varied considerably from vehicle to vehicle as well as from month to month. Independent of fuel type, fuel consumption is affected significantly by the actual duty cycle and engine loads experienced by the vehicle as well as the operator's driving style.

For the hybrid yard hostlers performing ship work (HYH 01 and Diesel UTR 180), the vehicles showed no difference in fuel consumption as both vehicles showed an average fuel consumption of 1.90 gallons per hour (gal/hr). The hybrid yard hostlers performing rail work consumed approximately 0.28 gallons more diesel fuel per hour compared to the diesel yard hostler working the same duty cycle, equating to a 14% increase in fuel use over the diesel yard hostler. The hybrid yard hostler performing dock work showed a 3.75% improvement over its diesel-fueled counterpart, demonstrating a fuel economy of 2.31 gal/hr, while the diesel yard hostler also working at the dock showed slightly increased fuel use at 2.40 gal/hr. However, it should be noted that the increase in fuel consumption of the hybrid was considered to be due to the vehicles having different rear differential ratios, which is discussed in detail below.

A summary of the average monthly fuel economy in gallons per engine operating hour (gal/hr) for all test vehicles is shown in Table 2 below. A summary of the gallons of fuel consumed per month for all test vehicles is shown in Table 3. A summary of engine hours per month for all test vehicles is shown in Table 4.

Table 2. Summary of Average Yard Hostler Fuel Economy by Month (gal/hr)

Vehicle ID	June 2010	July 2010	August 2010	Sept 2010	Oct 2010	Nov 2010	*Average*
Hybrid							
HYH 01	1.76	NA	1.78	1.75	2.00	2.20	*1.90*
HYH 02	NA	2.04	2.36	2.62	2.04	2.29	*2.27*
HYH 03	NA	NA	2.38	NA	2.36	2.20	*2.31*
Diesel							
UTR 180	1.67	NA	1.99	1.83	1.99	2.01	*1.90*
UTR 159	NA	2.05	2.04	1.92	1.94	1.68	*1.99*
UTR 172	NA	NA	2.3	2.45	2.50	2.63	*2.40*

Notes

NA – Data not available

1. HYH 02 operated in diesel only mode from July 30 to September 18.
2. HYH 03 operated in diesel only mode from August 29 to August 31.

Table 3. Summary of Yard Hostler Fuel Consumption Per Month (Gallons)

Vehicle ID	June 2010	July 2010	August 2010	Sept 2010	Oct 2010	Nov 2010
Hybrid						
HYH 01	313.6	NA	98	145.1	176.70	13.2
HYH 02	NA	130.4	190.9	131	51.1	80.2
HYH 03	NA	NA	95.2	NA	101.4	70.5
Diesel						
UTR 180	307.8	NA	95.3	140.6	167.2	203.6
UTR 159	NA	122.9	124.5	142.4	94.9	237.1
UTR 172	NA	NA	112.7	132.5	204.70	210

Notes

NA – Data not available

1. HYH 02 operated in Diesel only mode from July 30 to September 18.
2. HYH 03 operated in Diesel only mode from August 29 to August 31.

Table 4. Summary of Yard Hostler Operating Hours Per Month (Hours)

Vehicle ID	June 2010	July 2010	August 2010	Sept 2010	Oct 2010	Nov 2010
Hybrid						
HYH 01	178	NA	55	83	88	6
HYH 02	NA	64	81	50	25	35
HYH 03	NA	NA	40	NA	43	32
Diesel						
UTR 180	184	NA	48	77	84	101
UTR 159	NA	60	61	74	49	141
UTR 172	NA	NA	49	56	82.00	80

Notes

NA – Data not available

1. HYH 02 operated in diesel only mode from July 30 to September 18.
2. HYH 03 operated in diesel only mode from August 29 to August 31.

4.1.1 Data Collection Issues

Issues potentially affecting the reliability and accuracy of the raw fuel economy data collected for both the diesel and hybrid yard hostlers, included instances of missing or obviously inaccurate data discovered in the fueling logs, and unrecorded incidents of fueling connected with service actions or testing. As these issues were identified during analysis of the data, follow-up discussions with the LBCT staff usually resulted in correction of erroneous data, reasonable estimation of missing data or modifications to LBCT data collection procedures, therefore providing a reasonably accurate and useful picture of the hybrid yard hostlers used in this demonstration.

4.1.1.1 Fuel Economy and Rear Axle Differential Ratio Differences

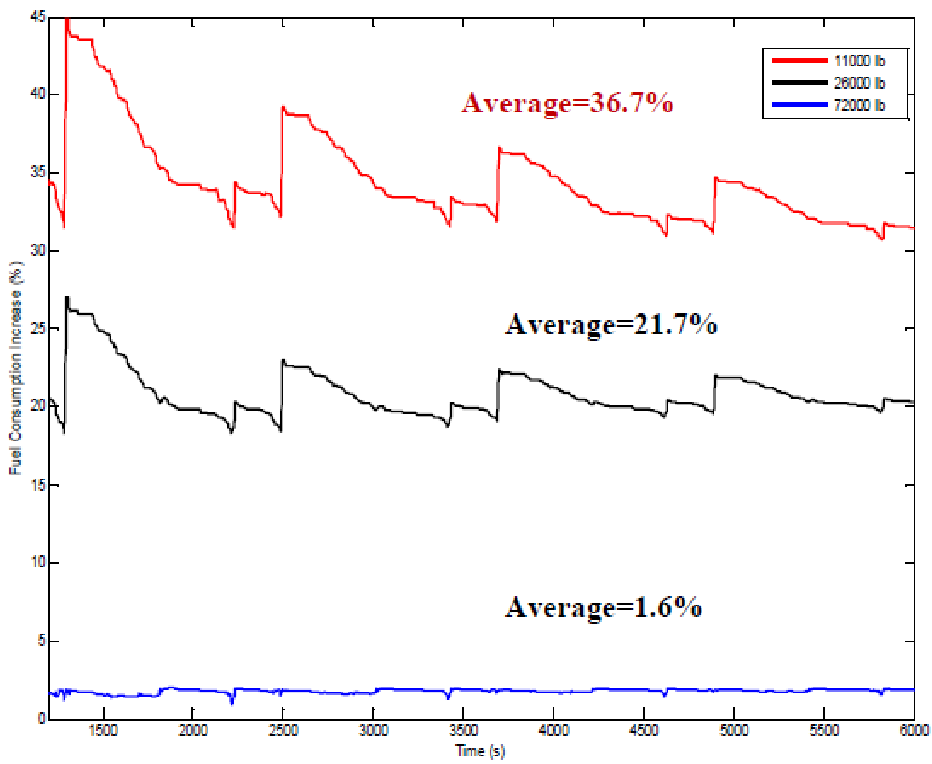
Midway through the project, a preliminary analysis of fuel data indicated that the hybrid vehicles were operating less efficiently than expected. This led to the discovery that the rear axle differential ratios of the diesel and hybrid yard hostlers differed, potentially affecting the fuel economy comparisons.

A detailed modeling analysis of the rear axle differentials for the hybrid and baseline diesel yard hostlers was conducted by US Hybrid and is provided in Appendix G. It was found that the rear axle differential ratios differed between the hybrid yard hostler and the diesel baseline vehicles. The conventional diesel yard hostlers in LBCT's fleet uses the Arvin Meritor (formerly Rockwell) RS-30-380 rear axle with 10.62:1 ratio, whereas the hybrid yard hostler was manufactured using a Sisu axle with a 12.28:1 ratio.

A modeling analysis was performed by US Hybrid to determine the operational differences between the hybrid and diesel vehicles as they relate to the different rear axle differential ratios. When comparing the diesel and hybrid vehicles, the higher rear axle differential ratio on the hybrid yard hostler requires the engine to operate at 20% higher revolutions per minute (RPM) and lower torque for the same amount of work, resulting in the lower fuel economy for the hybrid yard hostler.

US Hybrid's modeling results indicated that due to the hybrid yard hostler's higher rear axle differential ratio, the engine on the hybrid yard hostler operates less efficiently compared to the diesel vehicle, resulting in decreased fuel economy when operated with the lower load (26,000 lbs). At the higher load (72,000 lbs), the measured engine efficiency between the hybrid and baseline diesel yard hostlers were not significantly different, making the operational differences negligible. As shown in Figure 1, it was found that the fuel efficiency penalty due to the higher rear axle differential used on the hybrid can be as low as 1.6% with a load of 72,000 pounds, and as high as 21.7% with a low load of 26,000 pounds and 36.7% with no load.

Figure 1. Fuel Efficiency Reduction due to Higher Rear Ratio with Calstart Drive Cycle



With yard hostlers operating with various combinations of light loads and heavy loads, and approximately one-third of the time operating with no load, this greatly increased fuel consumption for the engine on the hybrid yard hostlers, resulting in no fuel savings when compared with the conventional diesel vehicles.

4.1.1.2 Hybrid Yard Tractor Operating in Diesel-Only Mode

During performance testing, it was also found that two of the hybrid yard hostlers, HYH 02 and HYH 03, experienced malfunctions to the hybrid system. HYH 02, performing rail work, had a blown fuse that resulted in the vehicle operating in “diesel-only” mode with no hybrid capabilities between July 30 and September 18. The vehicle did not exhibit any noticeable loss in performance and therefore the problem was overlooked during that time. HYH 03 operated in diesel-only mode for three days performing dock work after the battery box was damaged due to operator errors.

Nonetheless, data from the vehicles were analyzed and comparisons were made between the hybrid and diesel operational modes. By comparing the data from each mode, an “apples to apples” comparison could be made by eliminating the difference in rear differential ratios between the hybrid and diesel vehicles as described previously.

The hybrid yard hostler showed a fuel economy improvement of 20.7% with the hybrid system in working order, a fuel economy of 1.96 gal/hr in hybrid mode and 2.47 gal/hr in diesel-only mode, which significantly increased the overall fuel economy in August and September.

4.2 Operator Acceptance

Based on the driver surveys, 100% of the drivers found the hybrid yard hostlers to have the same or better performance than traditional diesel yard hostlers with 74.5% rating them as superior in general. Written comments provided by the hybrid yard hostler drivers were positive. The features of the hybrid yard hostlers most consistently rated better than the diesel yard hostlers were steering, braking, in-cab controls, ride comfort and interior/exterior noise levels, cab entry and exit. Interior and exterior noise levels and braking are most directly related to the operation of the hybrid drive train. A number of drivers also emphasized the relative low fumes of the hybrid yard hostlers in their comments.

Some drivers cited slow acceleration and vehicle “jerking” during shifting of the automatic transmission. The only feature of the hybrid yard hostlers frequently rated as worse than diesel yard hostlers was acceleration, with 30.4% of respondents rating it as “worse.” However, this is a deliberate design function implemented by US Hybrid. In conversations with US Hybrid, it was found that the limiting of the acceleration was to provide the driver with a safe and smoother ride when the vehicle is operating without a load, since the instant torque provided by the electric motor can cause the vehicle to change its handling characteristics drastically. The acceleration limiting feature can be turned off or specifically tuned for the hybrid yard hostler, which can provide better operational characteristics for drivers.

A summary of hybrid yard hostler driver survey results is provided in Table 5. A total of 47 surveys were completed during the six-month performance testing period. Results for each of the fourteen items in the survey are expressed as percentages of the total responses for each of the three possible ratings of “better,” ”same” or “worse”. Driver survey results for each month and can be found in Appendix E.

Table 5. Summary of Hybrid Yard Hostler Driver Survey Results

Hybrid Yard Hostler Performance Characteristic	*Better*	*Same*	*Worse*
1. Maneuverability for connection to chassis	17.0%	80.9%	2.1%
2. Pulling power with full container	10.6%	76.6%	12.8%
3. Acceleration with no container	19.6%	50.0%	30.4%
4. Smoothness of shifting under acceleration	27.7%	66.0%	6.4%
5. Steering (turning radius, ease of parking, negotiating tight places and steering effort)	31.9%	63.8%	4.3%
6. In-cab visibility (no blind spots, rear view)	14.9%	78.7%	6.4%
7. Ride comfort (vibration and shocks, feel of seat)	42.6%	57.4%	0.0%
8. In-cab controls (convenience & functioning of switches, controls, etc.)	10.6%	87.2%	2.1%
9. Braking (stops load quickly and smoothly)	34.0%	66.0%	0.0%
10. Interior noise level	38.3%	57.4%	4.3%
11. Exterior noise level	36.2%	63.8%	0.0%
12. HVAC system (heating, ventilation, A/C)	12.8%	80.9%	6.4%
13. Cab entry and exit	8.5%	91.5%	0.0%
14. Overall vehicle rating	74.5%	25.5%	0.0%
15. Average	27.1%	67.6%	5.3%

Driver Comments

Written comments from drivers are shown below. Comments ranged from a few words to one or more paragraphs on a variety of subjects. Comments were grouped into four basic categories—Performance, Comfort and Convenience, Safety, and Additional Driver Observations and Remarks. Many of the same comments appeared several times indicating a common perception or experience among different drivers. A summary of driver comments arranged by category and frequency of occurrence is provided below. (For comments received more than once, the number in parentheses indicates the number of times that comment was received.)

Performance

"Excellent control"
"Turning and handling is better"
"Acts typical to newer hostler"
"I really like the shutdown while in neutral"
"Slower" (9)
"Vehicle jerks if you try to speed up too fast" (4)
"Turning radius is larger, not as tight"
"Steering a little tight"
"Idle - shutoff engine too soon" (2)
"Loss of force when driving"
"Reverse was jerky once"

Comfort and Convenience

"Better"
"Very smooth"
"It has a fan!"
"Less fumes" (4)
"Didn't smell exhaust all day"

"Needs air hose connector extensions" (2)
"Right side of hybrid has a big muffler, hard to see if parking blind side"
"In- cab vibration"
"Hard to unlock door, handle acting up"
"Louder In-cab humming"
"Needs A/C, very hot day, fan blows hot air, very hot inside" (3)
"Mirror needs to be positioned better. Harder to see" (2)
"Fumes entered the cab"

Safety
"Slower but feels safer"
"Alarm for backing up did not work all the time"
"Sometimes it wants to accelerate on its own"

Driver Observations and Remarks
"I love what we are doing, the next step is all electric."
"I liked driving this hybrid for the last 6 days. I feel like it's a cleaner machine and I don't mind that it shuts down when it idles for too long. This truck pulls the heavy 20's just fine and goes fast enough for driving around the dock."
"The hybrid is very nice, the ride is great! Although it is a bit slower, it is safer. The idle time, before it shuts off, be nice if it could be increased a bit."
"In my opinion, the hybrid UTR is a better overall truck. I highly recommend it."
"It's a pleasure driving this hybrid yard hostler."
"I liked driving the hybrid."
"So much better for my health and the environment."

4.3 Service and Maintenance

The hybrid yard hostlers' availability served as the primary metric to evaluate their reliability. Surveys were distributed to mechanics to gather subjective feedback on serviceability and maintainability of the hybrid yard hostlers compared to diesel yard hostlers. Vehicle availability during the performance test period and mechanics' responses in the surveys are summarized in this section.

4.3.1 Vehicle Availability

Although the hybrid yard hostler system's design allows full yard hostler operation in diesel mode in case of a hybrid system failure, Table 6 reflects hybrid yard hostler availability while operating in hybrid mode only. In September and October, HYH 02 was discovered to be inadvertently operating in diesel mode, resulting in 36.6% and 42% availability, respectively. Periods of time when the hybrid yards hostlers were taken from operations for emissions testing or servicing related to development were not reflected in the vehicle availability percentages. Availability of the hybrid yard hostlers was slightly lower than the diesel yard hostlers early in the testing phase. During the latter half of the testing period, the hybrid yard hostlers experienced various issues ranging from operator error to hybrid system malfunctions.

During the six-month performance test period, the three hybrid yard hostlers were available an average of 88%. Periods of time when the hybrid vehicles were taken out of service for optimization of the hybrid system at US Hybrid's facility decreased the overall availability of the vehicles. Table 7 summarizes the reasons why the various hybrid yard hostlers were removed from service and the duration during the performance test period.

Table 6. Summary of Average Yard Hostler Availability by Month

Vehicle	June 2010	July 2010	August 2010	Sept. 2010	Oct. 2010	Nov. 2010	Dec. 2010	*Average*
Hybrid								
HYH 01[1]	100%	100%	100%	100%	NA[4]	NA[4]	80%	*96%*
HYH 02[2]	NA	100%	100%	36.6%	42%	100%	NA	*75.7%*
HYH 03[3]	NA	NA	100%	NA[5]	74.2	100%	NA	*91.4%*
								Average = 88%
Diesel								
UTR 180	100%	100%	100%	100%	100%	100%	100%	*100.00%*
UTR 159	100%	100%	100%	100%	100%	100%	100%	*100.00%*
UTR 172	100%	100%	100%	100%	100%	100%	100%	*100.00%*

Notes: NA – Data not available

1. HYH 01 was delivered on May 28, 2010.
2. HYH 02 was delivered on July 7, 2010. In September and October, HYH 02 hybrid system inadvertently disengaged and operated in diesel mode only.
3. HYH 03 was delivered on July 27, 2010
4. HYH 01 was not in service in October due to emissions testing at UCR's facility. In November, HYH 01 was taken out of service for US Hybrid to address malfunction of hybrid system (hybrid system inadvertently disengaged)
5. HYH 03 was out of service for the month of September due to a crushed battery box from driver error.

Table 7. Periods when Hybrid Yard Hostlers were out of Service

Vehicle	Reason	Date Removed from Service	Date Returned to Service
HYH 01	Engine surging when stopped in Drive. The Truck high Idle switch was on.	N/A	N/A
HYH 01	Controller Failure during warm up cycle due to high speed operation at UC Riverside (Testing)	9/17/2010	10/11/2010
HYH 01	Software Update followed by testing at UC Riverside (Testing) Engineering system upgrade	10/28/2010	11/22/2010
HYH 01	20 second Diesel shut-off not acceptable (Software Update) Engineering system upgrade	11/24/2010	11/26/2010
HYH 01	Hybrid system power-on failure	11/29/2010	12/1/2010
HYH 01	Hybrid system power-on failure	12/7/2010	12/9/2010
HYH 02	Hybrid System Fuse Blown - Short in wire harness	9/19/2010	10/18/2010
HYH 03	Crushed Battery Box and wiring short. Operator vehicle accident.	9/1/2010	10/8/2010

4.3.2 Mechanics Survey

The LBCT shop lead mechanic completed the survey at the conclusion of the performance testing period. According to LBCT maintenance records, LBCT mechanics did not perform routine maintenance on the hybrid yard hostlers during 6-month performance testing period as the hybrid yard hostlers did not require routine maintenance during the testing period. Therefore, the survey was completed based on his experience and knowledge of the vehicles. The survey contained a series of subjective questions, and a rating scheme of 1 to 5 was used, with 1 being "unacceptable" and 5 being "excellent," and an area for the mechanic to record additional comments.

A summary of hybrid mechanic survey results is provided below.

Question 1: *"Describe any hybrid yard hostler problems observed during the early part of the demonstration period that were subsequently corrected by the manufacturer."*

Responses to Question 1 are summarized as follows:

"Initially, no problems were observed during the start up phase. The vehicles were based off of the Kalmar platform that the mechanics have had a lot of experiences with."

LBCT maintenance staff is capable of performing routine preventative maintenance actions (e.g. oil changes, engine tune-ups, etc.) on only the diesel drivetrain due to the similar design and their experience with the Kalmar yard hostler platform. However, during performance testing, preventative maintenance actions were not performed, as they were not required. Service of the hybrid drivetrain of the hybrid yard hostler was performed only by US Hybrid.

Questions 2 – 6 of the survey asked the mechanic to rate various maintenance and service characteristics of the hybrid yard hostlers on a scale of one to five where 1 was "unacceptable" and 5 was "excellent." A summary of the responses is provided in Table 8.

Table 8. Summary of Hybrid Mechanic Survey Results for Questions 2 – 6

Hybrid Mechanic Survey Question	Rating
2. Hybrid systems and component training	1
3. Design for maintainability	3
4. Design for serviceability	3
5. Manufacturer support	4
6. Hybrid System Support	3

The mechanics surveyed gave the hybrid yard hostlers a rating of 1, or "unacceptable" when asked to rate the hybrid drive systems and component training. However, this was because no training was provided because the LBCT maintenance staff was familiar with the Kalmar yard hostler platform. US Hybrid was responsible for service of the hybrid drive systems.

For maintainability, serviceability and manufacturer support, the LBCT Maintenance staff gave an average rating of "acceptable" due to the similar design of the vehicles and, for the hybrid system, the quick response of US Hybrid to provide support on the hybrid drive system.

Question 7: *"Describe any trends observed regarding non-routine service actions associated with the hybrid yard hostlers including the long-term effectiveness of corrective actions"*

Responses to Question 7 are summarized as follows:

"Shortage of parts resulted in increased number of days the vehicles are out of service."
"The battery packs of the hybrid system are placed too high, which in one instance, lead to damage of battery pack while the yard hostler was connecting to a chassis/container."

Question 8 of the survey provided a space for additional comments and these are summarized below:

"The vehicle was good to work with. The staff is very experienced with the diesel drivetrain of the hybrid yard hostler as it is very similar to the diesel baseline vehicle."
"US Hybrid's response is good."
"Maintenance staff cannot troubleshoot problems with the hybrid system and relies on US Hybrid's expertise."
"When problems occur, problems can only be diagnosed in-person, which requires additional wait time for US Hybrid engineers to arrive onsite."

Based on the responses to Question 7 and additional comments provided, LBCT maintenance staff felt their experience with the vehicles was good but the prototype nature of the vehicles, though addressing issues associated with the hybrid system required US Hybrid's dedicated response. Not having necessary parts onsite resulted in slightly longer delays to return the vehicle to service. LBCT staff also felt that the design on the hybrid system could be improved by lowering the location of the battery pack to avoid direct contact with cart connectors, which could be damaged in the process of backing up to connect to a chassis/container.

5 EMISSIONS TEST RESULTS

5.1 Initial Chassis Dynamometer Emissions Test

As part of the project, emissions of the hybrid unit were evaluated and compared with emissions from a baseline conventional diesel yard hostler. Emissions testing of the vehicles was coordinated by the ports' consultants Tetra Tech, Inc and TIAX, LLC, and performed by UCR. The transient duty cycle developed by West Virginia University was used in both tests utilizing a chassis dynamometer.

Emissions testing included the measurement of the primary and dilution exhaust flow rate, and the concentrations of carbon monoxide (CO), carbon dioxide (CO_2), NO_x and total hydrocarbons (THC). $PM_{2.5}$ mass was measured but was undetected due to the PM exhaust aftertreatment devices (diesel particulate filters) installed on the vehicles. In addition to measuring the concentrations of pollutants, a number of engine parameters were recorded during the testing, including exhaust temperature, both dynamometer and engine revolutions per minute (RPM), horsepower at the wheels, engine exhaust pressure, electronic fuel delivery and electronic load. Other measurements included: elevation, cycle duration, ambient temperature and pressure, humidity and ambient gas concentrations. A triplicate run was carried out for each of the test cycles.

The two transient cycles for both medium-heavy loads and heavy-heavy loads are shown in Figure 2 and Figure 3.

Figure 2. Transient Test Cycle for Medium Loads

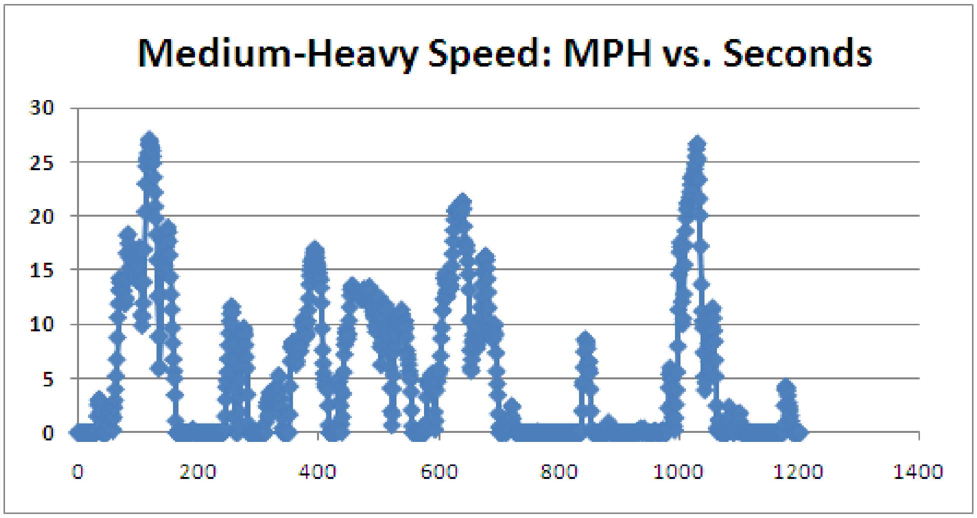
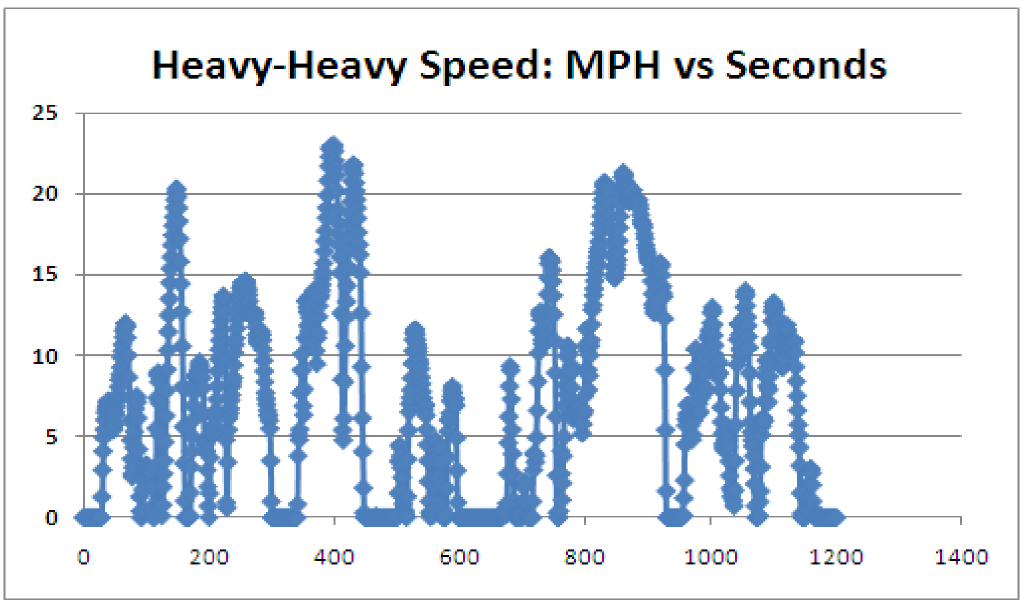


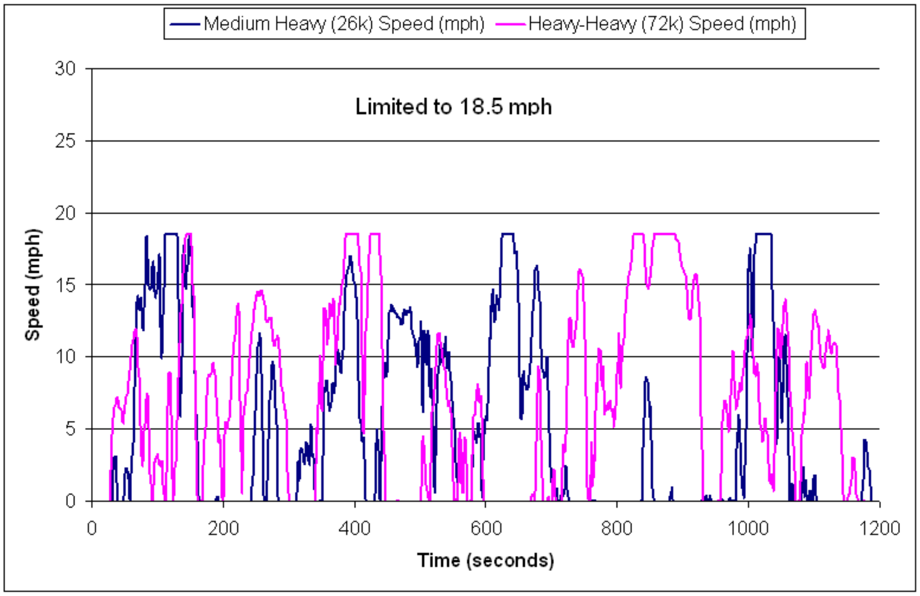
Figure 3. Transient Test Cycle for Heavy Loads



5.1.1 Modifed Transient Drive Cycle for Hybrid Yard Hostler

During preparation of the hybrid yard hostlers for testing on the chassis dynamometer, UCR learned that the prototype hybrid yard hostlers were limited by U.S. Hybrid to a maximum speed of 18.5 mph. Because the drive cycle developed by WVU indicated speeds of yard hostlers operating at LBCT to be as high as 27 miles per hour, the transient drive cycle had to be modified, in particular, the peak speed at which the vehicles would be tested. The modified transient yard tractor cycle is shown in Figure 4 and was used when testing both the hybrid and diesel yard tractors to ensure a comparison of the two vehicles.

Figure 4. Modified Transient Yard Tractor Driving Cycles



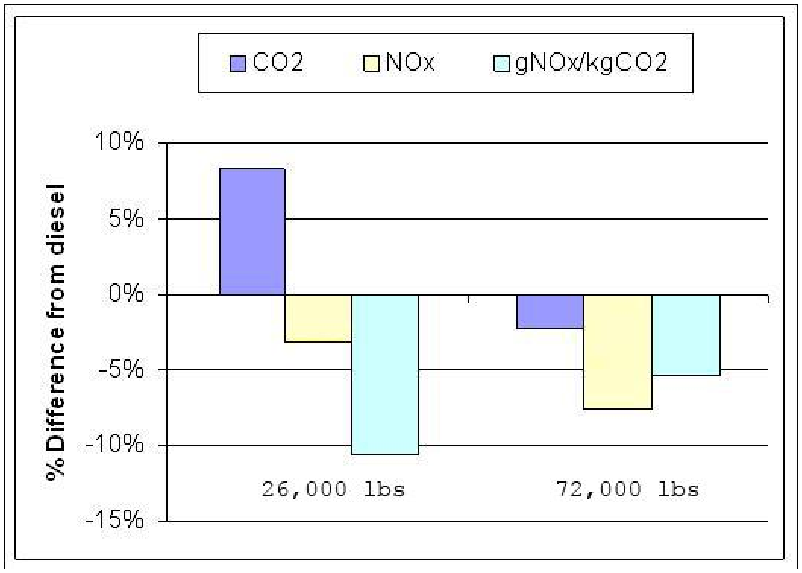
5.1.2 Initial Emissions Test Results

Table 9 provides the comparative data of the total grams of NO_x and CO_2 measured during the same transient cycle for the two yard tractors and these data are shown graphically in Figure 5. Because over 99% of fuel carbon is converted into CO_2, CO_2 is used as a surrogate for fuel consumption.

Table 9. Comparison of the NO_x and CO_2 Emissions over the Two Transient Cycles

	NOx g/cycle		CO_2kg/cycle		gNOx/kgCO2	
	ave	stdev	ave	stdev	ave	stdev
Hybrid_26	21.8	0.9	4.4	0.1	4.9	0.3
Diesel_26	22.5	0.2	4.1	0.1	5.5	0.1
Hybrid_72	30.1	0.2	6.7	0.1	4.5	0.0
Diesel_72	32.5	0.6	6.9	0.0	4.7	0.1

Figure 5. Graph of the NO_x and CO_2 Emissions over the Two Transient Cycles



The comparison shows that 1) at low loads, the hybrid actually uses about 7% more fuel and NO_x is 3% lower and 2) at the higher loads, the hybrid is about 3% more fuel efficient and NO_x is 7% lower than the conventional yard tractor.

5.1.3 Hybrid System Batteries State of Charge

In order to calculate or measure the work carried out by a hybrid diesel-electric vehicle, energy from the batteries must also be taken into consideration. For the chassis dynamometer testing, UCR observed slight differences in the initial and final state of charge (SOC). A battery SOC of 72 % was achieved during the conditioning of the chassis dynamometer. However when the system was initialized before the next test, the initial SOC had dropped to 65-68%. The minor fluctuations of the SOC are a possible indication that the batteries are potentially being underutilized in the hybrid mode. Section 6 addresses this issue as a future study area.

5.1.4 Investigation of Engine Parameters

When the testing indicated that the emissions and fuel economy results did not meet original estimates, UCR conducted a further investigation to determine whether differences in engine parameters between the hybrid vehicle and the diesel vehicle potentially affected the emissions and fuel economy results.

From the test results, it was discovered that the throttle for the hybrid vehicle operated about 40% higher than the throttle of the diesel vehicle; however, it was not clear whether the throttle position caused the observed differences in emissions and fuel economy. In addition, the engine percent load measured by the electronic control module (ECM) was slightly higher for the hybrid vehicle compared to the conventional diesel vehicle. The increased load on the hybrid engine is likely due to the downsizing of the engine on the hybrid vehicle, which is rated at 200 hp, while the conventional diesel engine is rated at 240 hp. As such, the hybrid engine would require a higher load in order to perform the same work as the baseline diesel engine. However, this does not indicate a difference in the amount of work performed, which was confirmed by the chassis dynamometer measurements showing that both vehicles exerted the same amount of power at the wheels.

Other parameters evaluated by UCR included coolant temperature, intake temperature, distance, and dynamometer load. In general, the standard deviation between the tests on the hybrid yard hostler and the baseline diesel yard hostler was less than 1%, indicating that there were no significant differences and that the tests were performed in a repeatable manner. Table 10 shows the results of the investigation.

Table 10. Engine Parameters for Hybrid and Diesel Yard Hostlers

	speed (mph)		distance (mi)		dyn Load		eLoad (%)		throttle (%)		boost (kPa)		intake (F)		coolant (F)	
	ave	stdev	ave	stdev	ave	stdev	ave	stdev	ave	stdev	ave	stdev	ave	stdev	ave	stdev
Hybrid_26	5.02	0.03	1.69	0.01	27.7	0.1	26.3	0.6	17.3	0.6	10.1	0.3	105	1	190	0.1
Diesel_26	5.07	0.04	1.70	0.01	27.3	0.1	25.0	0.5	11.6	0.7	9.7	0.5	103	5	193	0.1
Hybrid_72	6.90	0.06	2.31	0.02	63.6	0.5	30.8	0.4	28.1	0.3	18.3	0.4	111	1	191	0.2
Diesel_72	6.98	0.03	2.33	0.01	63.6	0.2	28.4	0.3	20.8	0.7	19.9	0.6	112	3	194	0.2

5.1.4 Additional Test: Hybrid Yard Hostler Operating in Hybrid Mode vs. Full Diesel Mode

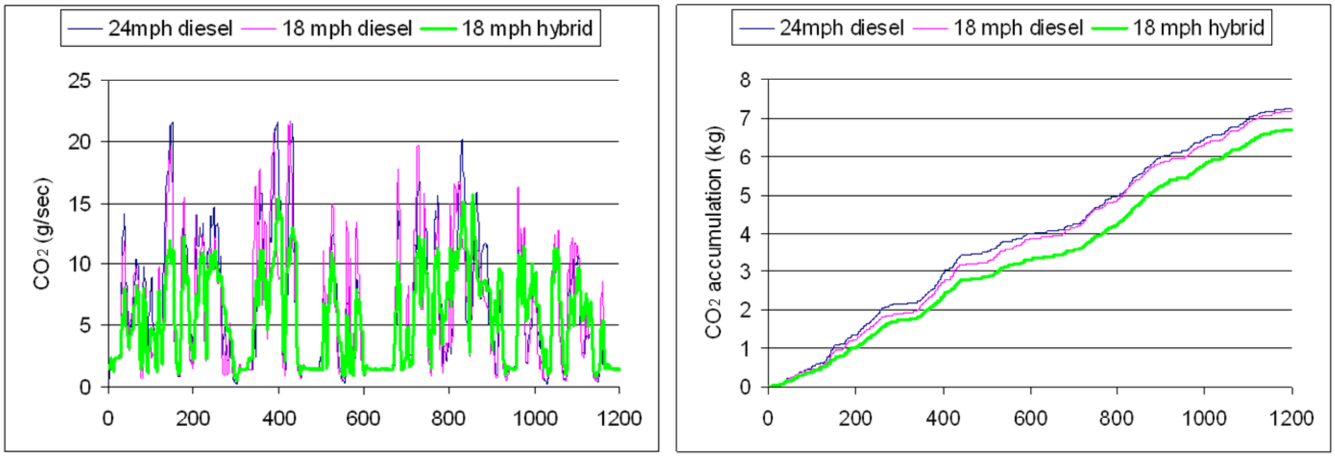
As a result of the original project testing results, which were less than expected, further evaluation of the hybrid technology was conducted to determine its impact on vehicle emissions and fuel economy. Since the hybrid vehicle has the capability to completely disconnect the hybrid system and allow the yard hostler to operate in either full diesel mode or in diesel-electric hybrid mode, UC CE-CERT performed an additional test using the high-load transient cycle with 1) the original cycle with speeds to 24mph and, 2) the modified-clipped cycle established when the hybrid electronic unit governed the speed to 18.5 mph. Figure 6 shows the streaming and cumulative data for CO_2 as a function of time during the test cycle.

UC CE-CERT made the following observations for CO_2:

1. When operating in the diesel mode, the emissions were independent of whether the yard hostler followed the original transient cycle or the chopped version created by the hybrid unit.

2. The data indicated that the cumulative CO_2 emissions were lower while hybrid mode throughout the cycle.

Figure 6. Integrated CO_2 Data for the Yard Hostlers

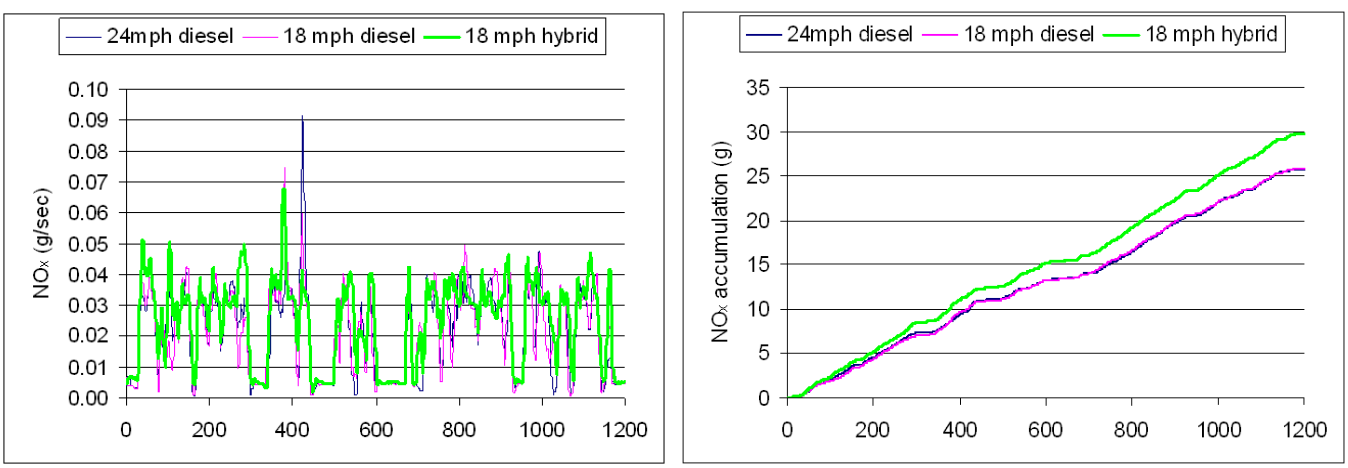


A comparable measurement of NO_x emissions during the full-diesel and hybrid operating modes was also conducted. Results are shown in the Figure7. The analysis showed:

1. NO_x emissions were similar for the hybrid unit operating in full-diesel mode, independent of whether it followed the original duty cycle or the modified duty cycle limited to 18.5 mph.

2. As shown in Figure 7 below, an analysis of accumulated NOx emissions indicated that when the vehicle was tested in hybrid mode, NO_x emissions were higher compared to when tested in diesel mode. According to UCR, a possible explanation is that operation of the exhaust gas recirculation (EGR) may have differed in the two tests leading to the higher NO_x emissions, however, this would have to be evaluated in further study.

Figure 7. Integrated NO_x Data for the Yard Hostlers



5.1.5 Initial Emissions Test Findings

The results comparing the hybrid and diesel yard hostlers indicate that at lower loads the hybrid consumed approximately 8% more fuel than the baseline diesel vehicle. At high loads, the hybrid used approximately 3% less fuel than the baseline diesel yard hostler. NO_x emissions from the hybrid yard hostler were reduced by about 3% at low load and 7% at high load. The results of the emissions test performed by UCR are provided in Appendix H.

5.2 Subsequent Fuel Economy Test Results

In November 2010, another test on UCR's chassis dynamometer was commissioned by US Hybrid to determine the hybrid yard hostler's fuel economy after modifications were made to the hybrid drive system. The modifications were made to find an optimal control specification to improve the vehicle's fuel economy. The evaluation was conducted on a hybrid yard hostler operating in both hybrid mode and in full-diesel mode with the hybrid drive system disengaged.

Results from this evaluation showed that at the lower load (26,000 lbs) the hybrid yard hostler operating in hybrid mode consumed 0.297 liters less than the amount of fuel consumed during the first test. This resulted in about an 18% improvement in fuel economy after modifications were made to the hybrid vehicles. The test at 72,000 lbs. showed a fuel consumption reduction of 0.174 liters, or 7%. Table 11 summarizes the comparison of fuel economy results from the initial and additional chassis dynamometer fuel economy evaluations.

At the lower load of 26,000 lbs, the yard hostler consumed about 0.3 liters less fuel in hybrid mode than when operated in full diesel mode, an improvement of about 18%. At the higher load of 72,000 lbs, the vehicle operating in hybrid mode consumed 0.327 liters less fuel than the vehicle operating in full diesel mode, an improvement of about 12%. Table 12 summarizes the comparison of fuel economy results for the vehicle operated in hybrid mode and full diesel mode.

Table 11. Comparison of Fuel Economy – Hybrid Yard Hostler Operating in Diesel-Electric Hybrid Mode (Initial and Second Chassis Dynamometer Test)

Load	Fuel Consumed (liters)		Improvement from Initial Test
	Initial Test	Second Test	
26,000 lbs.	1.667	1.370	**18%**
72, 000 lbs.	2.497	2.323	**7%**

Table 12. Comparison of Fuel Economy - Hybrid Yard Hostler Operating in Full-Diesel and Diesel-Electric Hybrid Mode (Second Chassis Dynamometer Test)

Load	Hybrid Yard Hostler Operation Mode	Fuel Consumed (liters)	Improvement between Diesel and Hybrid modes
26,000 lbs.	Full-Diesel	1.665	**18%**
	Diesel-Electric Hybrid	1.370	
72, 000 lbs.	Full-Diesel	2.650	**12%**
	Diesel-Electric Hybrid	2.323	

6 HYBRID YARD HOSTLER BUSINESS CASE ASSESSMENT

This project developed and evaluated prototypes of a diesel battery electric yard hostler in this configuration (parallel hybrid design), and so all business case conclusions must be considered preliminary. In addition, other hybrid yard hostlers have recently been offered as a standard commercial product by any of the major yard hostler original equipment manufacturers (OEMs). Kalmar has recently introduced a hydraulic hybrid yard truck, and Capacity currently offers the Plug-in Hybrid Electric Terminal Tractor (PHETT), which is a series battery-electric vehicle.

The costs for a first-of-its-kind prototype are not the same as actual costs when the vehicle becomes available for purchase. Detailed cost and market information is considered confidential information or unknown at the time of publication by the project stakeholders, the data are based on estimates of future costs at higher (production) volumes. Given these constraints, the major factors affecting the business case for hybrid yard hostlers will be examined. Note also that the scope of this business case analysis will be limited to off-road yard hostlers such as those used in port operations, as opposed to on-road yard hostlers.

6.1 Vehicle Costs

Depending on the vehicle options (including engine configuration), a new diesel yard hostler typically costs between $75,000 and $90,000 excluding taxes and delivery. In California, CARB regulations require new yard hostlers purchased or leased after January 1, 2007 to include either an on-road certified engine or a Tier 4 off-road certified engine.[7] Therefore, in California, the base cost of a diesel yard hostler includes an on-road certified engine. For the purposes of this analysis, the average cost of a new diesel yard hostler in California is assumed to be approximately $85,000. This is the cost of the baseline vehicles used in the project.

As previously stated, hybrid yard hostlers have only recently been offered as a commercial product. Incremental costs are not well known, but the costs for the prototypes in this test are known. Educated assumptions of future cost changes, based on volumes and technology improvements, can also be made. Table 13 summarizes the component cost and total cost of hybrid yard hostlers.

[7]California Air Resources Board Final Regulation Order, Regulation for Cargo Handling Equipment at Ports and Intermodal Railyards. (Amended, effective December 3, 2009).

Table 13. Hybrid Yard Hostler Component Cost Breakdown and Total Cost

Item	Estimated Prototype Costs (2007)	Actual Prototype Costs (2010)
Base Yard Truck	$85,000	$85,000
Electric Motor & Controller	$28,000	$28,000
Battery	$24,000	$14,000
Auxiliary Components	$6,000	$7,000
Total Incremental Cost Increase	$58,000	$49,000
Percent Incremental Cost Increase	68%	58%
Total Vehicle Cost	**$143,000**	**$134,000**

It should be noted that other recently commercialized hybrid yard hostlers, such as the Capacity PHETT and Kalmar Hydraulic Hybrid Terminal Tractor have an approximate incremental increase in cost of about 60% compared to conventional diesel yard hostlers. Therefore, the prototypes used for this project are reasonable and within the range of other prototypes that have gone into production.

Some funds to reduce the incremental costs may be available, but since none are certain, the business case analyses presume no incentives or tax credits. The business case also assumes no buy-downs or funding from external sources (government grants, etc.). Potential funding sources are described in Appendix I.

6.2 Annual Operating Hours

According to the 2009 POLB Air Emissions Inventory, the average annual operating hours for yard hostlers at POLB and is approximately 1,300 and approximately 1,700 at POLA. Based on field data collected at LBCT during this project, the average annual operating hours for an LBCT yard hostler is approximately 1,500 engine operating hours per year. Based on interviews with yard hostler manufacturers, an average value for port applications lies within the range of 1,500 – 2,500 hours per year. For purposes of this analysis, we will assume an average annual operating hour figure of 1,500 hours per year for port applications.

Average annual engine operating hours for yard hostlers varies by application. Based on interviews with yard hostler manufacturers, the port application has the lowest average annual operating hours. Estimated annual operating hours for yard hostlers used at distribution centers varies over a wide range of 2,000 – 6,000 hours per year. Estimated annual operating hours for yard hostlers used in the parcel and package delivery industry is 3,600 hours per year. Intermodal yards have the highest average annual operating hours at 3,000 – 6,000 hours per year.[8]

[8] Liquefied Natural Gas Yard Hostler Demonstration and Commercialization Project – Final Report

6.3 Service Life

Table 14 reflects the 2009 POLB Air Emissions Inventory and the 2009 POLA Air Emissions Inventory reports, providing the following data on yard hostlers operating at the ports:

Table 14. 2009 POLB and POLA Emissions Inventory Data for Yard Hostlers

Port	Count	Horsepower			Model Year			Annual Operating Hours		
		Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
POLB	713	173	245	189	1993	2008	2004	0	4073	1301
POLA	962	170	270	215	1995	2008	2006	0	5390	1699

Depending on the application, diesel yard hostlers typically have a service of life of five to twelve years. POLB and POLA fit within that range, with a fleet age ranging from one year to 17 years. First owners of yard hostlers generally expect about 20,000 – 25,000 engine operating hours from a yard hostler. Therefore applications with higher average annual engine operating hours tend to have shorter service lives and vice-versa. For port applications, an average diesel yard hostler service life is about ten (10) years. It would seem that POLB and POLA may be running slightly fewer hours (1,300 and 1,700 hours/ per year on average, respectively).

Due to the limited field data on battery electric hybrid yard hostlers, it is difficult to estimate the potential service life of hybrid yard hostlers. However looking at the traditional service life of the primary hybrid-related components, i.e., the batteries, controller, and electric motors, achieving a minimum 10 years/25,000 engine operating hours service life is currently possible. US Hybrid contends that a 10 year/25,000 hour lifespan can be achieved today with validated hard tooling and testing processes, as would be used in a production situation. POLB and POLA may actually require less than that, based on emissions inventory report data.

6.4 Maintenance and Service Costs

The frequency of periodic maintenance for yard hostlers is based on both engine manufacturers' recommendations and the experience and maintenance strategy of individual fleet operators. In general, the maintenance intervals recommended by the engine manufacturer appear to correlate strongly with engine certification, i.e., whether the engine is off-road or on-road. Specifically, recommended maintenance intervals for off-road engines are about 40% shorter than the corresponding maintenance intervals for on-road engines. Therefore periodic maintenance costs for off-road engines would be expected to be approximately 40% higher than for on-road engines.

The hybrid yard hostlers use certified on-road engines and have similar recommended maintenance intervals to on-road diesel engines. Since the engine in the hybrid vehicle is off during idling, accumulated engine operating hours are reduced, extending maintenance intervals. However, since the hybrid system components are designed to be 'maintenance free' the hybrid yard hostlers present no advantages or disadvantages compared to existing diesel yard hostlers with on-road engines. Therefore, periodic maintenance costs have been ignored in the business case analysis.

It is reasonable to assume that fleet operators will expect the same warranty for hybrid yard hostlers as diesel yard hostlers. Outside the warranty period, there are no major expected service expenses (e.g., an engine overhaul or replacement) for diesel yard hostlers during the average service life of the vehicle in the port application. (Note that the first owner of a yard hostler will typically sell the vehicle before an engine overhaul is required.)

A potential concern regarding service of the hybrid yard hostlers outside of the warranty period is the replacement cost of the major hybrid system components, in particular the batteries and electric motor(s). While there is insufficient data available on hybrid yard hostler service costs to make a comparison with diesel yard hostler service costs, general field experience with heavy-duty hybrid vehicles gives little evidence to suspect that the major hybrid system components will require more service than their diesel counterparts. For this reason, service costs have been ignored in the business case analysis.

6.5 Resale Value

Depending on the condition of the vehicle, diesel yard hostlers can have a resale value of anywhere between 5% and 50% of their original price. For port applications, older yard hostlers often show a lot of wear and reported resale values tend to be on the low end of this range, typically between $3,000 and $7,000. For the purposes of this analysis, we will use the "worst case" of 5% retained value. It is not expected that hybrid yard hostlers, which share many components with conventional hostlers, will have significantly different resale values. The business case analysis shows that the relatively low resale value for yard hostlers means this factor ultimately has very little impact on the life cycle costs for these vehicles.

6.6 Simplified Life Cycle Cost Analysis

Based on the data and assumptions given above, a simplified life cycle cost analysis (LCA) model was constructed for the hybrid and diesel yard hostlers by focusing solely on initial vehicle cost, fuel costs and resale value and ignoring all costs which are unknown, insignificant or are not expected to vary significantly between diesel and hybrid yard hostlers. In addition, it should be noted that the fuel economy data were derived from the second UCR emissions test. The simplified LCA equation is as follows:

$$\text{LCA} = (\text{Initial Cost of Vehicle}) - \text{Purchase Incentives} + PV_{Fuel} - PV_{Resale}$$

where

Purchase Incentives = Value of Grants, Tax Credits, etc. Applied to Vehicle Purchase
PV_{Fuel} = Present Value of Fuel Expenses During Vehicle Service Life
PV_{Resale} = Present Value of Resale Value of Vehicle at End of Service Life
$PV = F_t /(1 + d)^t$
F_t = Future Cash Flow in Year t
d = Discount Rate

The LCA parameters associated with the business case for diesel vs. hybrid yard hostlers are shown in Table 15. The LCA using the cost values for one hybrid drive system is shown in Table 16.

Table 15. Lifecycle Cost Analysis for Yard Hostlers at Current Production Costs

Parameter	Conventional Diesel	Hybrid
Initial Vehicle Cost	$85,000	$134,000
Purchase Incentives	$0	$0
Fuel Cost per Gallon After Tax Credits	$3.25	$3.25
Fuel Economy (gal/hr)	1.71	1.46*
Annual Operating Hours	1,500	1,500
Annual Fuel Costs	$8,335.15	$7,134.76
Service Life	10 Years	10 Years
Discount Rate	3%	3%
PV_{Fuel}	$83,352	$6,700
PV_{Resale}	$4,250	$7,150
Vehicle Lifecycle Cost	**$172,610**	**$209,273**

NOTE:
*The average value is based on the second chassis dynamometer fuel economy test, as the in-use comparison data were not representative of the hybrid system performance due to the rear axle differential ratio issue.

Table 16. Hybrid Yard Hostler Business Case Analysis – One Unit

Vehicle Parameter	Conventional Diesel	Hybrid	Savings
Initial Vehicle Cost	$85,000	$134,000	($49,000)
Fuel Economy (gal/hr)	1.71	1.46	14%
Per Vehicle LCA - Present Cost	$172,643	$209,273	($36,630)
Average Annual Fuel Usage (gal)	2,565	2,190	375
Average Annual Fuel Costs (2010)	$8,336	$7,118	$1,218

Based on the LCA in Table 16, the costs for a diesel and hybrid yard hostler *without vehicle purchase incentives* differ by $36,630. Assuming that vehicle fleet operators will accept payback on the incremental cost of the vehicle over the full service life of the vehicle, there will be no need for incentives in the purchase of these vehicles, since fuel savings would to offset the incremental vehicle cost. However, fleet operators usually require a payback on their investments within two to three years which can only be met if there are purchase incentives available.

According to US Hybrid, the cost of the hybrid drive system would also decrease with increased unit production. Table 17 shows the anticipated hybrid drive system production unit price for the quantities noted.

Table 17. Hybrid Drive System Unit Cost

Quantity	Cost
500	$38,313
1,000	$29,727
2,000	$26,730
3,000	$23,409

As shown in Table 18, using the cost values for a production quantity of 1,000 hybrid drive systems, the LCA becomes even more attractive but purchase incentives will still be necessary to offset the increased cost of the hybrid system.

Table 18. Business Case Analysis for Large Scale Use of Hybrid Yard Hostlers - 1,000 Units

Vehicle Parameter	Conventional Diesel	Hybrid	Savings
Initial Vehicle Cost	$85,000	$114,727	($29,727.00)
Fuel Economy (gal/hr)	1.71	1.46	14.40%
Per Vehicle LCA - Present Value	$172,643	$190,718	($18,074)
Average Annual Fuel Usage (gal)	8,773	7,669	1,104
Average Annual Fuel Costs (2010)	$26,906	$23,519	$3,387

Appendix I provides a summary of potential funding sources for tax credits, grants, and incentives. In general, to be eligible for tax credits, grants, or incentives, it is usually required that projects demonstrate that emission reductions above and beyond what is required by regulation could be achieved. Appendix J provides a summary of current policies and regulations that could have an impact on the hybrid yard hostler market.

7 SUMMARY OF FINDINGS

- The diesel-electric hybrid yard hostlers used in the demonstration were able to perform all the tasks required of a yard hostler in real world use, and were well accepted by the drivers.
- Fuel savings in the range of 14%-20% across the three duty cycles were achieved in the demonstration. This finding is based on all the analyses conducted, as the direct in-use comparison testing was not fully applicable due to the differential ratio problems discussed earlier.
- While the prototypes in this test may not have performed at the levels originally estimated, they did deliver performance equivalent to other hybrid hostler designs currently commercialized. If

manufacturers are seeing a production case for hybrid systems that deliver 20% fuel economy improvement with a 60% incremental cost increase, then the battery-electric diesel hybrids in this demonstration are equally viable for production.

- With the current pricing and assumptions used in the life cycle cost analysis, incentives are necessary to make the business case viable, given the levels of performance delivered by the prototypes. At production volumes, about $18,000 per vehicle in incentives or buy-down would be needed to make the business case, based on the assumptions used here. However, as noted above, other systems have come to market with very similar performance and costs, so the assumptions used in this report may be overly conservative.

8 LESSONS LEARNED

This section describes insights and experience gained during the course of the hybrid yard hostler demonstration project that may be helpful to future hybrid vehicle demonstration projects.

Some of the important lessons learned include:

- **Clear testing requirements based on prototype design limitations.**
    - One prototype vehicle was damaged during chassis dynamometer testing due to hybrid drive system limitations that were not known at the time of testing (e.g. maximum speed limitation).
- **Ensure all project team members understand the desired/required outcomes.**
    - Project partners must be clear about the desired project outcomes (e.g. a production-ready design versus a verified prototype ready for further development).
- **Plan for delays in prototype development.**
    - Incorporate lessons learned from previous projects, and understand that prototype development is a process that requires the cooperation of all project partners. In some cases, delays may occur.
    - Quantifying and characterizing the power train and auxiliary loads for the typical UTR operation.
- **Plan for testing the same vehicle with hybrid system on and off (if possible).**
    - Training needed to recognize when the hybrid system failure occurs.
    - Improve process to collect reliable in-use fuel consumption data.
- **Incorporate up-front time in project planning and schedule for adjustment of software/controller operations.**
    - A “Pre-Test” period of observation and adjustment before testing would be beneficial and allow for any system modifications before the performance test to reduce vehicle downtime and allow for maximum performance/operation time.

- **The specifications of the test trucks and the control/comparison trucks must be completely verified and double checked to ensure an "apples to apples" comparison.**
    - While the differential gear ratio was included in the hybrid yard hostler vehicle specifications, it was not clear which ratio had been used on the actual prototype until the issue was discovered later in the demonstration. If the test trucks and the control trucks cannot be identical, then up-front planning for how to address the unavoidable differences must be considered.

- **Monitor performance of the test vehicles closely throughout the demonstration period to determine if the vehicles are performing as expected.**
    - With closer monitoring of the vehicle's performance parameters, earlier discovery of the hybrid system disengaging itself on one of the test vehicles may not have inadvertently affected the vehicle's fuel economy evaluation. Modifications to the hybrid system could have been made and performance of the hybrid vehicle could have been more fully evaluated during the demonstration period.

9 RECOMMENDED NEXT STEPS

- Modifications were made to the hybrid drive system and software late in the demonstration period when it was discovered that the hybrid vehicle was not achieving the expected fuel economy. Continued demonstration and evaluation of the prototype vehicles would provide further beneficial data on how well the vehicles are performing with the modifications.

- Further examination of the following variables that this demonstration uncovered as potentially significant:
    - Driver behavior in particular operations
    - Differential ratios
    - Application/task/duty cycle specific impacts
    - Exhaust after-treatment system design (may need to be specific for hybrids)
    - In-cab displays to better inform driver
    - Hybrid system diagnostics to ensure proper operation

- Further development of the hybrid drive system to further improve the fuel economy and emissions reduction performance.
- Further development in cooperation with engine manufacturers and exhaust aftertreatment manufacturers is needed to develop systems specifically designed for hybrid use. The more frequent on/off cycles of a hybrid have impacts on engine efficiency and EGR efficiency that were not fully addressed in this project.
- Once the hybrid vehicle system design is finalized, regulatory agency approval for the emissions reduction performance (e.g. verification or certification) should be pursued to ensure that future vehicles are eligible for local, state and federal grant funding.

APPENDIX A

Request for Information (RFI) – Hybrid Drive System Suppliers

The Port of Long Beach

P. O. BOX 570 · LONG BEACH, CA 90801-0570 · TELEPHONE (562) 437-0041 · FAX (562) 901-1725

DATE August 4, 2007

TO Potential Hybrid Drive System Suppliers

FROM Robert Kanter, Ph.D., Managing Director of Environmental Affairs and Planning

SUBJECT Hybrid Terminal Tractors for Port Application – Request for Information (RFI)

The Port of Long Beach (POLB) and the Port of Los Angeles (POLA) are pleased to inform you of an upcoming opportunity to participate in a project to supply and integrate hybrid drive systems into port terminal tractors. The project team (POLB, POLA, Long Beach Container Terminal, Kalmar Industries, the U.S. Environmental Protection Agency, and WestStart-CALSTART) presents this RFI package and requests that hybrid drive system suppliers indicate their interest in bidding for this project.

After reviewing this package we request that you provide two pieces of information:

1. An expression of interest in bidding to be a supplier;
2. Comments and questions you have about our draft specifications and performance parameters.

The immediate goal of this particular demonstration project is to determine if the use of hybrid technology in a Kalmar Ottawa 4x2 terminal tractor in this application can provide significant reductions in emissions of NOx and PM. A document describing the specifications and requirements for the Kalmar Ottawa 4x2 Hybrid Terminal Tractor is attached.

We are also interested in evaluating improvements in fuel economy while meeting all terminal tractor performance requirements. The long-term goal is to commercialize a hybrid terminal tractor for this application if the economic factors (business case) are positive. This project is technology neutral and all hybrid drive technologies will be evaluated equally.

This project, which is funded by the Ports and the U.S. EPA, will develop and demonstrate <u>three</u> hybrid terminal tractors at a POLB container terminal. Please note that a similar project is currently being launched at an east coast port which will be run in parallel with this one. The east coast project will demonstrate <u>two</u> hybrid terminal tractors. Therefore, the successful bidder will be required to bid on <u>five</u> hybrid drive systems for integration with the Kalmar tractors.

After bids for the five hybrid drive systems are procured and a supplier is selected, the winning bidder will also assist and support the project team during the integration, shakeout, and evaluation periods with any maintenance or operational issues that arise.

A complete Request for Proposals (RFP) will be issued this autumn and a contract for the hybrid drive system will be awarded soon thereafter. The RFP will include detailed information about the terminal tractor duty cycle and economic assumptions for this application. After the hybrid drive system integration process is complete, the hybrid terminal tractors will be put into service and evaluated at POLB. It is our intention that emissions and fuel economy tests will be performed in the second half of 2008.

For those unfamiliar with the application, terminal tractors are used at ports to transport containers on and off ships, trains, and storage stacks. At the demonstration site—Long Beach Container Terminal—they spend approximately 50% or more of their duty cycle idling.

Speeds within the yard vary from a crawl (typically while waiting in a loading or unloading queue) up to 25 mph or more in some cases. Terminal tractors at this facility average 2,500 hours of operation annually and consume approximately 1.7 gallons of diesel fuel per hour of operation.

As stated above, one of the main goals of this project is to maximize emissions reductions. To this end, a 2007 on-road diesel engine will be required as part of the hybrid drive system. It is anticipated that the hybrid drive system will contribute additional emissions reductions and fuel savings through features such as hybrid launch assist, regenerative braking and idling reduction or elimination. A key component of this project will be the evaluation of the business case for a hybrid terminal tractor and suppliers will need to optimize their designs to maximize emissions reductions and fuel savings within the constraints of the terminal tractor business case.

We will accept responses in either hard copy (mail) or electronic (e-mail) form.

Responses to this RFI are due no later than **Friday, September 14, 2007**. Answers to any questions received in the responses will be sent to all parties within two weeks after the deadline. We will treat all comments made in response as confidential. Please submit your responses to:

Allyson Teramoto
Environmental Specialist Associate
Port of Long Beach
925 Harbor Plaza
P.O. Box 570
Long Beach, CA 90802
Teramoto@polb.com

We look forward to your response to this RFI as we approach the next steps in developing hybrid terminal tractors for this important application.

Sincerely,

Robert Kanter

Robert Kanter, Ph.D.
Managing Director of Environmental Affairs
and Planning

AT:s

Attachment

POLB/POLA Hybrid Terminal Tractor Request for Information - Questions by Topic

A. Questions about the Vehicle Specifications

1. What are the charging requirements if a pure electric (battery electric) architecture is proposed?
If the supplier team proposes an all-electric architecture, the supplier team should also propose the necessary charging infrastructure. Vehicles are potentially available to be charged for 1 hour during first shift lunch break, for 1 hour between first and second shifts, for 1 hour during 2nd shift meal break and for 5 hours between the end of second shift and the beginning of first shift. All decisions will be evaluated as to their impact on the business case.

2. Does the vehicle have to be built with the current components (i.e. rear axle) or could a complete system be proposed?
A complete system could be proposed but that does not seem cost-effective for the overall project, unless the hybrid drive supplier is willing to provide the components themselves. Also, the hybrid drive supplier must obtain application approvals for certain components, such as the rear axle, before the project begins.

3. Is the 0-20 in 16 sec. assumed to be on flat level ground?
Yes

4. How long does the maximum grade need to be sustained?
In most applications, especially in ports, the grade is no greater than 1%, however, the performance of the hybrid drive system will be compared to the mechanical system currently provided by Kalmar.

5. 16% grade is typically how long in ft or m?
See previous question. 16% was set as a startability grade – this grade reflects maximum torque requirements.

6. What would be frequency of 16% grade climbing to flat run operation? Trying to estimate the time available between "pulls" to charge an energy storage system?
See response above regarding gradeability. The length of the grade is not continuous for port applications and in fact, besides the occasional ramp, the terrain at LBCT is level (<1% grade). However, for other applications such as distribution centers, grades may be longer.

7. Does the maximum weight take into consideration over-packing or is it an average?
The maximum weight is the maximum weight that Kalmar expects the terminal tractor to be subjected to.

8. Cummins engine preferred, ISB '07 is referenced in the drawing, are there other engines are currently used on the vehicle(s)?
Kalmar offers Caterpillar diesel engines also, but the Cummins diesel is the preferred engine. CARB requires an EPA 2007 certified engine or Tier 4 industrial engine to be used at ports in California.

9. Which of the ISB models do they use?
Kalmar offers both the ISB07 200 HP and ISB07 240 HP engines.

10. Allison Rugged Duty Series 3000 transmission identified in the drawing: MAX GCW in Allison spec is 80,000 lbs but spec identifies 96,000 lbs as max vehicle combined weight, is there a variant of the RDS 3000 being used with a higher rating or is there a different transmission used on the 96,000 lb vehicle?
The 3000 RDS Allison transmission used by Kalmar is not a special variant. Allison allows Kalmar to use these transmissions with higher loads due to the low speeds that the terminal tractor sees and engines that are used.

11. Are the standard RDS 3000 ratios used in this application 3.49/1.86/1.41/1.00/.75/.65?
Yes these are the standard gears, however, Kalmar limits the range to fourth gear or even third, depending on the application. This is done through the TCM.

12. Are there other transmissions that are used in the application by Kalmar?
Yes, but only for specific applications and will not be an option for this program.

13. Is there a retarder used, if so, what is the rating High/Medium/Low?
Retarders are not offered by Kalmar.

14. Does the transmission have a PTO?
A PTO is mounted to the left hand side of the transmission and is used to drive a hydraulic pump.

15. What is the torque converter used in the RDS 3000 typically? TC411/413/415/417/418/419/421
This information will be supplied once the hybrid drive system supplier has been selected.

16. What is the rear axle ratio(s) used on the vehicle?
10.59:1 or 12.28:1, others are offered but these are the preferred

17. What is the effective rolling radius of the tire(s) used on the vehicle?
Loaded radius is 19.2"

18. What is the frontal area of the vehicle w/o trailer?
8 ft. wide x 12 ft. high (96 sq. ft.) is what is used by Kalmar for running scans.

19. What is the effective frontal area of the vehicle w/ trailer?
This would be dependant upon the trailer. It is an unknown and will need to be discussed during the design process.

20. With an ISG approach, the key packaging information would be that of the engine/transmission area. Going forward we would want to work with Kalmar to understand the package constraints in the engine bay. This would require some CAD models of the cab/engine/transmission area.
This information will be supplied during the design process after a supplier has been selected.

21. Respondent would want to explore the potential to shift the transmission slightly rearward, and whether changes to the prop. shaft are acceptable, given the axle travel and critical prop. shaft angles.
This information will be supplied during the design process after a supplier has been selected.

22. What is the max "loaded" weight that would be applied to the rear wheels?
Kalmar does not expect more than 42,000 lbs.(21,000 kg.) to be applied at the rear axle.

23. What is the max load the front and rear axles are rated to?
See earlier responses and the Technical Specifications document.

24. Is there a DC battery voltage that Kalmar is not comfortable going beyond?
No.

25. What is the tire radius of these tractors today?
Refer to earlier response

26. The mentioned minimum speed of 40 km/h should be reached up to what combined vehicle mass?
Fully loaded

27. Are there special safety regulations for port applications, particularly for hydraulic accumulators or hydraulic components in general?
These details will be discussed with the selected supplier

28. Are there requirements for durability of the components and maintenance periods?
These details will be discussed with the selected supplier

29. What are the vehicle performance requirements?
Refer to the Technical Specifications document

30. Is the PTO driven hydraulic pump required? Can it be driven directly by the engine?
Yes, the hydraulic pump to raise and lower the 5th wheel is required, however, the engine drive systems (front or rear accessory drives) are not capable of providing the torque required for driving a hydraulic pump large enough for the 5th wheel lifting system.

31. What power rating of the proposed diesel engine will be available for this project?
200, 240 or 260 HP depending on the type of the hybrid drive system

32. Is there an electronic diesel control? Is the diesel control accessible via CAN-Bus for reading (speed, torque, power) and setting (speed, torque)?
Yes

33. Is it possible to get the tractor equipped with a larger wheel radius?
No

34. What is the articulation of the drive shaft and suspension?
Terminal tractors with rear suspensions generally will have 4" of total travel, 2" up and 2" down, however the tractors in Long Beach do not have rear suspension so the rear axle does not move relative to the frame.

35. Are there ABS or TCS? What kind?
Neither ABS nor TCS are required for port application.

36. Can we get a copy of Kalmar electrical specification ESN-0021?
Once the supplier has been selected

37. How much support can we expect from the engine supplier and brake supplier?
Full support

38. What CCP (CAN Calibration Protocol) s/w are they planning on using? What files are we to supply (dbc)?
This depends on the engine selected

39. Does the vehicle need a red emergency stop function for the hybrid function?
No.

40. Can the gas tank and other equipment be moved around?
Yes, but new locations will need to be reviewed by Kalmar

41. Can we take up the space behind the driver's rear window or other space behind the cab?
There is space in various locations that could potentially be used, however, this will be addressed after a supplier has been selected

42. Concerning the accessory drive package on page 1-2, do we have the freedom to run all accessories from the hydraulic systems or is there a requirement for any of these devices to be electric?
The hybrid drive system supplier will have the freedom to determine the drive method for accessories, but Kalmar will have the final approval

43. What us the range at top speed? (Are there limits to the duty cycle or are these expected to be used for occasional transport regionally or across regions at top speed?)

These vehicles are certified for off-road use only and will not leave the port.

44. What is the typical vibration on these tractors? Standard environmental specification requirement.

No information available

45. Is the Allison transmission RDS3000 a manual 6 speeds forward, 3 speed reverse?

6 forward, 1 reverse

46. Is the truck equipped with a dual differential?

No

47. Is ABS required? Is there a ABS preferred system? Is the preferred system J1939 compliant for its speed sensor inputs and engine brake disable output? Does it have an engine brake disable output?

ABS is not required for the port tractor

48. Do the vehicle engines use brake retarders such as compression or exhaust brakes? If so, what is the user interface for selecting the enable/disable and level?

There are no brake retarders used for these vehicles

49. Does the hydraulic system need to operate above where it would operate with the engine at idle speed (700RPM or so?) i.e. does the operator need to select a high idle or engine PTO control mode in the existing system when operating hydraulics other than power steering?

Currently, the operator does not need to speed up the engine for operating the Power Steering. However, some drivers will speed up the engine to raise the boom quicker.

50. Is air compressor only for brake system or for other components of the tractor and the trailer?

It is also used for other components besides the brakes. Refer to section 14 of the technical specifications.

51. Can we add capacity to the reservoir or does the air system need to remain unaltered?
Yes, additional capacity can be added but the brake system must not be affected

52. Fuel choice – The specification requests *diesel* hybrid vehicles. In recent years, a significant amount of progress has been made with cleaner burning alternative fuels such as gasoline, CNG, LNG and hydrogen. It is our understanding that hydrogen can be made available at the ports via a pipeline from nearby refinery suppliers.

a. Is diesel the only fuel choice that will be considered in the RFP?
The Port of Long Beach has a preference for diesel however other fuel choices will be entertained.

b. If not, can we be provided with some indication of the order of fuel preference?
We prefer ULSD, O2 diesel, or gasoline due to the current infrastructure situation at the container terminal however other fuels may also be proposed

B. Questions about the Vehicle in General

1. Will supplier information for the hydraulic pump, power steering, HVAC, and air compressor be provided to the bidders?
Only the information found in the Technical Specification document will be provided at this point. The selected supplier will have access to more detailed information

2. Is there a preference to hydraulic vs. electric architectures? If yes, what benefits are given by the system that creates that preference?
No. This project is technology neutral and bidders are encouraged to propose any and all types of hybrid architectures. All hybrid architecture will be evaluated equally. However, all technologies must be justified by the business case.

3. Bidder requests that UL standards be added as an acceptable standard because the industrial drives we use conform to 508C.
This will be taken into consideration

4. The bidder requests that information provided from the Altoona Bus test results that included similar equipment, installation, and wiring methods be accepted in lieu of SAE testing.
This will be taken into consideration but additional testing may be required.

5. The bidder requests the use of orange-colored conduit for high-voltage wirings.
Kalmar does not have any objection to this

6. The diagram on page 1-2 of the specification indicates a series hybrid configuration. Is this the desired configuration?
No. Any configuration will be considered

7. Hybrid configuration – Recent developments in energy storage have expanded the potential for all electric and plug-in hybrid applications. In many cases, minor changes in the operating profile can yield significant emissions, fuel economy and operating cost benefits.

a. Will POLB and Kalmar consider a proposal for an all electric (battery only) vehicle that could operate for extended periods (2 hours) before requiring a rapid (20 minutes) recharge of the batteries?
Due to operational concerns, that arrangement would not be feasible at the test site. Vehicles must be capable of operating for at least 4 hours continuously with a minimum of 1 hour for recharging prior to the next 4 hour work segment.

b. Could the operating profile be modified slightly to permit rapid recharge while the vehicle is waiting in line and normally idling?
This does not appear to be feasible at LBCT.

c. Will POLB and Kalmar consider a proposal for a battery dominant (PHEV) vehicle which would include a small engine or other power source for battery recharging?
This would be considered only if charging could be completed during the 1 hour meal break.

d. If so, is diesel the only fuel option?
No. See above for acceptable fuel options.

e. Would a near ZEV capable hydrogen fueled charging system be of interest to POLB?
All proposals will be considered equally. For a hydrogen-fueled system, the hydrogen fueling infrastructure must also be proposed and the associated costs would be weighed as part of the business case.

C. Questions and Information about the Duty Cycle

1. Will a duty cycle be provided in the RFQ?
A complete duty cycle will not be available until the 2nd or 3rd quarter of 2008 but some key duty cycle statistics may be available by the time the RFP is issued.

2. How much of the duty cycle is being used by engine idle?
Approximately 50%. However, fuel consumption during idling is only about 20%. Se next question for more details.

3. The cover letter states that the vehicles are expected to operate approximately 2,500 hours per year with 50% idle time. We would like to get more detail on the operating profile.
A more detailed duty cycle analysis will be performed at a later date and will be provided to the selected supplier.

   a. Is the time spent idling included in the 2,500 hour estimate or is that additional? In other words, does the vehicle work for 1,250 hours and idle for 1,250 hours?
   Yes, over a one-year period, the vehicle operates in a non-idle state for approximately 1250 hours and is running at idle for approximately 1250 hours.

   b. Has the operating data been analyzed to give a time distribution of working and idling times?
   No. The project team is currently in the process of developing a detailed duty cycle. While the entire duty cycle will most likely not be completed before the RFP is issued, some details may be available. A general description of terminal tractor duty cycles is given below.

   c. Is the vehicle required to work continuously for extended periods of time? If so, what is the maximum duration (4 hours, 18 hours, etc.)?
   The work cycle at the test facility is 4 hours of work and then a one-hour meal break. The maximum continuous time a vehicle will work is 6 hours.

<u>Note: General Description of Terminal Tractor Duty Cycles</u>

Observations and timing studies of terminal tractor activities at LBCT indicate that terminal tractors spend approximately 50% – 60% of their duty cycle idling. Most idling periods last 1 – 2 minutes at a stretch and are typically associated with terminal tractors waiting in loading or unloading

queues. Queues of 3 – 4 terminal tractors waiting for their turn to be loaded or unloaded by a piece of cargo handling equipment are fairly routine.

In general, individual terminal tractor activities average between 10 and 15 minutes in duration depending on conditions in the yard. Speeds within the yard vary from a crawl (typically while waiting in a loading or unloading queue) up to around 35 mph (typically a bobtail or a UTR pulling a bare chassis). Average speeds for heavily loaded terminal tractors (e.g. a UTR pulling a full container) tend to be around 15 – 20 mph sustained.

The total driving distance for a particular terminal tractor activity depends on many factors including the size and layout of the yard. At LBCT, the total driving distance associated with most activities is around 0.8 – 1.0 miles. Depending on the location of a particular container however, a particular activity can easily involve a driving distance of up to approximately 1.5 miles. Note that LBCT is considered a relatively small terminal and the driving distances for similar activities at larger terminals may be considerably longer, e.g. several miles. In such cases, the percentage of terminal tractor idling would tend to decrease as the relative percentage of driving time increases.

D. Questions about the Overall Project

1. What is the expected project timing?
It is anticipated that the RFP will be issued before the end of the year or early 2008 and the contract awarded in the first quarter of 2008. Depending on the systems integration period, the on-site demonstration is expected to begin during the second half of 2008.

2. Are the testing requirements that are called out in Section 4.3 to be included as part of the bid or are there other sources already established that will cover the cost?
Section 4.3 will be removed in the Request for Proposals

3. Will there be a third-party review of simulation and test information prior to acceptance of a bid?
The project team will review this information as part of the overall evaluation process. No separate third party will be used.

4. What kind of non-identity will be maintained regarding hybrid solutions through the RFQ process?
Anything submitted is public domain. Therefore, bidders should be cognizant of that when submitting their bids.

5. How much involvement will there be with the OEM?
Kalmar is a key member of the project team and will be responsible for the entire vehicle integration process. They intend to work hand-in-hand with the chosen supplier.

6. Will tractors be provided as part of the program?
The 5 tractors to be upfitted with the hybrid drive system will be provided to successful bidder as part of integration process. Kalmar and the supplier will jointly decide where the integration takes place.

7. Respondent needs to understand more about the EPA's role in this project as EPA is currently actively involved with their competitors on hybrid technologies. (The EPA recently announced the East Coast Port Project and their partnership with Kalmar and another hybrid drive system supplier)
This project is completely separate from the hydraulic hybrid terminal tractor project that is underway on the East Coast. EPA Region IX has provided grant funds to the San Pedro Bay ports for this project. A separate part of the EPA is involved in the East Coast hydraulic hybrid terminal tractor project.

8. How many vehicles are in the current fleet that are possible for hybridization if technology proves out favorably?
The number of vehicles in any particular fleet is irrelevant. The overall market for new terminal tractors in North America is approximately 4,000 vehicles/year.

9. Where is the development of Kalmar located for this terminal tractor?
This will be decided by Kalmar and the selected supplier.

10. Where will hybrid tractors be manufactured in series production scenario?
Ottawa, Kansas

11. Will it be a requirement of winning bidder to be a currently approved Kalmar supplier?
No, however, the approval process will be initiated upon award, if the winning bidder is not a currently approved supplier.

12. Will baseline tractors be provided to winning bidder for integration of hybrid system or will winning bidder supply a system "kit" for Kalmar to integrate/install?
From a production perspective, this will depend on the integration process that is established by Kalmar and the winning bidder. With respect to the 5 prototype tractors in this project, the supplier team will play an active, hands-on role in the integration of the hybrid drive system with the vehicle.

13. Will the 5 hybrid drive systems be purchased by project team?
To be specific, the 5 hybrid vehicles will be purchased by members of the east and west coast project teams.

14. Is there a specific cost-share requirement?
No.

15. For the evaluation of the fuel consumption benefits for all applicants should be provided with the same consumption characteristics.
This will be covered in the RFP.

16. For the evaluation of the emissions benefit of hybrid system it would be useful to receive emission data of the engine in a table form like NOX and PM depending on engine speed n, torque M and its gradients dn/dt, dM/dt. Furthermore as this data is possibly not available from measurements it would be useful if such an assumption would be provided for all hybrid applicants by the project team and all applicants will estimate the emission benefit on that basis.
Duly noted

17. How will emission be measured, what is the test procedure?
Emissions and fuel economy will be tested on a chassis dynamometer using the duty cycle that is currently being developed. Fuel economy will also be evaluated as part of in-use testing during an 8-month vehicle deployment phase.

18. Are there target values for emissions and fuel usage?
There are no set target values but we expect that the supplier will maximize emissions and fuel usage reductions within the constraints of the business case.

19. Does POLB have a target budget for this program? If yes, will the budget be disclosed in the RFP?
Yes. The basic project budget will be disclosed in the RFP.

20. The documentation provided to date has been impressive. However to fully model the hydraulic hybrid requirements and to deliver the best data possible we would request hat the following information if not previously provided be included in the RFP.

a. Modeling information requirements
   i. Weight of the vehicle
   ii. Vehicle rolling friction
   iii. Drag coefficient
   iv. Engine map showing fuel usage relative to power output
   v. Grade capability up hills in forward and reverse
   vi. Minimum acceleration requirements (they probably use 0-50Kph and 0-100Kph and a 50-100Kph)

b. Additional information requirements
   i. Weight of OEM transmission
   ii. Dimensions of vehicle (needed for stall size)
   iii. Performance goals of POLB
   iv. Detailed driving cycle (If we do not get this we will have to use the standard stop and go and highway model U.S.)
   v. CAD packaging models so we can confirm our stuff will fit

We will provide as much of this information as possible.

21. Fuel economy and emissions will be most improved if there are smaller engine candidates available (relative to the conventional vehicle). Have candidate engines of lower power ratings been identified?

No but the supplier team may propose a lower rated engine if they wish.

22. In addition to the hybridization of the drivetrain, can hybridization be expanded to include the electrification of auxiliary components such as the hydraulic pump and engine cooling fan?

Yes. All proposals to expand hybridization opportunities will be welcome.

E. Questions about the Business Case

1. What payback or business case criteria is required to make this a feasible commercialization project?

The project team has no set targets. Commercialization will depend on the successful bidder's business case proposal along with Kalmar's production costs.

2. Will you be looking at a total cost for project or a per vehicle cost?
Per vehicle cost however the project team will also pay a one-time lump sum of $300K to the selected supplier to help defray hybrid drive system development costs.

3. Do you have an established base that will be utilized for development of a lifecycle cost?
No but typical elements will include fuel savings, maintenance costs and incremental costs. Emissions reductions will also be factored in.

4. What does POLB consider the lifetime expectancy of the vehicle with a hybrid drive train?
10 years

5. Post validation, what is POLB's most desirable OEM supply model? (Vehicle OEM, Upfitter, Leasing company or other)
Vehicle OEM

6. What is POLB's target return on investments for:
   i. Fleet basis?
   ii. Per vehicle basis?
   iii. On a MTBF and MTTR basis?

It is impossible to answer this question at this time. POLB normally does not purchase the vehicles and this project is a demonstration only. Future ROI determinations will depend on the specific application and its business case.

7. What are the advantages or disadvantages to POLB of a "hybrid" vehicle with a reduced or weight neutral curb weight when compared to the conventional transmission vehicle?
The main driver for the Port is reduced emissions. Reduced weight is not a major factor in the decision to proceed with this demonstration.

8. What is the preferred supply chain for hybrid transmission spare or replacement parts?
   i. Are the vehicles repaired in house? Regional distribution points
   ii. At what point are the vehicles sent out for repair? Where are they sent?

Major service and parts needs are handled by Kalmar's regional distributor. LBCT handles minor repairs in-house. A key determinant to the supply chain is whether a vehicle is still under warranty.

10. How do carbon credits or carbon trading influence the vehicle purchase opportunity?

These are not significant factors at this time. However this may change in the future as the value of GHG reductions increases.

11. Cost analysis – Based on the current fuel consumption, the business case for this vehicle will be a challenge for all hybrid system suppliers. We would like more details on the method that will be used to evaluate proposals from a cost basis.

a. Is the POLB and Kalmar looking for the lowest cost hybrid option?

Cost is not the only factor in this project. Emissions-reductions capabilities and reliability will both be given high weights in the evaluation of responses.

b. Will any value or credit be given for a more expensive, but cleaner, more fuel efficient system?

Emissions reductions potential will be highly weighted but there must also be a business case.

c. Will environmental and medical cost impacts be considered in the overall cost analysis of the proposals?

Overall lifecycle costs and impacts will be considered. The relative importance of environmental and medical cost impacts will be factored into the weighting for emissions reductions.

d. Hybrid-electric or electric drive system components have an operating life that typically exceeds the operating life of present day vehicles. Would there be any consideration towards keeping the drive system and changing out the rest of the vehicle for a mid-life overhaul?

This is generally considered unlikely.

APPENDIX B

Request for Proposals (RFP) – Hybrid Drive System Suppliers

925 Harbor Plaza, Long Beach, CA 90802 Tel 562.437.0041 Fax 562.901.1725

The Port of
LONG BEACH

DATE: February 7, 2008

TO: Potential Hybrid Drive Suppliers

SUBJECT: Hybrid Terminal Tractor Demonstration Project Request for Proposals

The Port of Long Beach (POLB) and the Port of Los Angeles (POLA) are pleased to invite you to submit a proposal for hybrid drive systems to be integrated into terminal tractors in accordance with the attached Request for Proposals (RFP). You have received this RFP because we believe your company is either a potential supplier of hybrid drive systems for this type of vehicle, or may perform a critical role in a hybrid drive system supplier team. In addition to POLB and POLA, other project team members involved in this demonstration include the U.S. Environmental Protection Agency (U.S. EPA), Long Beach Container Terminal Inc. (LBCT), Kalmar Industries, and WestStart-CALSTART.

This RFP is specifically aimed at reducing emissions from cargo-handling equipment (CHE) at marine ports, but the technology is also applicable to other terminal tractor applications such as distribution centers and intermodal rail yards. The selected supplier team will be contracted to develop and deliver up to five (5) hybrid drive systems that will be integrated into Kalmar Ottawa 4x2 Terminal Tractors. Specifications and requirements for a hybrid version of the Kalmar Ottawa 4x2 Terminal Tractor are included in the attached RFP. One of the main goals of the project is to help accelerate the commercialization of hybrid terminal tractors, provided that the vehicles demonstrate they can meet the performance requirements for the application, and there is a clear path towards an eventual business case.

This project, funded by the ports and the U.S. EPA, will demonstrate three (3) hybrid terminal tractors at LBCT and two (2) hybrid terminal tractors at an east coast container terminal. Details of the east coast demonstration project are expected to be finalized in the near future and information will be made available at that time.

Final responses to the RFP are due by 4:00 p.m. Pacific Time, March 24, 2008.
Please submit one (1) copy of your proposal in either hard copy (U.S. Mail) or e-mail form to:

Allyson Teramoto
Environmental Specialist Associate
Port of Long Beach
925 Harbor Plaza
P.O. Box 570
Long Beach, California 90802
teramoto@polb.com

Any questions concerning this RFP should be directed to Allyson Teramoto at the email address listed above.

On behalf of the ports and the rest of the project stakeholders, we are excited about this opportunity to demonstrate the benefits of hybrid technology in a marine terminal tractor application, and are looking forward to your responses.

Sincerely,

Richard D. Cameron
Director of Environmental Planning

AT:s

Ports of Long Beach and Los Angeles
Hybrid Terminal Tractor Demonstration Project

Request for Proposals (RFP)

Dated: February 7, 2008

Queries to: Allyson Teramoto, Port of Long Beach
teramoto@polb.com

Deadline for proposals: March 24, 2008

TABLE OF CONTENTS

1.0 Background

On November 20, 2006, the Board of Harbor Commissioners of the Ports of Long Beach and Los Angeles adopted the Final 2006 San Pedro Bay Ports Clean Air Action Plan (CAAP)[1]. The CAAP is a cooperative effort involving the two Ports, the United States Environmental Protection Agency Region 9 (EPA), the California Air Resources Board and the South Coast Air Quality Management District. The CAAP is a five-year action plan and is expected to reduce port-related smog-forming NO_X emissions by more than 45% and diesel particulate matter emissions by more than 50%.

A significant initiative of the CAAP is the Technology Advancement Program (TAP), which is intended to accelerate the availability and implementation of new technologies and strategies that will ultimately reduce diesel particulate matter (DPM), nitrogen oxides (NOx), sulfur oxides (SOx), and other pollutants. PM and NO_x are of particular concern due their potential impacts to public health and ozone formation.

Terminal tractors (also referred to as yard hostlers, yard trucks, utility tractor rigs, yard goats, yard hustlers and yard tractors) are heavy-duty off-road truck tractors designed for moving cargo containers. Normally, the terminal tractor is connected to a trailer which is used to help transport containers. In a typical operation, a container is loaded onto the trailer by a piece of cargo handling equipment (CHE) such as a top-pick, side-pick or rubber-tired gantry (RTG) crane. The terminal tractor then drives (tows) the trailer with the container to a destination within the terminal where the container is unloaded by another piece of CHE. Hybrid terminal tractors present a new application for a proven technology that could potentially provide significant emissions reductions and fuel economy benefits.

The 2005 air emissions inventories[2] for the ports of Long Beach have estimated that tenant-owned CHE is responsible for the greatest portion of landside air emissions from port operations. Within the CHE category, approximately two-thirds (67%) of the equipment/vehicles in operation are diesel powered terminal tractors. The 2005 emissions inventory also showed that terminal tractors were responsible for 62.1% of NO_x emissions, 57.3% of total organic gas (TOG) emissions, 66.7% of carbon monoxide (CO) emissions, and 67.9% of particulate matter (PM) emissions from all CHE at container terminals.

Hybrid drive systems have been demonstrated to be successful in reducing emissions and meeting operational requirements in medium- and heavy-duty on-road applications. However, hybrid drive systems have never been demonstrated in off-road terminal tractors. This demonstration project will be the first to utilize a hybrid propulsion system to power off-road terminal tractors at marine ports. In addition, major benefits of diesel

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[1] www.cleanairactionplan.org

[2] Emissions Inventory 2005 Full Report, Port of Long Beach, http://www.polb.com/environment/air_quality/documents.asp

or gasoline hybrid technology includes no change in fueling infrastructure required to operate the new equipment, as well as regenerative braking that allows energy normally lost during mechanical braking, to be captured by the energy storage system, resulting in increased fuel efficiency. Further, it is expected that operating characteristics will be practically unchanged compared to conventional diesel terminal tractors. These factors will potentially increase operator acceptance and ease of implementation of the hybrid technology by terminal operators.

2.0 Project Overview and Goals

2.1 Overview

This project will demonstrate hybrid drive system technology in terminal tractors at the POLB and potentially at an east coast port. An expected total of five (5) terminal tractors integrated with hybrid drive systems will be delivered and placed into service to evaluate performance and emissions compared to baseline diesel terminal tractors. Three (3) of the hybrid terminal tractors will be placed with a tenant of the POLB and two (2) will potentially be placed into service at the east coast port.

To carry out this project, a knowledgeable and experienced team has been assembled to address the goals described below. The project team consists of POLB, POLA, Long Beach Container Terminal Inc. (LBCTI), Kalmar Industries, and WestStart-CALSTART. LBCTI, a container terminal operator at POLB, has volunteered to place the hybrid terminal tractors into their fleet and assist with evaluation of the vehicles under real-world marine terminal conditions. Kalmar Industries, the world's largest terminal tractor original equipment manufacturer, will be providing technical expertise to assist with the specification and integration of the hybrid drive systems into Kalmar's existing terminal tractor product line. WestStart-CALSTART, a non-profit, fuel-neutral, advanced transportation technology consortium, will be providing technical management of the project for POLB and POLA. In addition to the project team, $300,000 in project co-funding is being provided by the U.S. Environmental Protection Agency's (EPA's) West Coast Diesel Collaborative specifically for the development of the hybrid drive system.

There is a high probability that this demonstration project will be expanded to include two (2) additional hybrid terminal tractors that will be operated at an east coast port in parallel with the POLB demonstration. Due to the timing of this RFP, the details of the east coast project have not been finalized but are expected to be announced during the first quarter of 2008. Kalmar and WestStart-CALSTART will also be involved as the OEM supplier and third-party project manager respectively for the east coast expansion of the hybrid terminal tractor project.

In this RFP, the term "supplier team" is intended to indicate either a single supplier or a group of suppliers acting as a supplier team. It is the intent of this RFP that a single supplier team will be selected for the POLB and the potential east coast project. The supplier team will be responsible for providing and integrating the hybrid drive system into the current model Kalmar Ottawa 4x2 terminal tractor platform. With the addition of

the east coast port demonstration project, a total of five (5) terminal tractors are anticipated to be integrated and delivered by the selected supplier team.

2.2 Project Goals

The primary focus of the demonstration projects is to reduce emissions in marine terminal environments. In addition, it is anticipated that the hybrid drive systems will at least partially offset the increased vehicle cost via reduced fuel consumption, thus paving the way to widespread acceptance of hybrid technology for this application.

While hybrid technology has been demonstrated in on-road applications, off-road terminal tractors operating in demanding marine terminal environments are subject to different performance requirements. Therefore, an important element of the demonstration projects is to determine the capability and reliability of the hybrid terminal tractors in real-life settings and duty cycles at port terminals. Moreover, evaluations of the fuel consumption, operational impacts and emission reductions are necessary to understand the business case for expanded use of hybrid terminal tractors in marine terminals and other terminal tractor applications such as intermodal rail yards and distribution centers.

The goals of the demonstrations are:

- Performance Evaluation: Evaluate the in-use performance of the hybrid terminal tractor compared to baseline diesel terminal tractors in a marine terminal environment. This evaluation will include fuel consumption, vehicle performance, operator acceptance, reliability, maintenance and service.
- Quantification of Emissions Reductions: Chassis dynamometer testing will be performed to compare emissions of hybrid vs. baseline diesel terminal tractors using a port terminal tractor duty cycle currently being developed.
- Assessment of Business Case: Assess the business case for large-scale tenant fleet use of hybrid terminal tractors including life-cycle cost (LCC) assessment, potential market size, identification of any issues for commercialization and general recommendations.

3.0 Technical Information

3.1 General

This RFP is technology- and fuel-neutral and all proposals will be considered regardless of the hybrid architecture, technology or supporting infrastructure proposed. Bidders are encouraged to propose any and all types of hybrid architectures. However, all technologies and fuel choices must show a clear path towards commercialization and be justified by the business case.

3.2 Hybrid Terminal Tractor Vehicle Specifications

The hybrid terminal tractor technical specifications are provided in Appendix A: "Ottawa 4x2 Hybrid Terminal Tractor Specifications and Requirements." Additional technical

details regarding the vehicle will be provided to the winning supplier team following selection.

3.3 Integration

An integration process and location of integration for the hybrid drive systems will be mutually agreed upon by the winning supplier team and Kalmar. With respect to the five (5) prototype tractors in this project, both the supplier team and Kalmar will play an active, hands-on role in the integration of the hybrid drive system with the terminal tractor chassis and components. Note that Kalmar will be supplying new, current year terminal tractors for integration with the hybrid drive systems.

3.4 Fuel Choice

While this RFP does not mandate a particular fuel, fuel choice preferences for POLB and LBCTI are Ultra Low Sulfur Diesel (ULSD), O2Diesel™, or gasoline based on the current infrastructure at LBCTI. No modification to the existing fuel infrastructure or changes in fuel supply will be made to implement the project, unless the cost can be justified and a reasonable business case presented. Other fuel choices (e.g. hydrogen, compressed or liquefied natural gas, biofuels, etc.) may also be proposed and will be considered. However, fueling infrastructure must also be proposed and the associated costs will be evaluated as to their impact on the business case.

3.5 Duty Cycle

A terminal tractor duty cycle is currently being developed for emissions testing purposes. A final duty cycle will not be completed until the 2nd or 3rd quarter of 2008, however, some high level duty cycle statistics are provided below.

The typical in-use duty cycle for a terminal tractor includes a high percentage of idling as the vehicles wait in queues during loading and unloading of containers. Observations and timing studies of terminal tractor activities at POLB indicate that the vehicles spend approximately 50% of their duty cycle idling, depending on terminal size, utilization, and other factors. The inventory of equipment conducted in 2005 indicated an average annual operating time of terminal tractors of 2,200 hours, resulting in an average of around 1,100 hours of idling. Most idling periods last 1 – 2 minutes at a stretch and are typically associated with terminal tractors waiting in loading or unloading queues. Queues of 3 – 4 terminal tractors waiting for their turn to be loaded or unloaded by a piece of cargo handling equipment are fairly common. However, fuel consumption during idling is only about 20% of the total fuel consumption.

In general, individual terminal tractor activities average between 10 and 15 minutes in duration depending on conditions in the yard. Speeds within the yard vary from a crawl (typically while waiting in a loading or unloading queue) up to 25 mph or more (typically a bobtail or a terminal tractor pulling a bare chassis). Average speeds for heavily loaded terminal tractors (e.g. a terminal tractor pulling a full container) tend to be around 15 – 20 mph sustained.

The total driving distance for a particular terminal tractor activity depends on many factors including the size and layout of the yard. At LBCT, the total driving distance associated with most activities is around 0.8 – 1.0 miles. Depending on the location of a particular container however, a particular activity can easily involve a driving distance of up to approximately 1.5 miles. Note that LBCT is considered a relatively small terminal and the driving distances for similar activities at larger terminals may be considerably longer, e.g. several miles. In such cases, the percentage of terminal tractor idling would tend to decrease as the relative percentage of driving time increases.

3.6 Requirements Related to Charging Infrastructure and Schedule

If a plug-in hybrid or all-electric architecture is proposed, the supplier team should also propose the necessary charging infrastructure. Vehicles are potentially available to be charged for one less than (1) hour during first shift lunch break, for less than one (1) hour between first and second shifts, for less than one (1) hour during 2nd shift meal break, and for less than five (5) hours between the end of second shift and the beginning of first shift. These are the only allotted times for charging, it is not feasible for LBCT to accommodate additional charging times for rapid charging between shifts. Proposed charging infrastructure and operations will be evaluated as to their impact on the business case.

3.7 Warranty and Service Support

The supplier team shall specify the proposed warranty and support plans for the prototype hybrid drive systems, including the energy storage components (batteries or hydraulics). In addition, the supplier team shall outline their proposed warranty and support plans for future production hybrid drive system including major components.

4.0 Project Schedule

The project will be divided into three phases:

- Phase 1- Vehicle Prototype Development
- Phase 2 - Emissions and Performance Testing
- Phase 3 - Final Report including Business Case Assessment

4.1 Phase 1: Vehicle Prototype Development

Description:

Phase 1 includes selection of a hybrid drive system supplier and integration of the hybrid drive systems with the Ottawa 4x2 terminal tractor chassis' supplied by Kalmar. Fully integrated hybrid terminal tractors will be delivered to a terminal operator at POLB (and potentially the east coast port) at the end of phase 1.

Tasks:

- Selection of hybrid drive system supplier team.

- Development of detailed port terminal tractor duty cycle.
- Development of hybrid drive system.
- Integration of hybrid drive system with Ottawa 4x2 terminal tractors.
- Delivery of fully integrated hybrid terminal tractors to POLB (and potentially the east coast port).

Schedule:
- Supplier selected in the first or second quarter of 2008.
- Winning supplier team to propose dates for delivery of hybrid drive systems and integration with vehicle chassis. The time frame proposed will be considered in the selection of the winning supplier.
- Terminal tractor duty cycle development is expected to be complete by summer of 2008.
- Initial delivery of fully integrated hybrid terminal tractors expected by the end of 2008 or early 2009 with the remainder to follow within a reasonable period of time.

Deliverables:
- Hybrid drive systems delivered to Kalmar for integration with Ottawa 4x2 terminal tractor chassis'.
- Fully integrated hybrid terminal tractors delivered to customers for testing in Phase 2.

4.2 Phase 2: Performance and Emissions Testing

Description:

Detailed performance and emissions testing will be conducted at the specified sites during Phase 2. Emissions will be tested on a chassis dynamometer using the duty cycle currently being developed. Fuel economy and other performance data will be collected as part of in-use testing during an eight (8) month vehicle deployment phase. There are no set target values for emissions reductions or fuel economy improvements but it is expected that the supplier team will reduce emissions and fuel consumption to the greatest extent possible within the constraints of the business case.

Phase 2 will be broken down into two parts: Performance Testing and Emissions Testing.

<u>Performance Testing</u>

Tasks:
- Train LBCTI mechanics for maintenance and service of hybrid terminal tractors.
- Collect fuel economy data.
- Collect driver survey data.
- Collect vehicle availability data.
- Collect maintenance/service data.
- Collect mechanic survey data.

Schedule:

- Anticipated two (2) month vehicle shake-out period.
- Six month performance testing following vehicle shake-out period.
- All performance testing expected to be completed before the end of 2009.

Deliverables:

- Performance testing data.

<u>Emissions Testing</u>

Tasks:

- Transient emissions testing on heavy-duty chassis dynamometer using previously developed port terminal tractor duty cycle.

Schedule:

- All emissions testing expected to be completed before the end of 2009.

Deliverables:

- Emissions testing report.

4.3 Phase 3: Final Report

Description:

The final project report will document the results of the performance and emissions testing. In addition, a business case assessment will be developed for expanded use of hybrid terminal tractors at ports and other terminal tractor applications such as intermodal rail yards and distribution centers. WestStart-CALSTART is responsible for the final project report and business case assessment.

Tasks:

- Summarize performance and emissions testing results.
- Perform hybrid terminal tractor business case assessment.

Schedule:

- The final report is expected to be available approximately four (4) months after the conclusion of performance and emissions testing. It is expected that the final project report will be released by the 2nd quarter of 2010.

Deliverables:

- Final report with business case assessment of hybrid terminal tractors.

5.0 Award

The POLB will award up to $300,000 to the selected supplier team on behalf of the EPA for the development of the hybrid drive system during Phase 1 of the project. Payment will be provided in capped incremental reimbursements of expenses at three (3)

milestones during the development of the hybrid drive system. The milestones and maximum amount for reimbursements for the development of the hybrid drive system are:

1. Acceptance of hybrid drive system design by Kalmar - $125,000
2. Delivery of hybrid drive system to Kalmar- $100,000
3. Hybrid drive system integrated into Kalmar Ottawa 4x2 chassis - $75,000

5.1 Project Budget

The anticipated total project cost is $1.2 million. The EPA grant funding of $300,000 will be used in combination with a total of $600,000 in funding from POLB and POLA for project administration, emissions testing, and the cost of the vehicles. In addition, in-kind labor and/or financial contributions from project partners are estimated to be approximately $300,000. LBCTI will incorporate the hybrid yard hostlers into their daily activities during the testing and evaluation period. Kalmar will provide technical expertise to assist with the specification and integration of the hybrid drive systems into Kalmar's existing terminal tractor product line.

6.0 Proposal Format

6.1 Proposal Submission

RFP responses may be provided in electronic and/or hard copy form at the discretion of the respondent to the address provided below. If RFP responses are provided in hard copy form, please submit one (1) copy of the final proposal. All proposals submitted will become the property of the POLB and will be public records. Please do not submit any confidential material in your proposals. All proposals must be received by 4:00 p.m. PST, March 24, 2008.

Proposals should be submitted to:

Allyson Teramoto
Environmental Specialist Associate
Port of Long Beach
925 Harbor Plaza
P.O. Box 570
Long Beach, CA 90802
Teramoto@polb.com

6.2 Proposal Elements

The proposal should include the following elements:

6.2.1 Proposal Cover Page

Information required on cover page:

a. Name of company/companies (supplier team) proposing
b. Names, addresses and key contacts for the companies proposing
c. Cost proposal summary for five (5) prototype hybrid drive systems
d. Estimated emissions reductions
e. Estimated reductions in fuel consumption

6.2.2 Qualifications Statement (5 pages maximum)

Outline team involved including key team members, expertise, technical approach and relevant experience. It is not necessary that the winning supplier team is currently an approved Kalmar supplier. If the winning bidder is not a currently approved supplier, the approval process will be initiated upon contract award.

6.2.3 Technical Proposal (20 pages maximum)

Provide a description of the technical design for the system being proposed, its strengths, flexibility and how the hybrid terminal tractor requirements will be met. The technical proposal shall also provide estimates of emissions reductions and fuel savings as well as the technical basis for these estimates. If there are any deviations from the hybrid drive system technical specifications, provide a description for each deviation as well as a justification, i.e. the corresponding impact on cost, performance, emissions, etc. Furthermore, the hybrid drive supplier team must obtain approvals for certain components, such as the rear axle, before the project begins if any changes are deemed necessary. It is expected that the supplier team will take the lead in procuring and integrating these components and will be included in the overall cost vs. benefits analysis during the supplier selection process. Any graphics or attachments will be counted towards the page limit.

The technical proposal shall also include a work plan outline with the following information:

a. Provide a brief outline of the major tasks to be performed.
b. Note the major development milestones and schedule.
c. Provide a schedule for hybrid drive system delivery to Kalmar for integration.
d. Provide an expected integration timetable.
e. Provide a list of all major deliverables.

6.2.4 Warranty and Support Plans (5 pages maximum)

Provide a brief description of the warranty and support plans for the prototype hybrid drive systems to be supplied for this project. Also provide an outline of proposed warranty and support plans for future, commercial volume production hybrid drive systems.

The prototype hybrid drive system support plans shall identify how the supplier team will be organized and dedicate appropriate resources to provide timely response to issues that arise both during and after the warranty period. The plan shall identify key personnel

who will be responsible for responding to initial phone calls and how they will determine if or when additional personnel will be required.

6.2.5 Cost Proposal (4 pages maximum)

Provide a detailed cost description outlining the proposed cost on a per-unit basis for five (5) hybrid drive systems fully integrated into an Ottawa terminal tractor chassis. Please include any in-kind labor or financial contributions towards the development of the hybrid system, if available. Please note that the amount of in-kind leveraging will not be used as a selection criterion. In addition, please specify which components of the existing system the hybrid drive system will replace.

6.2.6 Business Case Proposal (4 pages maximum)

The supplier team shall provide a high level business case justification for the proposed hybrid terminal tractor drive systems. While no targets have been set by the project team for the business case, the bidder's business case proposal will be considered as part of the supplier team selection criteria.

The following table provides typical values for key business case parameters associated with terminal tractors in port applications that potential suppliers may find useful.

Parameter	Average Value
Average operating hours per year (including engine idle time)	2,200
Average fuel consumption rate	1.7 gallons per hour (diesel)
Average % of time spent idling	50% (i.e. 1,100 hours per year)
Average annual fuel consumption during idling	20% of total annual fuel consumption
GCVWR (Gross Combined Vehicle Weight Rating)	96,000 lbs.
Service life	10 years

In addition to the cost of the five (5) hybrid drive systems on a per unit basis, provide a description of expected price reductions at annual production volumes of 500, 1000, 2000, and 3000 units.

While cost is certainly a significant factor in the selection process, other factors including emissions reductions will also be highly weighted. Nevertheless it is important that the supplier team show a reasonable path to a business case for the incremental cost of the hybrid drive system compared to the existing diesel drive system.

7.0 Federal Grant Requirements

This contract will be partially funded by a grant from the Federal Environmental Protection Agency. See Appendix B. The winning supplier team will be required to

comply with all applicable terms of the grant, including audit requirements, recycled paper requirements, lobbying and litigation restrictions, suspension and disbarment rules and small and disadvantaged business utilization requirements, and to include any applicable requirements in subcontracts. Due to grant deadlines, time is of the essence in the project timeline and all submission deadlines. The winning supplier team will also be required to cooperate with the Port to ensure compliance with the grant and its reporting requirements, and with Federal Acquisition Regulations, including those attached as Appendix C.

8.0 Additional Contract Requirements

The winning supplier team will be required to execute a contract substantially in the form attached as Appendix D. The contract will incorporate the grant and require compliance with the grant. If a proposer is not prepared to execute a contract in this form, the proposal must indicate which provisions are unacceptable.

9.0 Selection Criteria

The selection of the winning proposal and supplier team will be a weighted assessment based on key criteria for success as outlined below. In its selection criteria, the project team will weigh the following parameters in choosing the winning team:

- Estimated emissions reductions – 30%
- Technical proposal including qualifications of supplier team – 30%
- Business case proposal – 15%
- Schedule proposed by supplier team for delivery of hybrid drive system – 15%
- Cost proposal – 10%

The project team reserves the right to reject all proposals if all potential suppliers are deemed unsatisfactory.

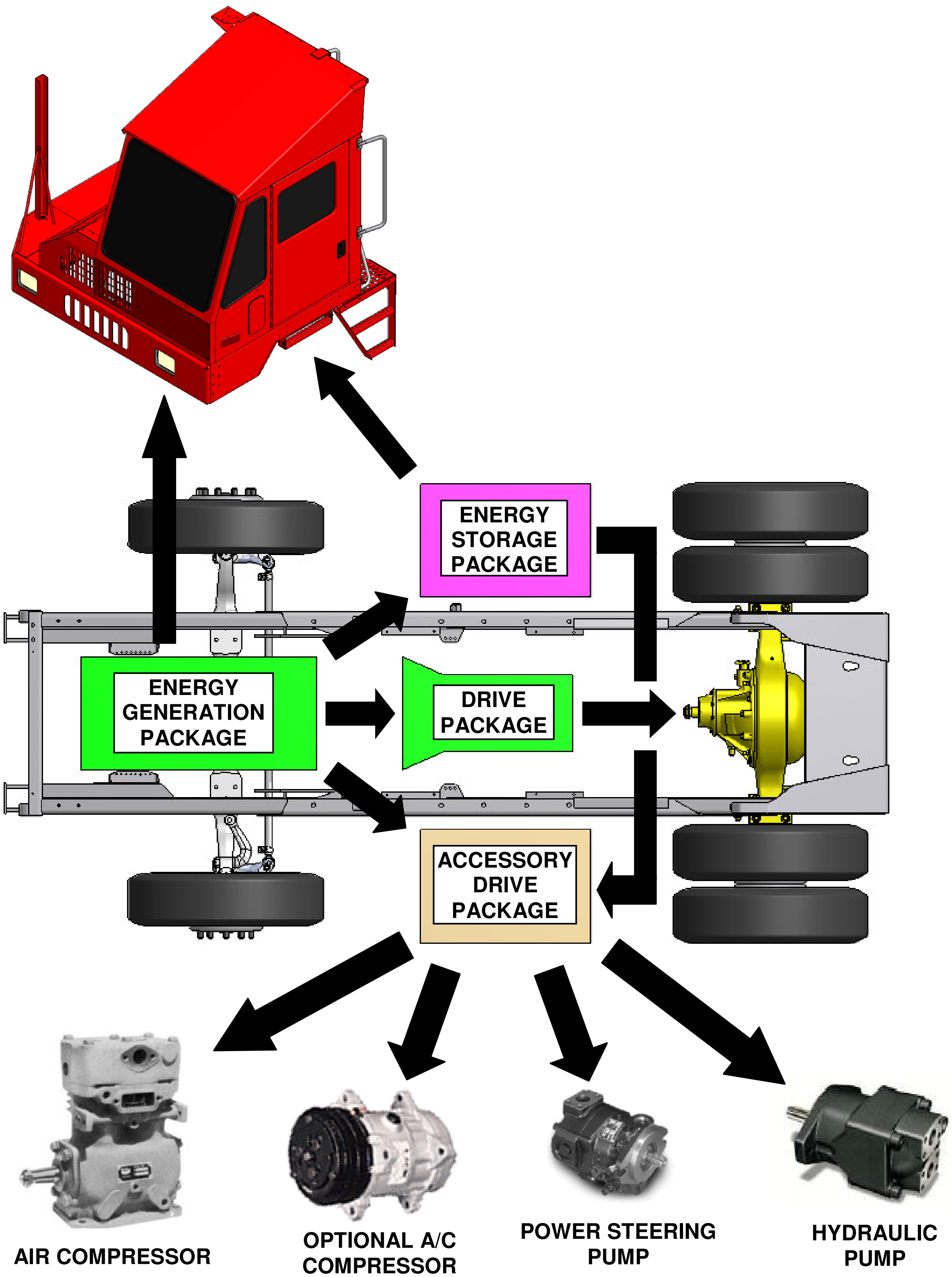
Appendix A

Ottawa 4x2 Hybrid Terminal Tractor Specifications and Requirements

October, 2007

Index

Section 1
Sample Hybrid Drive System Diagram


ENERGY STORAGE PACKAGE
ENERGY GENERATION PACKAGE
DRIVE PACKAGE
ACCESSORY DRIVE PACKAGE
AIR COMPRESSOR
OPTIONAL A/C COMPRESSOR
POWER STEERING PUMP
HYDRAULIC PUMP

Section 2
Performance Requirements

Performance

1. Performance requirements are to be based on the minimum GCVW of 96,000 lbs. (43,500 kg.) and the Coefficient of Drag (Cd) at 0.70.

2. 16% minimum launch gradeablity.

3. 25 MPH (40 KPH) minimum speed forward.

4. 5 MPH (8 KPH) minimum speed rearward.

5. 0-20 MPH (0-32 KPH) in minimum 16 seconds.

Section 3
Weight
Requirements

Weight Requirements

1. 96,000 lbs. (43,500 kg.) minimum Gross Combined Vehicle Weight (GCVW).

2. 16,000 lbs. (7,250 kg.) maximum gross vehicle weight (GVW). *Typical diesel powered terminal tractor weighs 14,200 lbs. (6,441 kg.).*

3. 9,800 lbs. (4,440 kg.) maximum weight at front tires with no load on 5^{th} wheel. *Typical diesel powered terminal tractor weight at front tires is 9,200 lbs. (4,173 kg.).*

4. 6,200 lbs. (2,810 kg.) maximum weight at rear tires with no load on 5^{th} wheel. *Typical diesel powered terminal tractor weight at rear tires is 5,000 lbs. (2,268 kg.).*

Section 4
Hybrid Drive System
General Design Requirements

Hybrid Drive System General Design Requirements

1. Hybrid drive systems using hydraulic propulsion:
    a. Hydraulic hoses are to meet the appropriate SAE J517 100R specifications based upon their size and pressure requirements.
    b. Hydraulic hose ends are to be 37 degree flared, o-ring boss or flange type and are to meet SAE J516 specifications.
    c. Hydraulic tube fittings and adapters are to be 37 degree flared or o-ring boss and are to meet SAE J514.
    d. If hydraulic flange type fittings or hose ends are used, then the flange heads and split flange clamp halves are to meet SAE J518 specifications.
    e. If hydraulic metallic tubing is used, the tubing is to meet SAE J1065 specifications and SAE J2551 is to be followed during the design process.
    f. All components used in the hydraulic drive system must be compatible with the medium that the hybrid drive system supplier selects to use for powering the drive system.

2. Hybrid drive system electrical propulsion:
    a. Battery design and mounting are to meet SAE J2289, J1797 & J1766.
    b. Primary cabling for an electrical propulsion system is to meet following applicable SAE standards: J1654, J1673, J2183, J2501 and J1742.
    c. Hybrid drive system supplier is to use SAE J1211 and SAE J1455 as guidelines for electronic equipment design.
    d. Hybrid drive system supplier will equip the vehicle with the appropriate overload and short protection. These protective devices are to be appropriately labeled.

3. Noise level inside the cab is to be no greater than 83 dBa using SAE J336 testing procedures.

4. Any components and their brackets mounted to the frame should be able to withstand a 8g shock load parallel to the ground and frame and a vertical shock load of 3g.

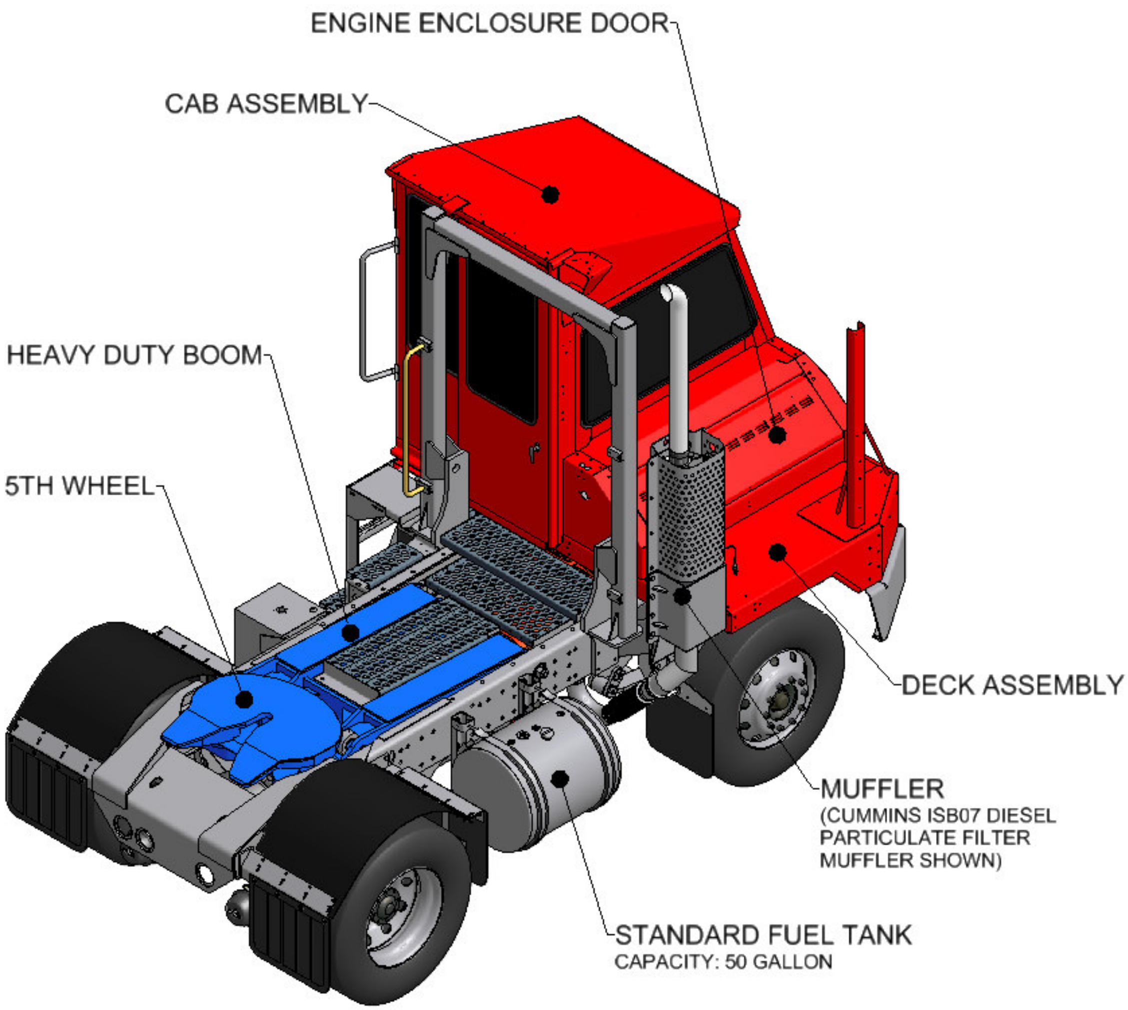
5. Hybrid supplier is to provide access to the back door by designing in steps that have the same rise and run and mounted in the same area as the battery box provided on the vehicle from Kalmar or they may use the battery box provided.

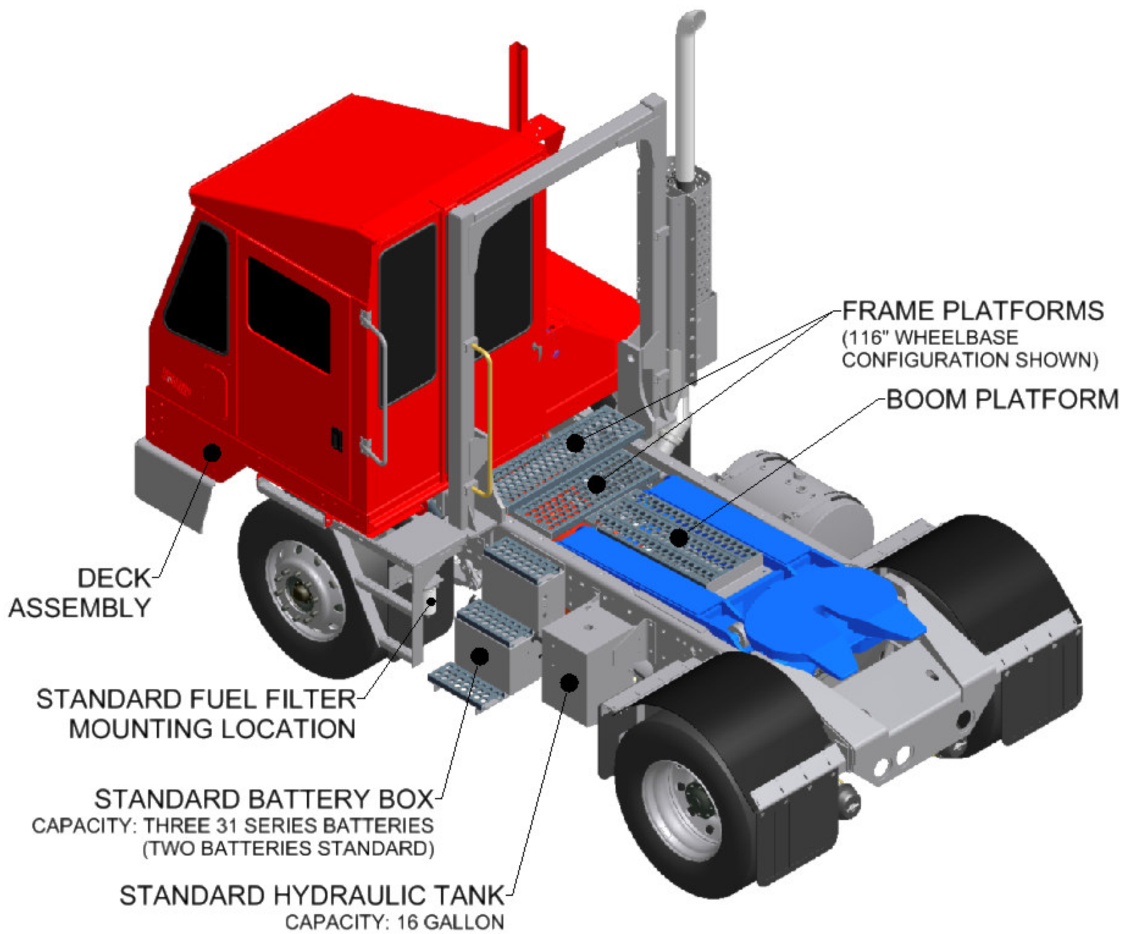
6. See “Total Space Available” section for areas to mount components.

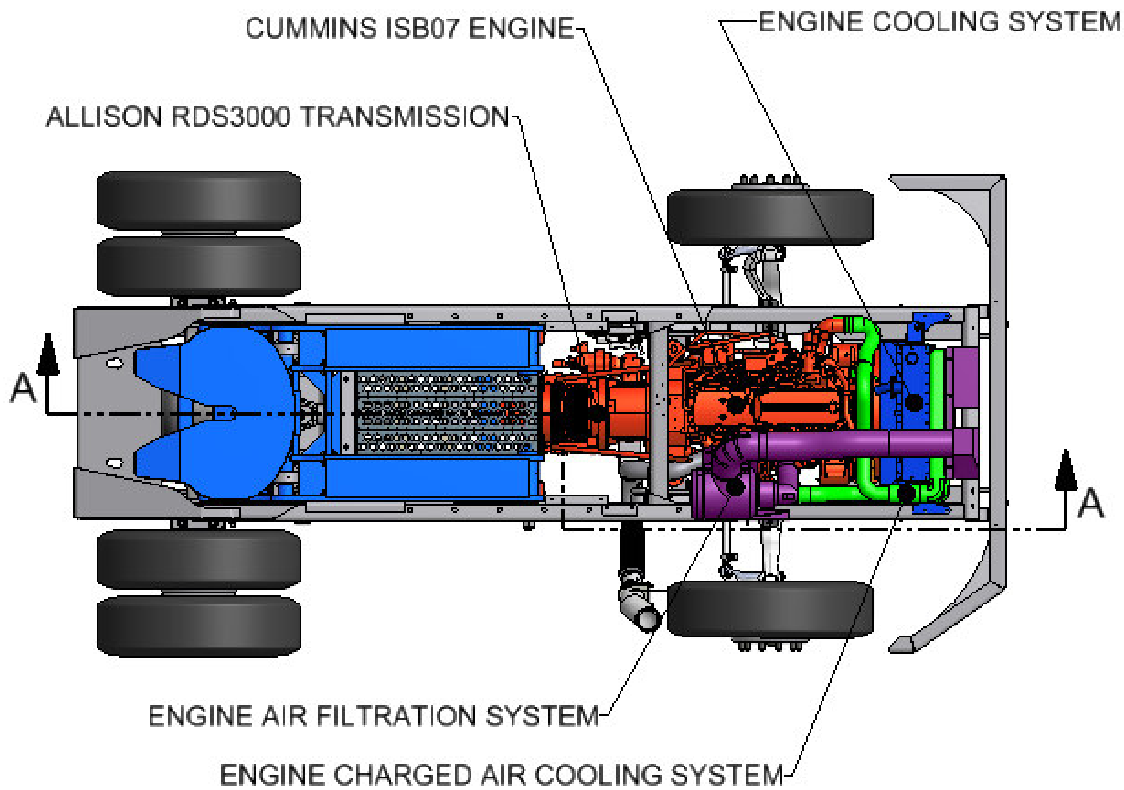
7. All hybrid drive system components must be able to operate at ambient temperatures of -10^{o} F (-23^{o} C) to 110^{o} F (43^{o} C).

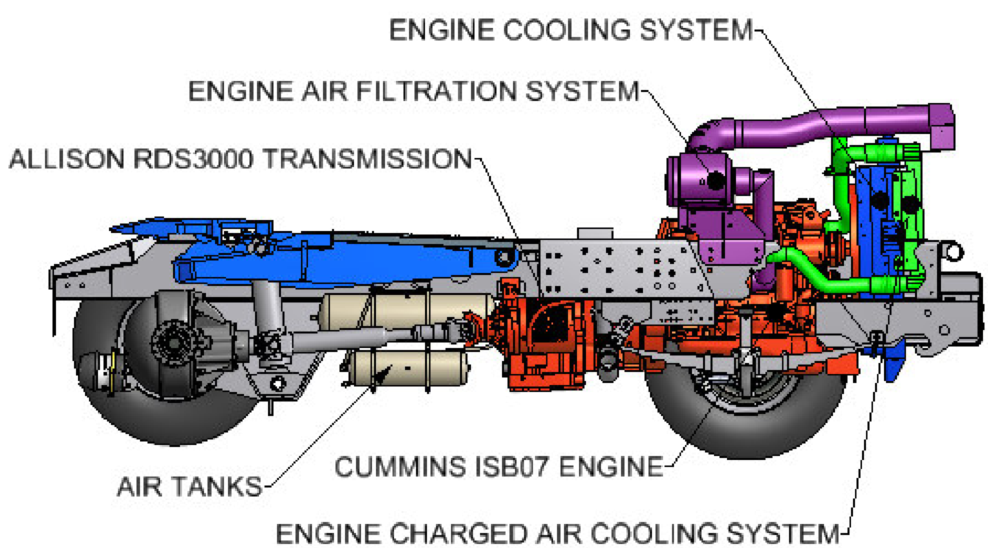
Section 5
Typical Ottawa 4x2 Diesel Powered Truck Configuration

Typical Ottawa 4x2 Diesel Powered Truck Configuration

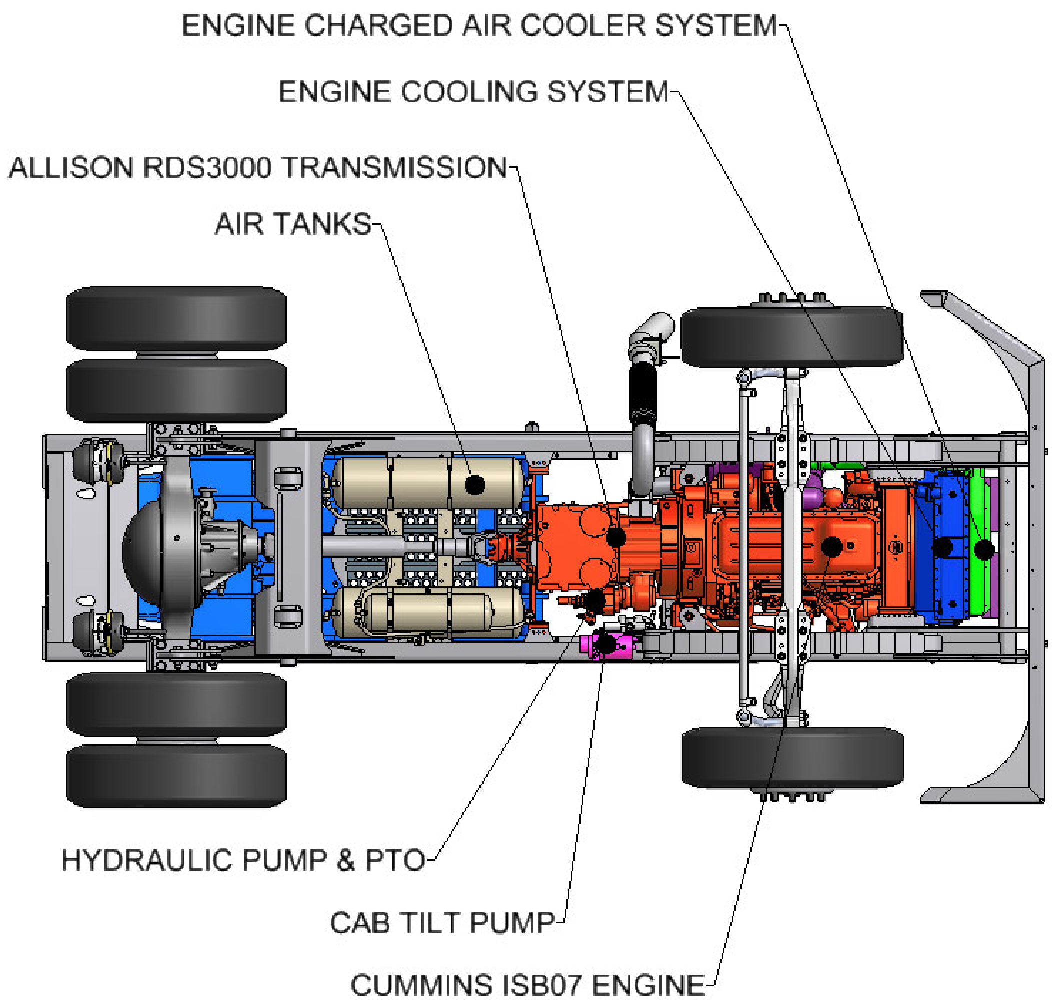


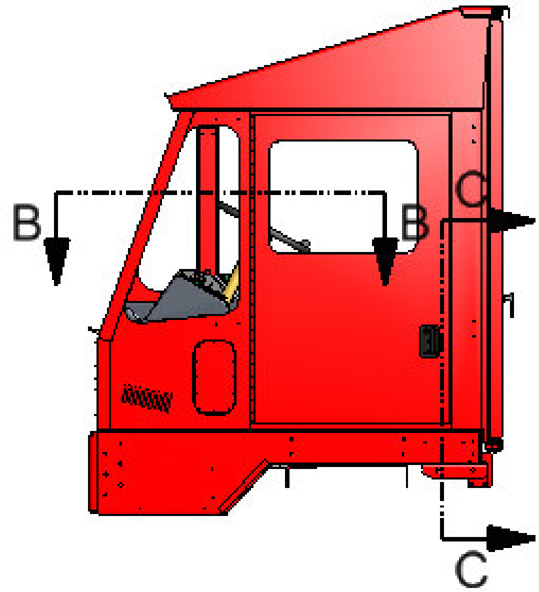

FRAME PLATFORMS
(116" WHEELBASE
CONFIGURATION SHOWN)
BOOM PLATFORM
DECK
ASSEMBLY
STANDARD FUEL FILTER
MOUNTING LOCATION
STANDARD BATTERY BOX
CAPACITY: THREE 31 SERIES BATTERIES
(TWO BATTERIES STANDARD)
STANDARD HYDRAULIC TANK
CAPACITY: 16 GALLON


CUMMINS ISB07 ENGINE
ENGINE COOLING SYSTEM
ALLISON RDS3000 TRANSMISSION
A
A
ENGINE AIR FILTRATION SYSTEM
ENGINE CHARGED AIR COOLING SYSTEM


ENGINE COOLING SYSTEM
ENGINE AIR FILTRATION SYSTEM
ALLISON RDS3000 TRANSMISSION
AIR TANKS
CUMMINS ISB07 ENGINE
ENGINE CHARGED AIR COOLING SYSTEM

SECTION A-A


ENGINE CHARGED AIR COOLER SYSTEM
ENGINE COOLING SYSTEM
ALLISON RDS3000 TRANSMISSION
AIR TANKS
HYDRAULIC PUMP & PTO
CAB TILT PUMP
CUMMINS ISB07 ENGINE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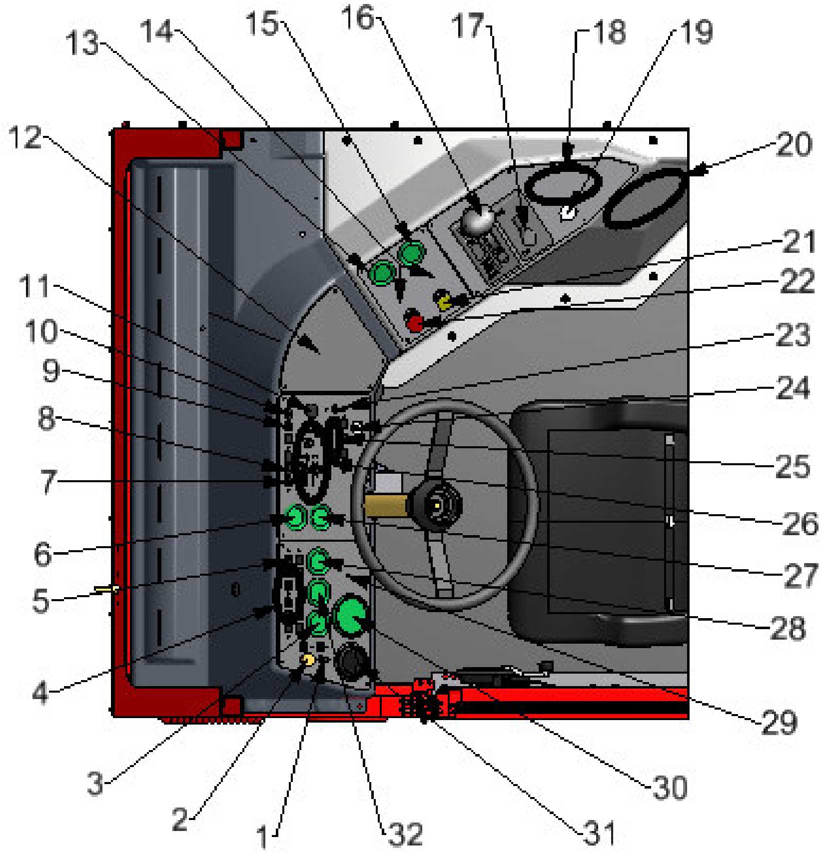
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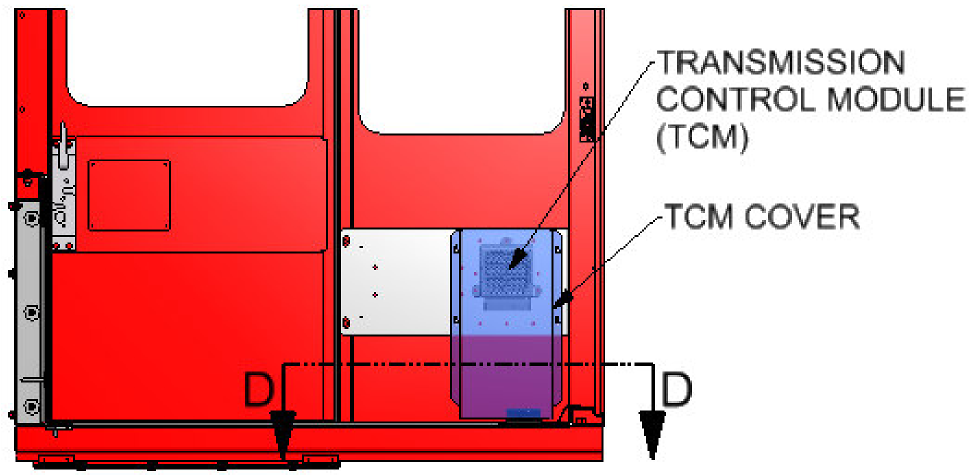
32

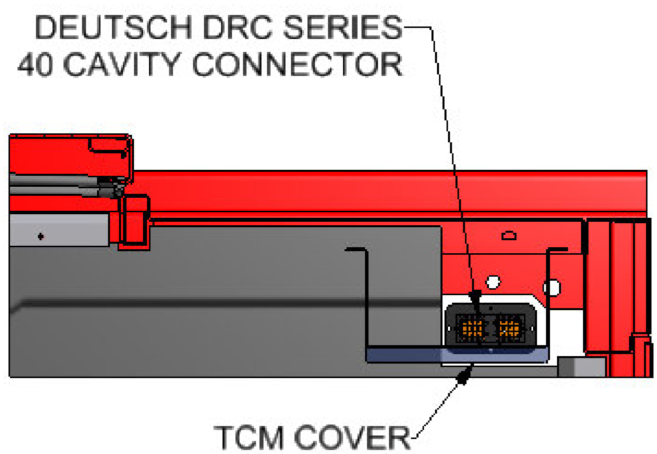
SECTION B-B

Legend for Section B-B

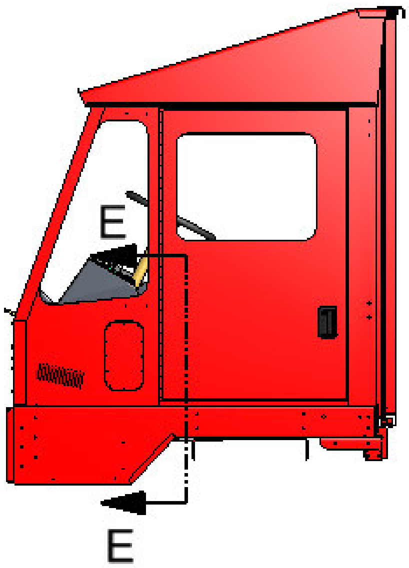
1	Headlight Switch
2	Panel Lights Dimmer
3	Fuel Level Gauge
4	Engine Function Indicator Lights
5	Turn Signal Indicator Light
6	Hourmeter
7	High Beam Headlight Indicator Light
8	Turn Signal Indicator Light
9	Check Transmission Indicator Light
10	Low Air Warning Light
11	Windshield Wiper Switch
12	Options Panel (Additional switches, gauges, lights, etc…)
13	Front Air Brake Pressure Gauge
14	Optional Gauges
15	Rear Air Brake Pressure Gauge
16	Transmission Gear Selector
17	Boom Elevation Control
18	Optional Controls & Gauges (Dollymaster control, load gauge, etc…)
19	5th Wheel Unlatch Control
20	Optional PTO, Differential Lock & Inter-axle Differential Lock Controls
21	Trailer Spring Brake Control
22	Tractor Spring Brake Control
23	Floodlight Switch
24	Ignition Switch
25	Optional Switches (Additional flood & strobe lights)
26	Heater Controls
27	Voltmeter
28	Engine Water Temperature Gauge
29	Optional 3-3/8" Gauge (Tachometer)
30	Speedometer
31	Heater Vent
32	Engine Oil Pressure Gauge

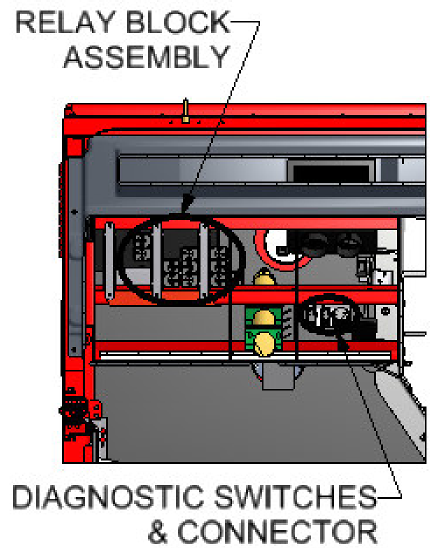


SECTION C-C

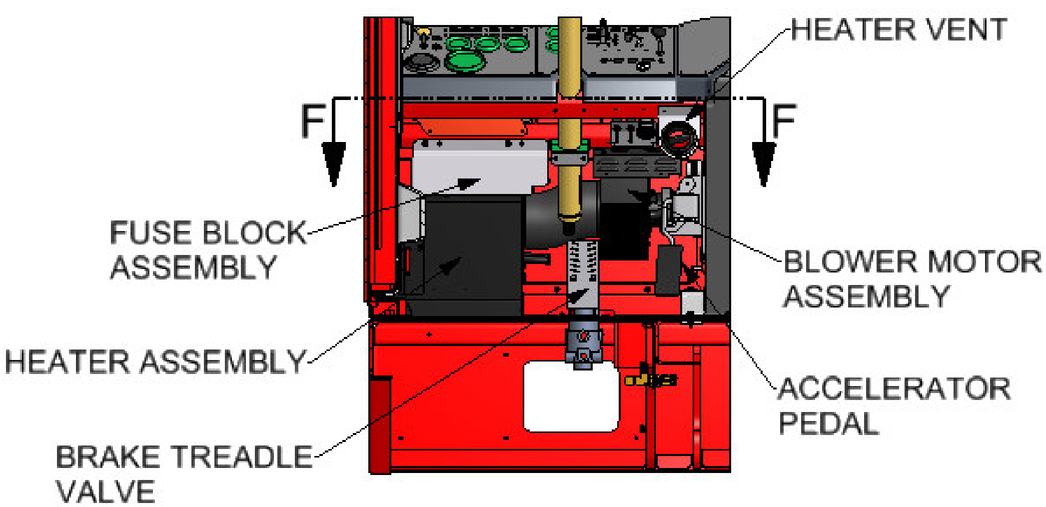


SECTION D-D





SECTION F-F



SECTION E-E

Section 6
Available Frame Space for Hybrid Drive System Components

Available frame space for hybrid drive system

1. Only 116” (2946 mm), 122” (3099 mm) & 132” (3353 mm) wheelbases are available. 116” (2946 mm) wheelbase is preferred. See TABLE 1 for available space between front and rear mud flaps.

2. Frame mounted components are not to protrude past the “OUTER LIMIT FOR FRAME MOUNTED COMPONENTS” line as shown in FIGURE 1. This applies to both sides of the vehicle.

3. Components mounted to the driver’s side of the frame must not interfere with the entry ladder on the side of the cab while the cab is being raised.

4. Frame mounted components are not to extend upward past the top of the frame, except for those items inside the engine enclosure area.

5. Boom platform and frame platforms are not to change.

6. Front axle in FIGURE 3 is shown in its unloaded position and the 27” (685 mm) dimension from top of axle to top of frame will decrease as the load on the truck increases. Axle stops will restrict the axle movement to 3” (76 mm) giving the hybrid drive system supplier no more than 24” (610 mm) of space from top of frame rail to top of front axle.

7. Components mounted between the frame rails must not interfere with the movement of the boom and cylinders.

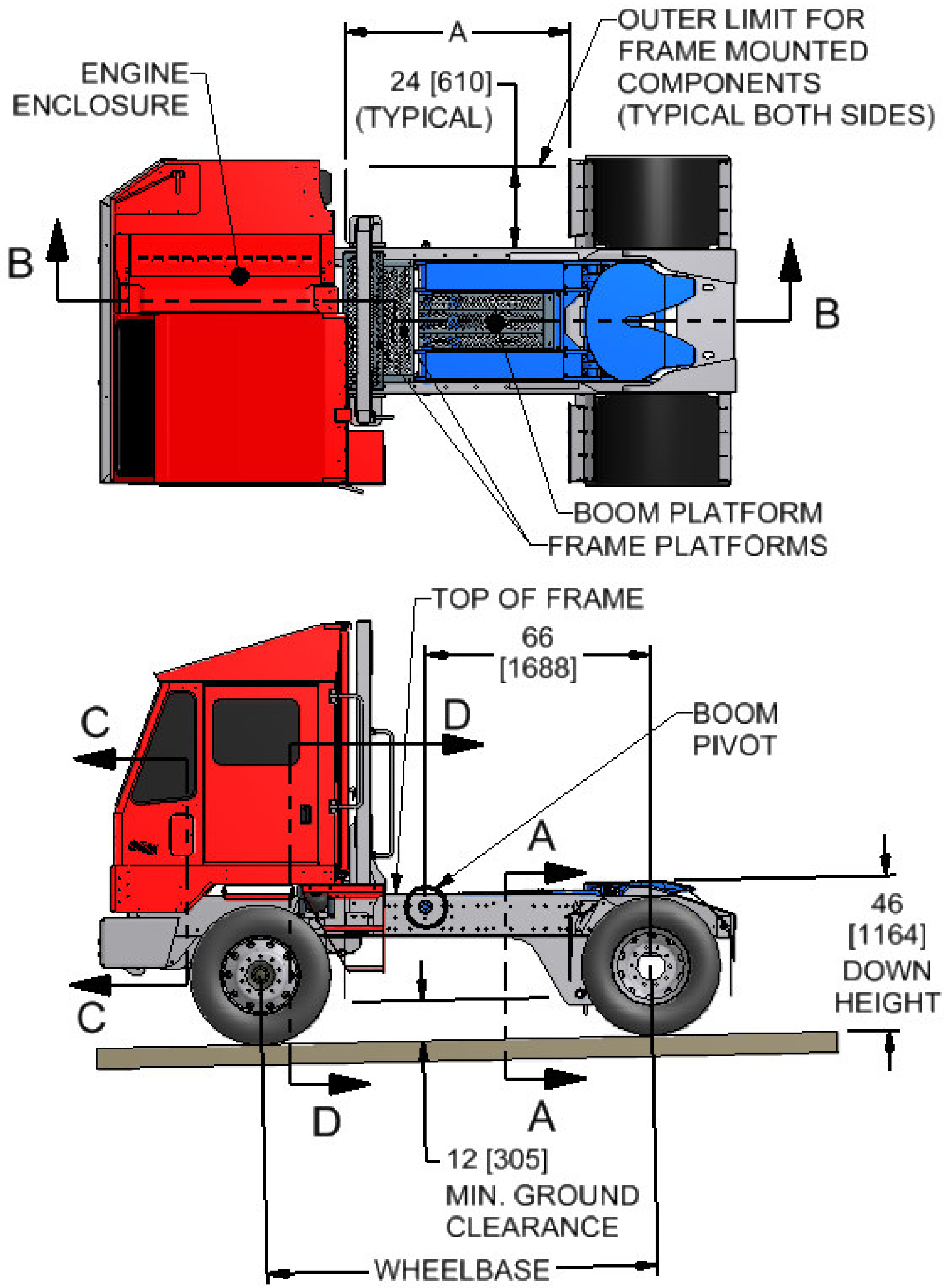

ENGINE ENCLOSURE
A
24 [610] (TYPICAL)
OUTER LIMIT FOR FRAME MOUNTED COMPONENTS (TYPICAL BOTH SIDES)
B
B
BOOM PLATFORM
FRAME PLATFORMS
TOP OF FRAME
66 [1688]
BOOM PIVOT
C
D
A
46 [1164] DOWN HEIGHT
C
D
A
12 [305] MIN. GROUND CLEARANCE
WHEELBASE

Figure 1

Wheelbase	116" (2964 mm)	122" (3099mm)	132" (3353 mm)
Dim. A	65.6" (1666 mm)	71.6" (1819 mm)	81.6" (2073 mm)

Table 1

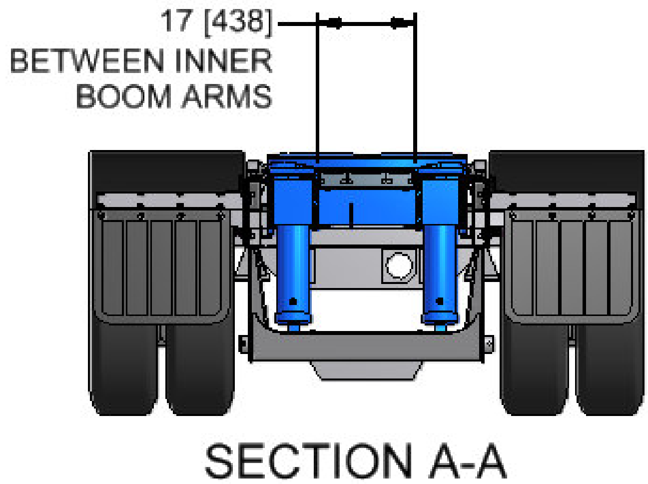


Figure 2

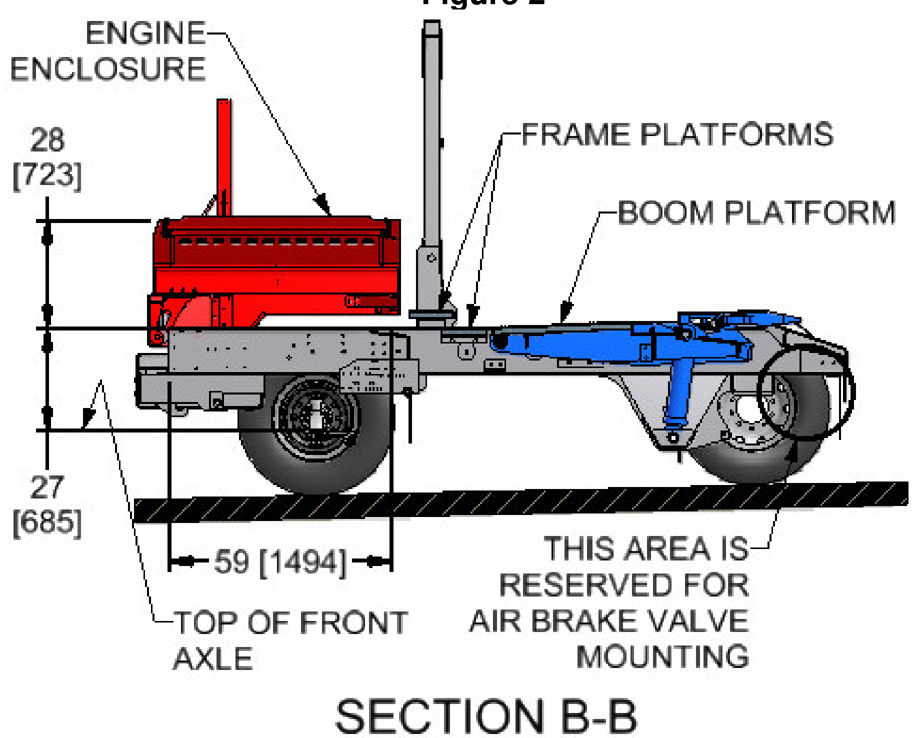


Figure 3

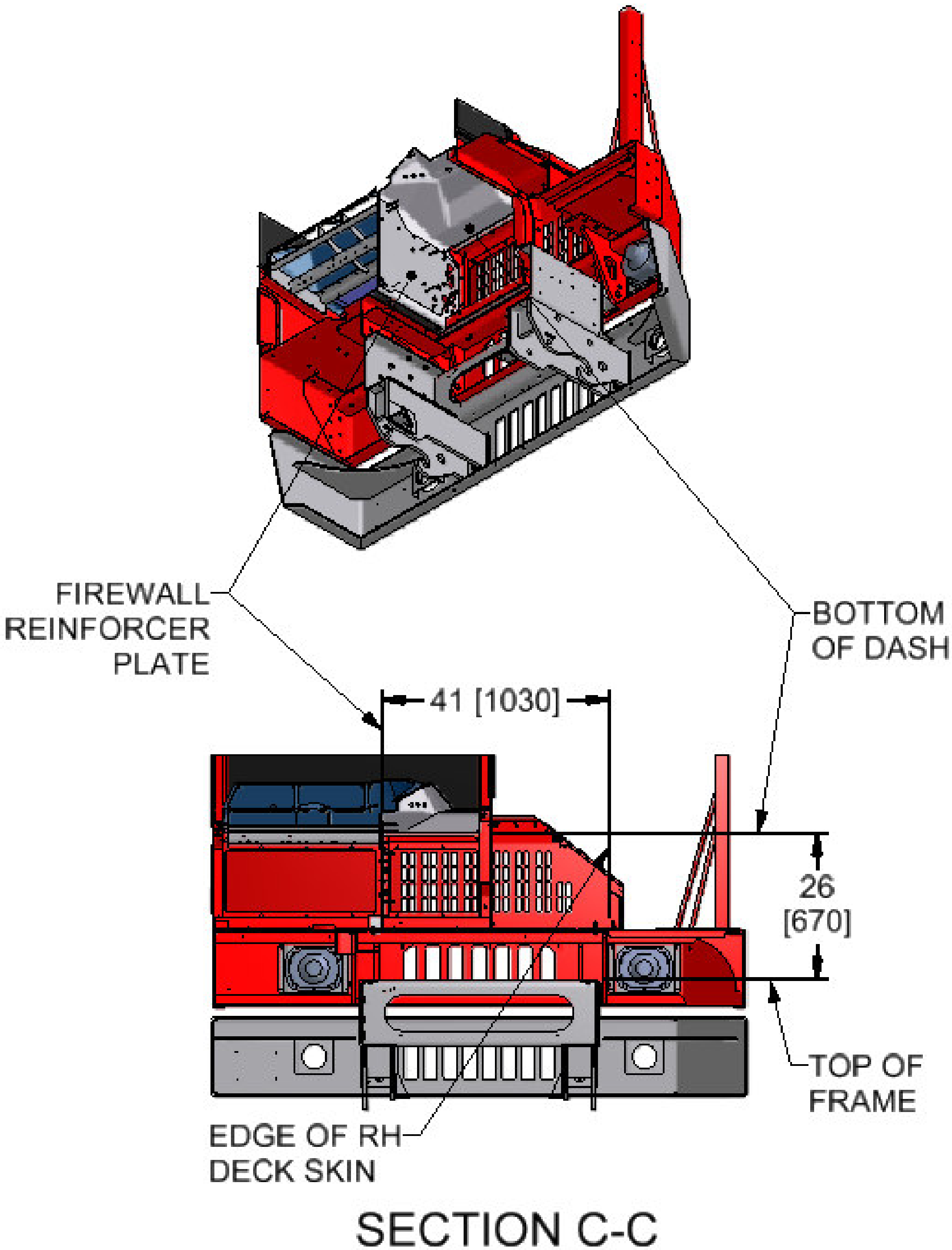

FIREWALL
REINFORCER
PLATE
BOTTOM
OF DASH
41 [1030]
26
[670]
TOP OF
FRAME
EDGE OF RH
DECK SKIN
SECTION C-C

Figure 4

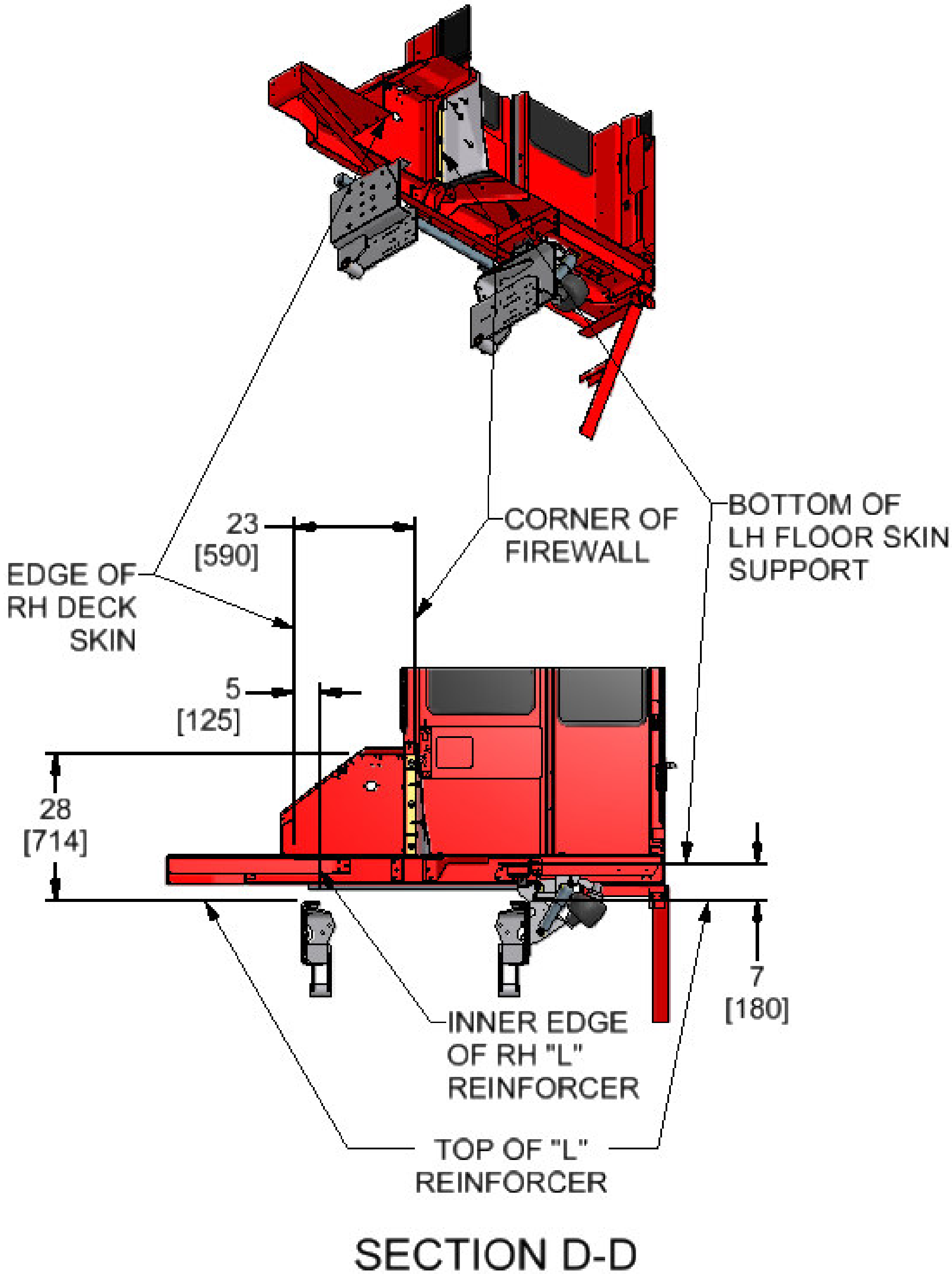

23
[590]
EDGE OF
RH DECK
SKIN
CORNER OF
FIREWALL
BOTTOM OF
LH FLOOR SKIN
SUPPORT
5
[125]
28
[714]
7
[180]
INNER EDGE
OF RH "L"
REINFORCER
TOP OF "L"
REINFORCER
SECTION D-D

Figure 5

Section 7
Basic Frame
Configuration

Basic Frame Configuration

1. Modifications (including but not limited to the addition of holes, cutting notches, welding, etc…) may **NOT** be made without prior written approval from Kalmar 4x2 Global Engineering.

2. The frame must have a mid-frame crossmember that is mounted in the same area and is of the same strength as Kalmar's current design (see figure 1). Kalmar 4x2 Global Engineering must approve, in writing, any changes to the mid-frame crossmember design.

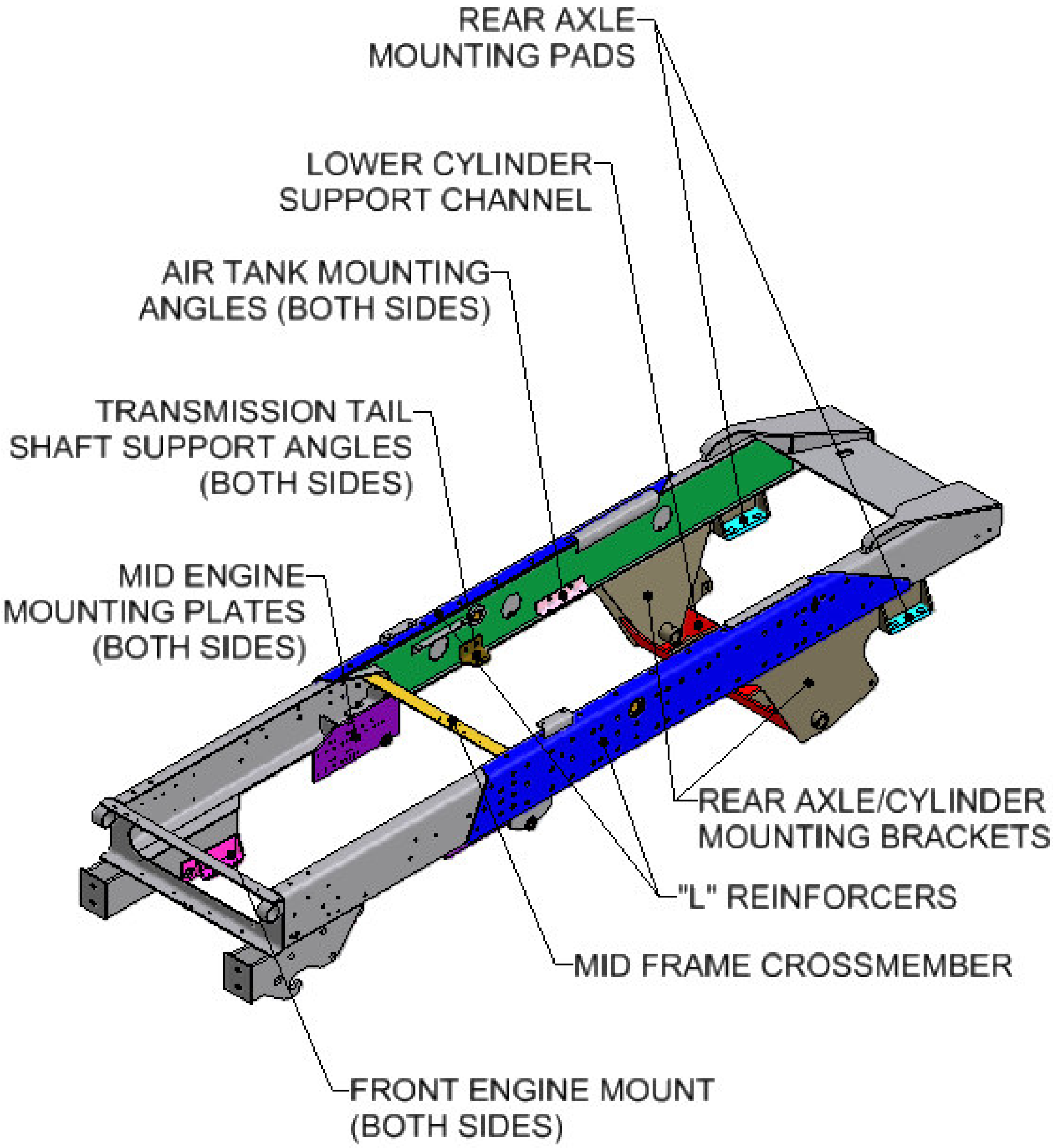

REAR AXLE
MOUNTING PADS
LOWER CYLINDER
SUPPORT CHANNEL
AIR TANK MOUNTING
ANGLES (BOTH SIDES)
TRANSMISSION TAIL
SHAFT SUPPORT ANGLES
(BOTH SIDES)
MID ENGINE
MOUNTING PLATES
(BOTH SIDES)
REAR AXLE/CYLINDER
MOUNTING BRACKETS
"L" REINFORCERS
MID FRAME CROSSMEMBER
FRONT ENGINE MOUNT
(BOTH SIDES)

Figure 1

Section 8
Hybrid Drive System
Engine
Requirements

Hybrid Drive System Engine Requirements

1. Cummins is the preferred engine manufacturer, however, other engine manufacturers will be considered.

2. Engine must be mounted so that vibration translated to the cab is kept to a minimum.

3. Engine must be certified to EPA 2007 & CARB 2007 emission standards.

4. Engine manufacturer must have parts & labor warranty of at least 2 yrs.

5. Engine cooling package must be sufficient to cool the engine in accordance with the engine manufacturer's performance requirements for automotive applications unless hybrid application performance requirements are available.

6. Engine air cleaner and piping must meet the engine manufacturer's performance requirements.

7. Engine air cleaner is to be of a design that will allow the filter to be replaced without the need for tools. Reference Donaldson EPG series air cleaner.

8. Muffler and exhaust system must meet the engine manufacturer's performance requirements.

9. Any of the muffler or exhaust system components that the operator may come in contact with during normal movement on or around the vehicle must have sufficient covering to prevent injury.

Section 9
Parasitic Loads On Typical Ottawa 4x2 Terminal Tractor Engine

Parasitic Loads on Typical Ottawa 4x2 Terminal Tractor Engine
(Based on truck equipped with Cummins ISB07 engine)

Air Compressor - 19.4 $in.^3$ (318 cc)/revolution displacement @ 22 PSI (1.5 bar) inlet air pressure:

@750 Engine RPM	1.50 HP (1.12 kW)
@2600 Engine RPM	6.75 HP (5.03 kW)

Alternator – Delco 22SI, 130 amp

@750 Engine RPM	3.00 HP (2.24 kW)
@2600 Engine RPM	6.25 HP (4.66 kW)

A/C Compressor – Sanden SD7H15

@750 Engine RPM	2.25 HP (1.68 kW)
@2600 Engine RPM	7.50 HP (5.59 kW)

Engine Cooling Fan – 26 in. (660 mm) Dia.

@750 Engine RPM	0.81 HP (0.60 kW)
@2600 Engine RPM	33.60 HP (25.06 kW)

Hydraulic Pump – 2.75 in3 (45 cc)/revolution @ 2250 PSI (155 bar)

@750 Engine RPM	12 HP (9 kW)
@2600 Engine RPM	42 HP (31 kW)

Section 10
Vehicle Electrical Requirements

Vehicle Electrical Requirements

1. Hybrid System must be capable of supplying 65 amps of 12VDC power to the positive pass thru stud mounted in the cab firewall (see FIGURE 1) while the truck is in normal operation of moving trailers/containers and 85 amps of 12VDC power to the cab while the truck is stopped, waiting to be loaded. This power must not be interrupted once the ignition switch has been turned on. Interruption of this power will cause engine and transmission faults to occur. These power requirements will increase with a more heavily optioned truck, for example a truck with the maximum number of floodlights will draw an additional 17 amps.

2. Programmable parameters and diagnostic functions must be accessible through a Windows 2000/XP/Vista compatible software and must connect through a 9-pin Deutsch HD10-9-1939P connector using the following pin arrangement: A – Battery (-); B – Battery (+); C – J1939 (+); D – J1939 (-); E – J1939 Shield; F – empty; G – empty; H – empty; J – empty

3. Interfacing and Controls Cabling
   a. Bulkhead connectors will be used for wires entering into the cab from the chassis. One connector will be attached to the cab and the connector on the chassis portion is to be loose. Wires routing through a grommet for entry into the cab will not be allowed.
   b. Harnesses are to conform to Kalmar 4x2 Global Engineering electrical specification ESN-0021

4. Hybrid drive system supplier is to supply the following indicator and warning devices:

a. Warning light labeled “Hybrid Drive Failure” to indicate to operator that one or more of the components of the hybrid drive system has failed or is operating outside of it’s designed parameters.
b. Light labeled “Hybrid Drive Active” to indicate to operator when the engine has stopped running and truck is being propelled with the hybrid drive system.

5. Hybrid drive system supplier is to equip the vehicle with batteries for starting the engine and supplying power to the tilt pump. These batteries are to be accessible without the need for tools. Kalmar understands that tools may be required to remove the batteries. Size and number of batteries for these functions are to be determined by the hybrid drive supplier. The vehicle supplied by Kalmar will be equipped with two 31 series batteries that the hybrid drive supplier may choose to use.

6. Packaging of battery modules is to meet SAE J1797.

7. The alternator that will be supplied on the engine with the truck is a Delco –Remy 22SI 130 amp @ 1442 engine RPM alternator. The hybrid drive system supplier may choose to use a different brand and size of alternator.

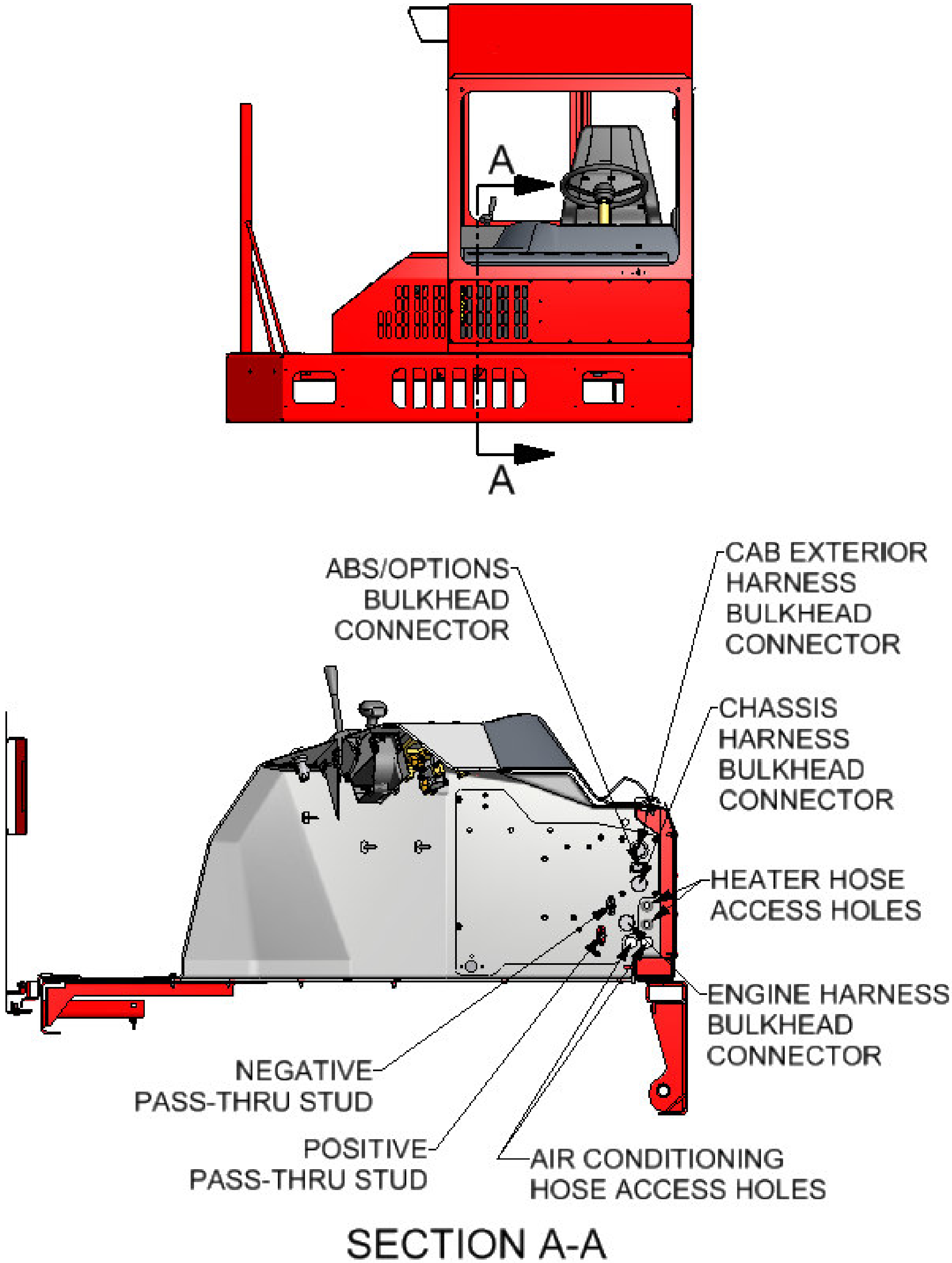

A
A
ABS/OPTIONS BULKHEAD CONNECTOR
CAB EXTERIOR HARNESS BULKHEAD CONNECTOR
CHASSIS HARNESS BULKHEAD CONNECTOR
HEATER HOSE ACCESS HOLES
ENGINE HARNESS BULKHEAD CONNECTOR
NEGATIVE PASS-THRU STUD
POSITIVE PASS-THRU STUD
AIR CONDITIONING HOSE ACCESS HOLES
SECTION A-A

Figure 1

Section 11
Axle Specifications and Requirements

Axle Specifications and Requirements

1. Front steer axle that will be supplied with the truck from Kalmar Industries.
   a. Arvin Meritor FF961
   b. 12,000 lbs. (5,440 kg.) weight rating
   c. Automatic slack adjusters
   d. 16.5” (419 mm) x 5” (127 mm) drum type brakes
   e. 30 in^2 (194 cm^2) brake chambers
   f. Requires 13.19” (335 mm) bolt circle hub pilot wheels.

2. Rear drive axle that will be supplied with the truck from Kalmar Industries.
   a. Sisu SRDP
   b. 70,000 lbs. (32,000 kg.) weight rating at 15 MPH (25 KPH)
   c. 120,000 lbs. (264,500 kg.) GCVW rating at 15 MPH (25 KPH)
   d. Automatic slack adjusters
   e. 16.1” (410 mm) x 7.1” (180 mm) drum type brakes
   f. 30 in^2 (194 cm^2) service brake chambers/30 in^2 (194 cm^2) spring brake chambers
   g. Requires 13.19” (335 mm) bolt circle hub pilot wheels.
   h. 71.89” (1826 mm) track
   i. 10.59:1 or 12.28:1 ratio
   j. 1710 full round end yoke

3. Minimum requirements for rear drive axle, if hybrid supplier chooses to supply the rear axle.
   a. 42,000 lbs. (19,050 kg.) minimum weight rating at 25 MPH (40 KPH).
   b. 96,000 lbs. (43,500 kg.) minimum GCVW rating at 25 MPH (40 KPH).
   c. Axle ratio is dependent on performance requirements
   d. Must accept 13.19” (335 mm) bolt circle hub piloted wheels.
   e. 71” (1,803 mm) to 75” (1,905 mm) track.
   f. The air brake system components must meet FMVSS 571.121 requirements.
   g. 1 year parts and labor warranty
   h. Once an axle has been selected that meets the requirements listed above, the hybrid drive system supplier is to submit drawings and solid models of the axle to Kalmar 4x2 Global Engineering. Kalmar 4x2 Global Engineering will then make recommendations for mounting the axle to the frame.

Section 12
Hydraulic System Requirements

Hydraulic System Requirements

1. Hydraulic pump must be able to deliver fluid the instant the operator actuates the 5th wheel control in the cab after the initial start of the vehicle and before the ignition switch has been turned off.

2. Hydraulic pump must deliver enough flow to extend 5" (127 mm) dia. x 14.5" (368 mm) stroke cylinders from fully collapsed to fully extended within 10 seconds. If engine must be running for pump operation, then the hydraulic pump must deliver enough flow to extend the cylinders in 10 seconds with the engine at 1200 RPM.

3. Hydraulic pump relief pressure is to be set at 2250 PSI (155 bar), but adjustable down to 2000 PSI (138 bar).

4. Hydraulic system fluid must be filtered.

5. Hydraulic fluid must be Dexron III, unless supplier has prior approval from Kalmar 4x2 Global Engineering.

6. Hydraulic hoses from pump to control valve (if control valve is not integrated into the hydraulic pump) and from control valve to filter and cylinders are to meet SAE J517 100R16 and are to have 37 degree flared (JIC) swivel hose ends that meet SAE J516. Return hoses from pump and filter to hydraulic tank are to meet SAE J517 100R4 are to have 37 degree flared (JIC) hose ends that meet SAE J516 where possible.

7. All hydraulic adapters are to conform to SAE J514 and are to be o-ring boss style that are made from steel or stainless steel, except at the hydraulic filter, these may be NPT style adapters.

8. Hydraulic reservoir must be sufficiently sized to provide adequate cooling or an oil cooler must be added.

9. The hydraulic cylinders are double acting resulting in a power down operation. This type of operation requires the reservoir to have 0.5 gal. (2 L.) of additional expansion volume for the change in cylinder volume.

10. See figure 1 for typical Ottawa 4x2 hydraulic & steering circuit.

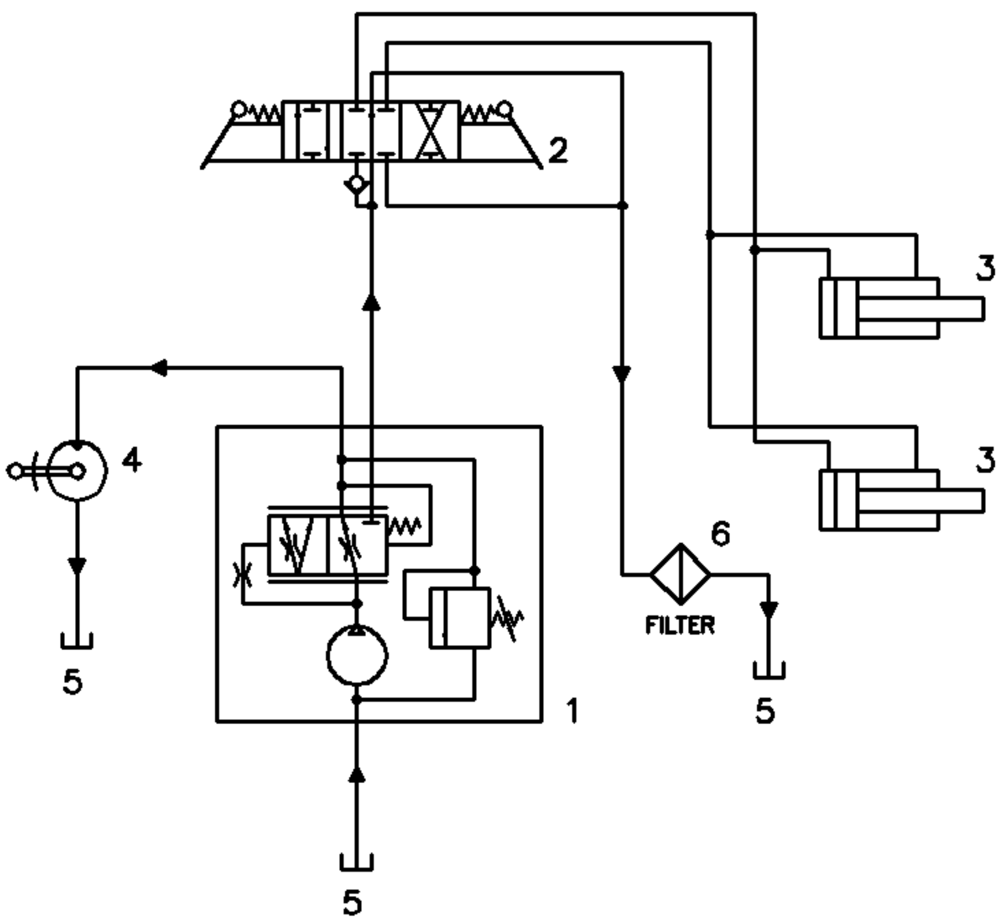


Figure 1

Legend for Figure 1

1. HYDRAULIC PUMP W/PRIORY FLOW VALVE:
   - 2.75 CU.IN. (8.2 CC) DISPLACEMENT
   - 4 GPM (15 LPM) MIN. PRIORTY FLOW
   - 2750 PSI (190 BAR) RATED PRESSURE
   - 2200 PSI (152 BAR) PRIORITY RELIEF PRESSURE
   - O-RING PORTS

2. HYDRAULIC DIRECTIONAL CONTROL VALVE
   - 4 WAY, 3 POSITION
   - 20 GPM (76 LPM) MAX. FLOW
   - O-RING PORTS

3. LIFT CYLINDERS
   - 5" (127 MM) DIA. BORE
   - 14.5" (368 MM) STROKE
   - 2" (51 MM) DIA. ROD
   - DOUBLE ACTING
   - O-RING PORTS

4. STEERING GEAR

5. HYDRAULIC TANK
   - 16 GAL. (61 L) CAPACITY
   - O-RING PORTS
   - VENT LINE DIRECTED DOWNWARD

6. FILTER
   - 10 MICRON FILTRATION
   - 250 PSI (17 BAR) MAX OPERATING PRESSURE
   - 15 GPM (57 LPM) MIN FLOW RATE
   - O-RING PORTS

Section 13
Steering System Requirements

Steering System

1. Power steering pump must deliver a minimum of 4 GPM (18 LPM) after the engine is initially started and must maintain this flow until the ignition switch has been turned off.

2. Power steering pump may be integrated in the hydraulic pump as long as the requirements in the hydraulic system specifications and in section 1 of this document are met.

3. Power steering pump relief pressure is to be set at 2000 PSI (138 bar).

4. Hose from power steering pump to steering gear is to meet SAE J517 100R16 and is to have 37 degree flared (JIC) swivel hose ends that meet SAE J516. Return hose from steering gear to hydraulic tank is to meet SAE J517 100R6.

5. All hydraulic adapters are to conform to SAE J514 and are to be o-ring boss style that are made from steel or stainless steel.

6. All other steering components (steering gear, pitman arm, draglink, etc…) are not to be affected.

Section 14
Air System Requirements

Air System Requirements

1. Air brake system must meet 49 CFR 571.121 (FMVSS 121).

2. Size of air compressor is to be determined using 49 CFR 571.121 (FMVSS 121).

3. Air reservoirs are to meet SAE J10 and 49 CFR 571.121 (FMVSS 121).

4. Non-metallic tube used in the air brake system is to meet SAE J844 and 49 CFR 571.106 (FMVSS 106). Metallic tube is not to be used.

5. Air brake hose used in the air brake system is to meet SAE J1402 and 49 CFR 571.106 (FMVSS 106).

6. Metallic body push to connect fittings conforming to J2494-1 or non-metallic body push to connect fittings conforming to J2494-2 are to be used with non-metallic tube referenced in section 2 of this document.

7. Only items 1, 2 & 3 of figure 1 and the hoses or tubing attached to them may be changed by the hybrid supplier. Items 1, 2 & 3 must meet the requirements listed above. All other air system components delivered on the vehicle by Kalmar are not to be relocated or changed.

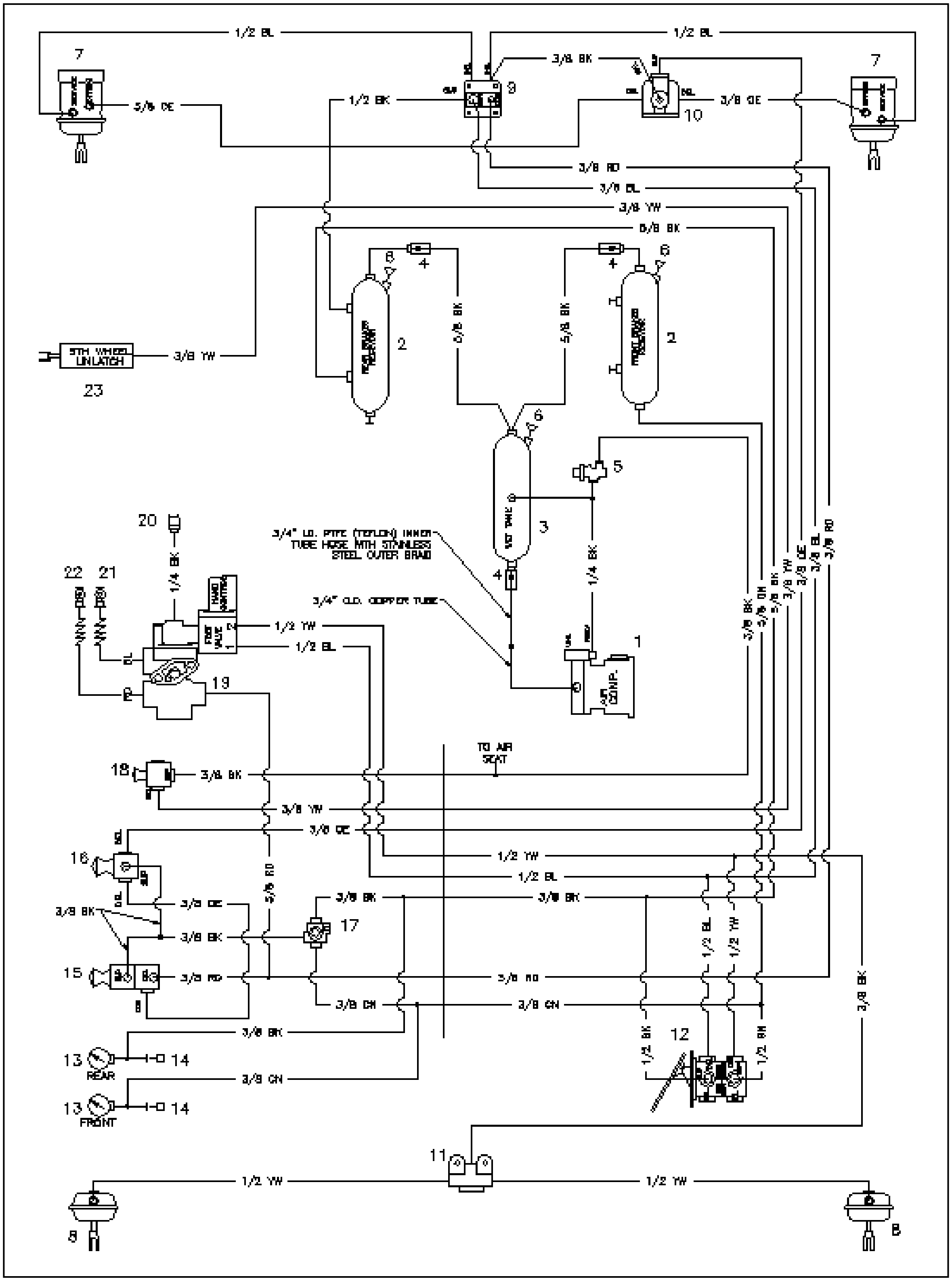


Figure 1

Legend for Figure 1

1. AIR COMPRESSOR (TURBOCHARGED) - 18 SCFM @ 1000 RPM
2. AIR RESERVOIR - FRONT & REAR BRAKES
   - 9" DIA. X 36" LONG
   - 2429 CU. IN. VOLUME
3. AIR RESERVOIR - WET TANK
   - 7" DIA. X 24" LONG
   - 830 CU. IN. VOLUME
4. ONE WAY CHECK VALVE
5. PRESSURE PROTECTION VALVE - SET AT 70 PSI
6. MANUAL DRAIN VALVE
7. REAR BRAKE CHAMBER - 30 SQ. IN. SERVICE CHAMBER/
   30 SQ. IN. SPRING CHAMBER
8. FRONT BRAKE CHAMBER - 30 SQ. IN. SERVICE CHAMBER
9. BOBTAIL PROPORTIONING RELAY VALVE
10. QUICK RELEASE/DOUBLE CHECK VALVE
11. QUICK RELEASE VALVE
12. DUAL BRAKE VALVE
13. 0-150 PSI AIR PRESSURE GAUGE
14. LOW AIR PRESSURE SWITCH - NORMALLY CLOSED, SET AT 70 PSI
15. TRAILER SPRING BRAKE CONTROL VALVE
16. TRACTOR SPRING BRAKE CONTROL VALVE
17. DOUBLE CHECK VALVE
18. 5TH WHEEL UNLATCH CONTROL VALVE
19. TRACTOR PROTECTION VALVE WITH DOUBLE CHECK
20. STOP LIGHT SWITCH
21. BLUE GLADHAND WITH BLUE COILED HOSE - SERVICE
22. RED GLADHAND WITH RED COILED HOSE - EMERGENCY
23. 5TH WHEEL UNLATCH SINGLE ACTING CYLINDER

Section 15
Heating and
Air Conditioning
Requirements

Heating and Air Conditioning Requirements

1. Heater is required, however, air conditioning is an option that the Hybrid supplier must take into consideration.

2. Hybrid drive system supplier is allowed to substitute components mounted to the engine and radiator, but may not change any components inside the cab. Heating and air conditioning (if equipped) systems must meet the performance requirements stated in TMC's (Technology & Maintenance Council) Recommended Engineering Practices Manual RP419 and RP427.

3. Heater and air conditioning (if equipped) systems must function while the vehicle is at idle and the driver has not turned the ignition switch off.

4. If truck is equipped with air conditioning, all air conditioning hose must meet SAE J2064.

Section 16
Cab Tilt System
Requirements

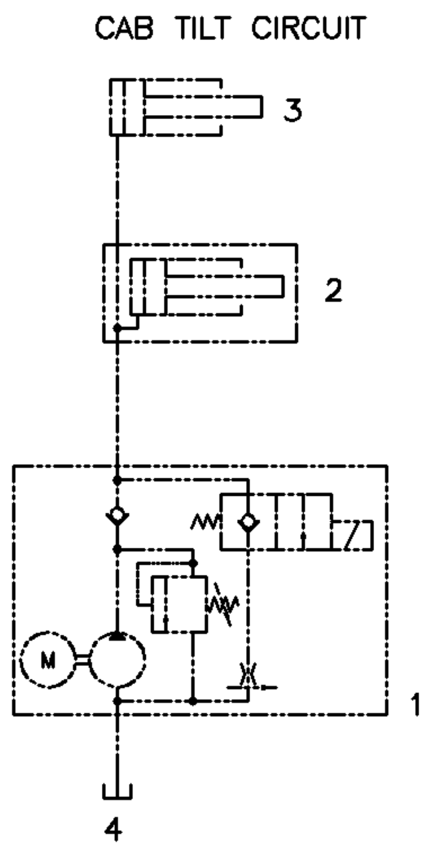
Cab Tilt System Requirements

1. Hose and fittings from hydraulic reservoir to cab tilt pump must meet the following requirements.
   a. Minimum working pressure of 500 PSI (3.4 MPa)
   b. -40^0 F (-40^0 C) or lower to 250^0 F (100^0 C) or higher operating range
   c. Compatible with Dexron III oil

2. Any wiring changes that are made must meet Kalmar 4x2 Global Engineering specification ESN-0021.

3. All other cab tilt system components are not to change from what is supplied from Kalmar Industries.

4. See figure 1 for diagram of cab tilt circuit as supplied from Kalmar Industries:



Legend for Figure 1

1. CAB TILT PUMP W/SOLENOID VALVE
   - 0.934 CU. IN. DISPLACEMENT (RAISE)
   - 3200 PSI BYPASS RELIEF SETTING
   - 0.5 GPM SOLENOID VALVE FLOW RATE (LOWER)

2. CAB LATCH

3. CAB TILT CYLINDER
   - 2" DIA. BORE
   - 12.5" STROKE
   - 1.50" DIA. ROD
   - 3000 PSI MAX. OPERATING PRESSURE
   - 1.5 GPM VELOCITY FUSE AT INLET

Figure 1

Section 17
Maintenance Requirements

Maintenance

1. Customer must be able to perform fluid level checks without raising the cab.

2. Hydraulic and fuel filters must be easily accessible from ground level.

3. Hydraulic and fuel filters must be mounted in such a way that when the filter is removed the fluid will not spill on to any other components.

Appendix B

Federal Environmental Protection Agency Grant Agreement No. XA-96042301-0

U.S. ENVIRONMENTAL PROTECTION AGENCY

Grant Agreement

ASSISTANCE ID NO.			DATE OF AWARD
PRG	DOC ID	AMEND#	8/29/2006
XA -	96042301	- 0	
TYPE OF ACTION New			MAILING DATE 9/06/2006
PAYMENT METHOD:			ACH# 9693

RECIPIENT TYPE:	Send Payment Request to:
Municipal	Las Vegas Finance Center FAX # 702-798-2423

RECIPIENT:	PAYEE:
City of Long Beach - Harbor Dept 925 Harbor Plaza Long Beach, CA 90802 EIN: 95-6000733	City of Long Beach - Harbor Dept 925 Harbor Plaza Long Beach, CA 90802

PROJECT MANAGER	EPA PROJECT OFFICER	EPA GRANT SPECIALIST
Heather Tomley 925 Harbor Plaza Long Beach, CA 90802 E-Mail: tomley@polb.com Phone: 562-590-4160	Asia Yeary 75 Hawthorne Street, AIR-8 San Francisco, CA 94105 E-Mail: yeary.asia@epa.gov Phone: 415-972-3831	Cathy Reese 1200 Sixth Ave., OMP-145 Seattle, WA 98101 E-Mail: Reese.Cathy@epa.gov Phone: 206-553-6286

PROJECT TITLE AND DESCRIPTION

Hybrid ~~Electric~~ Yard Hostler Demonstration and Commercialization Project

This Port of Long Beach (POLB) hybrid ~~electric~~ yard hostler demonstration and commercialization project seeks to reduce diesel emissions in marine terminal environments through technology development and evaluation.

BUDGET PERIOD	PROJECT PERIOD	TOTAL BUDGET PERIOD COST	TOTAL PROJECT PERIOD COST
10/01/2006 - 09/30/2008	10/01/2006 - 09/30/2008	$300,000.00	$300,000.00

NOTICE OF AWARD

Based on your application dated 06/15/2006, including all modifications and amendments, the United States acting by and through the US Environmental Protection Agency (EPA), hereby awards $300,000. EPA agrees to cost-share 100.00% of all approved budget period costs incurred, up to and not exceeding total federal funding of $300,000. Such award may be terminated by EPA without further cause if the recipient fails to provide timely affirmation of the award by signing under the Affirmation of Award section and returning all pages of this agreement to the Grants Management Office listed below within 21 days after receipt, or any extension of time, as may be granted by EPA. This agreement is subject to applicable EPA statutory provisions. The applicable regulatory provisions are 40 CFR Chapter 1, Subchapter B, and all terms and conditions of this agreement and any attachments.

ISSUING OFFICE (GRANTS MANAGEMENT OFFICE)	AWARD APPROVAL OFFICE
ORGANIZATION / ADDRESS	ORGANIZATION / ADDRESS
EPA Region 10 Mail Code: OMP-145 1200 Sixth Avenue Seattle, WA 98101	U.S. EPA, Region 9 Office of Air Waste and Toxics 1200 Sixth Avenue Seattle, WA 98101

THE UNITED STATES OF AMERICA BY THE U.S ENVIRONMENTAL PROTECTION AGENCY

SIGNATURE OF AWARD OFFICIAL	TYPED NAME AND TITLE	DATE
[signature]	Richard Albright, Director - Office of Air Waste and Toxics	8/29/2006

AFFIRMATION OF AWARD

BY AND ON BEHALF OF THE DESIGNATED RECIPIENT ORGANIZATION

SIGNATURE	TYPED NAME AND TITLE	DATE
Robert Kanter	Robert Kanter, Director of Planning	9/28/06

EPA Funding Information

XA - 96042301 - 0 Page 2

FUNDS	FORMER AWARD	THIS ACTION	AMENDED TOTAL
EPA Amount This Action	$	$ 300,000	$ 300,000
EPA In-Kind Amount	$	$	$ 0
Unexpended Prior Year Balance	$	$	$ 0
Other Federal Funds	$	$	$ 0
Recipient Contribution	$	$	$ 0
State Contribution	$	$	$ 0
Local Contribution	$	$	$ 0
Other Contribution	$	$	$ 0
Allowable Project Cost	$ 0	$ 300,000	$ 300,000

Assistance Program (CFDA)	Statutory Authority	Regulatory Authority
66.034 - Surveys-Studies-Investigations-Demonstrations and Special Purpose Activities relating to the Clean Air Act	Clean Air Act of 1963: Sec. 103 as amended (PL 95-95)	40 CFR PART 31

Fiscal

Site Name	DCN	FY	Approp. Code	Budget Organization	PRC	Object Class	Site/Project	Cost Organization	Obligation / Deobligation
-	BDG050	0607	B	10B	101A59E	41.83			300,000
									300,000

Budget Summary Page

Table A - Object Class Category (Non-construction)	Total Approved Allowable Budget Period Cost
1. Personnel	$0
2. Fringe Benefits	$0
3. Travel	$0
4. Equipment	$0
5. Supplies	$0
6. Contractual	$300,000
7. Construction	$0
8. Other	$0
9. Total Direct Charges	$300,000
10. Indirect Costs: % Base	$0
11. Total (Share: Recipient 0.00 % Federal 100.00 %.)	$300,000
12. Total Approved Assistance Amount	$300,000
13. Program Income	$0
14. Total EPA Amount Awarded This Action	$300,000
15. Total EPA Amount Awarded To Date	$300,000

Administrative Conditions

1. Payment Information

All recipients must be enrolled to receive funds electronically via the EPA-EFT Payment Process. This electronic funds transfer process was initiated by EPA in response to the Debt Collection Improvement Act of 1996, P.L. 104-134 that requires all federal payments be made via Direct Deposit/Electronic Funds Transfer(DD/EFT). By signing the assistance agreement you are agreeing to receive payment electronically.

In order to receive payments electronically, the ACH Vendor/ Miscellaneous Payment Enrollment Form (SF3881) must be completed and faxed to Marge Pumphrey at (702) 798-2423.

After reviewing and processing the SF3881, the Las Vegas Finance Center (LVFC) will send you a letter assigning you an EFT Control Number, an EPA-EFT Recipient's Manual, and the necessary forms for requesting funds and reporting purposes.

If you need further assistance regarding enrollment, please contact Marge Pumphrey at (702) 798-2492 or by e-mail to: pumphrey.margaret@epa.gov.

Any recipient currently using the Automated Standard Application for Payments (ASAP) system with another government agency should contact Marge Pumphrey at (702) 798-2492 or e-mail to: pumphrey.margaret@epa.gov.

Under any of the above payment mechanisms, recipients may request/draw down advances for their immediate cash needs, provided the recipient meets the requirements of 40 CFR 30.22(b) or 40 CFR 31.21(c), as applicable. Additionally, recipients must liquidate all obligations incurred within 90 calendar days of the project period end date. Therefore, recipients must submit the final request for payment, and refund to EPA any balance of unobligated cash advanced within 90 calendar days after the end of the project period.

2. Cost Principles/Indirect Costs Not Included (All Organizations)

The cost principles of OMB Circular A-21 (Educational Institutions), A-87 (State, Local or Indian Tribal Governments), or A-122 (Non-Profit Organizations) are applicable, as appropriate, to this award. Since there are no indirect costs included in the assistance budget, they are not allowable under this Assistance Agreement.

3. Financial Status Reports (FSRs)

FINAL FSR:
The final Financial Status Report (FSR), Standard Form 269A (or Standard Form 269 if program income is generated), for this award is due to EPA no later than 90 days after the budget period expires. The **report can be faxed to (702) 798-2423 or mailed to:**

US Environmental Protection Agency
Las Vegas Finance Center
P.O. Box 98515
Las Vegas, NV 89193-8515

INTERIM FSR:
If the budget period is longer than one year, or if the agreement is revised to extend the budget period beyond one year, the recipient must submit an annual FSR within 90 days after the end of each anniversary of the agreement. **The interim report can be faxed to (206) 553-4957 or mailed to:**

US Environmental Protection Agency
Grants Administration Unit
1200 Sixth Avenue, OMP-145
Seattle, WA 98101

For agreements with multiple budget activities, separate FSRs must be provided for each of the activities,

sites, or budgets, as applicable.

4. Audit Requirements

The recipient agrees to comply with the requirements of OMB Circular A-133, "Audits of States, Local Governments, and Non-Profit Organizations."

5. Hotel and Motel Fire Safety Act

Effective October 1, 1994, the recipient agrees to ensure that all conference, meeting, convention, or training space funded in whole or in part with Federal funds, complies with the Hotel and Motel Fire Safety Act of 1990.

6. Recycled Paper

ALL APPLICANTS:
In accordance with EPA Order 1000.25 and Executive Order 13101, *Greening the Government Through Waste Prevention, Recycling, and Federal Acquisition* , the recipient agrees to use recycled paper for all reports which are prepared as a part of this agreement and delivered to EPA. This requirement does not apply to reports prepared on forms supplied by EPA, or to Standard Forms, which are printed on recycled paper and are available through the General Services Administration. Please note that Section 901 of E.O. 13101, dated September 14, 1998, revoked E.O. 12873, *Federal Acquisition, Recycling, and Waste Prevention* in its entirety.

STATE AGENCIES AND POLITICAL SUBDIVISIONS:
Any State agency or agency of a political subdivision of a State which is using appropriated Federal funds shall comply with the requirements set forth in Section 6002 of the Resource Conservation and Recovery Act (RCRA) (42 U.S.C. 6962). Regulations issued under RCRA Section 6002 apply to any acquisition of an item where the purchase price exceeds $10,000 or where the quantity of such items acquired in the course of the preceding fiscal year was $10,000 or more. RCRA Section 6002 requires that preference be given in procurement programs to the purchase of specific products containing recycled materials identified in guidelines developed by EPA. These guidelines are listed in 40 CFR 247.

STATE AND LOCAL INSTITUTIONS OF HIGHER EDUCATION, HOSPITALS, AND NON-PROFIT ORGANIZATIONS:
Pursuant to 40 CFR 30.16, State and local institutions of higher education, hospitals, and non-profit organizations that receive direct Federal funds shall give preference in their procurement programs funded with Federal funds to the purchase of recycled products pursuant to EPA's guidelines.

7. Lobbying

ALL RECIPIENTS:
The recipient agrees to comply with Title 40 CFR Part 34, *New Restrictions on Lobbying* . The recipient shall include the language of this provision in award documents for all subawards exceeding $100,000, and require that subrecipients submit certification and disclosure forms accordingly.

In accordance with the Byrd Anti-Lobbying Amendment, any recipient who makes a prohibited expenditure under Title 40 CFR Part 34 or fails to file the required certification or lobbying forms shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such expenditure.

PART 30 RECIPIENTS:
All contracts awarded by a recipient shall contain, when applicable, the anti-lobbying provision as stipulated in the Appendix at Title 40 CFR Part 30.

Pursuant to Section 18 of the Lobbying Disclosure Act, the recipient affirms that it is not a nonprofit organization described in Section 501(c)(4) of the Internal Revenue Code of 1986; or that it is a nonprofit organization described in Section 501(c)(4) of the Code but does not and will not engage in lobbying activities as defined in Section 3 of the Lobbying Disclosure Act.

8. **Lobbying and Litigation**

ALL RECIPIENTS:
Pursuant to EPA's annual Appropriations Act, the chief executive officer of this recipient agency shall require that no grant funds have been used to engage in lobbying of the Federal Government or in litigation against the United States unless authorized under existing law: As mandated by this Act, the recipient agrees to provide certification to the award official via EPA Form 5700-53, *Lobbying and Litigation Certificate,* within 90 days after the end of project period.

Recipient shall abide by its respective OMB Circular (A-21, A-87, or A-122), which prohibits the use of federal grant funds for litigation against the United States. Any Part 30 recipient shall abide by its respective OMB Circular (A-21 or A-122), which prohibits the use of Federal grant funds to participate in various forms of lobbying or other political activities.

9. **Suspension and Debarment**

Recipient shall fully comply with Subpart C of 40 CFR Part 32, entitled "Responsibilities of Participants Regarding Transactions." Recipient is responsible for ensuring that any lower tier covered transaction, as described in Subpart B of 40 CFR Part 32, entitled "Covered Transactions," includes a term or condition requiring compliance with Subpart C. Recipient is responsible for further requiring the inclusion of a similar term or condition in any subsequent lower tier covered transactions. Recipient acknowledges that failing to disclose the information required under 40 CFR 32.335 may result in the delay or negation of this assistance agreement, or pursuance of legal remedies, including suspension and debarment.

Recipient may access the Excluded Parties List System at http://www.epls.gov. This term and condition supersedes EPA Form 5700-49, "Certification Regarding Debarment, Suspension, and Other Responsibility Matters."

10. **Small and Disadvantaged Business Utilization Requirements (Non-SRF Recipients)**

The recipient agrees to comply with the requirements of EPA's Program for Utilization of Small, Minority and Women's Business Enterprises in procurement under assistance agreements:

(a) The recipient accepts the applicable FY99 Minority Business Enterprise (MBE)/Womens' Business Enterprise (WBE) "fair share" goals/objectives negotiated with EPA by the California Air Resources Board as follows:

Construction: 20% MBE; 10% WBE
Supplies: 24% MBE; 44% WBE
Services: 20% MBE; 31% WBE
Equipment: 19% MBE; 16% WBE

(b) The recipient agrees to ensure, to the fullest extent possible, that at least the applicable "fair share" objectives of Federal funds for prime contracts or subcontracts for supplies, construction, equipment or services are made available to organizations owned or controlled by socially and economically disadvantaged individuals, women and Historically Black Colleges and Universities.

(c) The recipient agrees to include in its bid documents the applicable "fair share" objectives and require all of its prime contractors to include in their bid documents for subcontracts the negotiated "fair share" percentages.

(d) The recipient agrees to follow the six affirmative steps or positive efforts stated in 40 CFR 30.44(b), 40 CFR 31.36(e), or 40 CFR 35.6580, as appropriate, and retain records documenting compliance.

(e) The recipient agrees to submit an EPA form 5700-52A, "MBE/WBE Utilization Under Federal Grants, Cooperative Agreements and Interagency Agreements" as follows:

For grants awarded under 40 CFR Part 35, Subpart A (refer to the Regulatory Authority box shown in the middle of Page 2 of the Assistance Agreement/Amendment), reports are due annually by October 30 of each year (covers the Federal Fiscal Year October 1 - September 30).

For Assistance Agreements/Amendments with institutions of higher education, hospitals and other non-profit organizations awarded under the Regulatory Authority of 40 CFR Part 30, reports are due annually by October 30 of each year (covers the Federal Fiscal Year October 1 - September 30).

Grants awarded under any other Regulatory Authority are due Quarterly. These reports are due beginning with the Federal Fiscal Year quarter the recipient receives the award and continuing until the project period ends. These reports must be submitted within 30 days of the end of the Federal Fiscal Quarter (due dates are January 30, April 30, July 30, and October 30).

All reports must be submitted to the Grants Administration Unit, OMP-145, 1200 Sixth Avenue, Seattle, WA 98101. For further information, please contact Valerie Badon at (206) 553-1141, email: Badon.Valerie@epa.gov.

(f) If race and/or gender neutral efforts prove inadequate to achieve a "fair share" objective, the recipient agrees to notify EPA in advance of any race and/or gender conscious action it plans to take to more closely achieve the "fair share" objective.

EPA may take corrective action under 40 CFR Parts 30, 31, and 35, as appropriate, if the recipient fails to comply with these terms and conditions.

11. **Small Business in Rural Areas (SBRA)**

If a contract is awarded under this assistance agreement, the recipient is also required to utilize the following affirmative steps:

(a) Place SBRAs on solicitation lists.

(b) Make sure that SBRAs are solicited whenever there are potential sources.

(c) Divide total requirements, when economically feasible, into small tasks or quantities to permit maximum participation by SBRAs.

(d) Establish delivery schedules, where the requirements of work permit, which would encourage participation by SBRAs.

(e) Use the services of the Small Business Administration and the Minority Business Development Agency of the U.S. Department of Commerce, as appropriate.

(f) Require the contractor to comply with the affirmative steps outlined above.

There is no formal reporting requirement for SBRAs at this time; it is recommended that the recipient keep records of SBRA participation.

12. **Payment to Consultants**

EPA participation in the salary rate (excluding overhead and travel) paid to individual consultants retained by recipients or by a recipient's contractors or subcontractors shall be limited to the maximum daily rate for Level IV of the Executive Schedule, to be adjusted annually. This limit applies to consultation services of designated individuals with specialized skills who are paid at a daily or hourly rate. As of January 1, 2006, the limit is $548.16 per day ($68.52 per hour). This rate does not include overhead or travel costs and the recipient may pay these in accordance with its normal travel practices.

Subagreements with firms for services which are awarded using the procurement requirements in 40 CFR Parts 30 or 31, as applicable, are not affected by this limitation unless the terms of the contract provide the recipient with responsibility for the selection, direction, and control of the individuals who will be providing services under the contract at an hourly or daily rate of compensation. See 40 CFR 30.27(b) or 40 CFR 31.36(j)(2), as applicable, for additional information.

NOTE: For future years' limits, the recipient may find the annual salary for Level IV of the Executive Schedule on the following Internet site: http://www.opm.gov/oca. Select "Salary and Wages", and select

"Executive Schedule". The annual salary is divided by 2087 hours to determine the maximum hourly rate, which is then multiplied by 8 to determine the maximum daily rate.

Programmatic Conditions

1. Quarterly Performance Reports

In accordance with 40 C.F.R. §31.40, the recipient agrees to submit quarterly performance reports that include brief information on each of the following areas: 1) a comparison of actual accomplishments to the outputs/outcomes established in the assistance agreement work plan for the period; 2) the reasons for slippage if established outputs/outcomes were not met; and 3) additional pertinent information, including, when appropriate, analysis and formation of cost overruns or high unit costs. Reports should be submitted to the EPA Project Officer and may be provided electronically.

In accordance with 40 C.F.R. § 30.51 (d) and 40 C.F.R. § 31.40, as appropriate, the recipient agrees to submit performance reports that include brief information on each of the following areas:

a) a comparison of actual accomplishments to the outputs/outcomes established in the work plan;

b) the reasons for slippages if established outputs/outcomes where not met;

c) additional pertinent information, including when appropriate, analysis and information of cost overruns or high unit costs;

In addition to periodic performance reports, the recipient shall immediately notify the EPA Project Officer of developments that have a significant impact on the award-supported activities. In accordance with 40 C.F.R. § 30.51 (f) and 40 C.F.R. § 31.40(d), as appropriate, the recipient agrees to inform the EPA Project Officer as soon as problems, delays or adverse conditions become know which will materially impair the ability to meet the outputs/outcomes specified in the assistance agreement work plan. This notification shall include a statement of the action taken or contemplated, and any assistance needs to resolve the situation.

2. Final Performance Report

In addition to the periodic performance reports, the recipient shall submit a final performance report, which is due 90 calendar days after the expiration or termination of the award. The report shall be submitted to the EPA Project Officer and may be provided electronically. The report shall generally contain the same information as in the periodic reports, but should cover the entire project period. Furthermore, the recipient is required to submit a diesel emissions estimated reductions results spreadsheet. This spreadsheet must be approved by the EPA Project Officer before the project begins. Upon the completion of the project, this spreadsheet should include specific descriptions of equipment and/or fuel used and estimated resulting pollutant reductions (tons/year).

3. Quality Assurance Requirements

This grant includes the performance of environmental measurements, therefore, a QA Plan, a Sampling and Analysis Plan, or other comparable document covering QA activities, must be prepared. The recipient should consult with the Region 9 Quality Assurance Office to determine what type of QA documentation would be most appropriate and what QA guidance should be followed. The QA Plan must be approved by the EPA Project Officer, the Region 9 Quality Assurance Manager, and the recipient's Quality Assurance Officer before measurement activities are undertaken. Contact the QA Office at 415-972-3411.

END OF GRANT AGREEMENT NO. XA-960423-01-0

Appendix C

Contract Cost Principles Under the Federal Acquisition Regulation 48 CFR Part 31

Contract Cost Principles Under the Federal Acquisition Regulation
48 CFR Part 31

- When procuring property and services under a grant, Grantees must clearly delineate in the Request for Proposal ("RFP") or solicitation, that all contractor costs must comply with the contract cost principles and procedures found in the Federal Acquisition Regulation ("FAR") at 48 C.F.R. Part 31. In addition, once a contractor(s) is selected, the Grantee must ensure that the contract itself contains a clause which requires the contractor to comply with the contract cost principles and procedures of the FAR.[1]

- The rules for determining whether costs incurred by a grantee's contractor may be paid from grant funds are found at 48 C.F.R. §31.2 of the FAR.[2] The FAR lists five criteria which must be met in order for a cost to be allowable:
  1) Reasonableness[3];
  2) Allocability[4];
  3) Cost Accounting Standards, if applicable; otherwise generally accepted accounting principles and practices appropriate to the particular circumstance;
  4) Terms of the contract;
  5) Specific regulatory limitations in the FAR or agency FAR supplements.

- Some well-known unallowable costs include costs for alcoholic beverages, charitable donations, and interest. Unallowable costs must be segregated from any billing, indirect cost pool, claim, or proposal submitted.

- A cost is not presumed to be allowable merely because the contractor actually incurred the cost.

- Direct costs need to properly segregated from indirect costs.

Summary of Specific FAR Part 31 Cost Allowability Rules

FAR Clause	Title	Allowability
31.205-1	Public relations and advertising costs	May be allowable
31.205-3	Bad debts	Unallowable

[1] The cost principles in FAR Part 31 also apply to subcontracts.
[2] The cost principles apply to costs under cost-type contracts and subcontracts. The cost principles generally do not apply to fixed-price contracts or subcontracts unless the government performs a cost analysis or a determination of costs is otherwise required.
[3] A cost is reasonable if it would have been incurred by a prudent person in the conduct of competitive business. Reasonableness of a particular cost depends on the specific facts and circumstances.
[4] A cost is allocable to a government contract if it 1) is incurred specifically and exclusively for that contract (a "direct cost"); 2) benefits both the contract and other work and can be distributed to them in reasonable proportion to the benefits received (an "indirect cost" in an overhead cost pool); 3) is necessary to the overall operation of the business (an "indirect cost" in a general and administrative cost pool).

FAR Clause	Title	Allowability
31.205-4	Bonding Costs	Allowable
31.205-6	Compensation for personal services	May be allowable
31.205-7	Contingencies	Unallowable
31.205-8	Contributions or donations	Unallowable
31.205-10	Cost of money	May be allowable
31.205-11	Depreciation	May be allowable
31.205-12	Economic planning costs	Allowable
31.205-13	Employee morale, health, welfare, food service, and dormitory costs and credits	May be allowable
31.205-14	Entertainment costs	Unallowable
31.205-15	Fines, penalties, and mischarging costs	Unallowable
31.205-16	Gains and losses on disposition or impairment of depreciable property or capital assets	Unallowable
31.205-17	Idle facilities and idle capacity costs	May be allowable
31.205-18	Independent research and development and bid and proposal costs	May be allowable
31.205-19	Insurance and indemnification	May be allowable
31.205-20	Interest and other financial costs	Unallowable
31.205-21	Labor relations costs	May be allowable
31.205-22	Legislative lobbying costs	May be allowed
31.205-23	Losses on other contracts	Unallowable
31.205-24	Maintenance and repair costs	Allowable
31.205-25	Manufacturing and production engineering costs	Allowable
31.205-26	Material costs	Allowable
31.205-27	Organization costs	Unallowable
31.205-28	Other business expenses	May be allowable
31.205-29	Plant protection costs	Allowable
31.205-30	Patent costs	May be allowable
31.205-31	Plant reconversion costs	May be allowable
31.205-32	Precontract costs	May be allowable
31.205-33	Professional and consultant service costs	May be allowable
31.205-34	Recruitment costs	May be allowable
31.205-35	Relocation costs	May be allowable
31.205-36	Rental costs	May be allowable
31.205-37	Royalties and other costs for use of patents	May be allowable
31.205-38	Selling costs	May be allowable
31.205-39	Service and warranty costs	Allowable
31.205-40	Special tolling and special test equipment costs	May be allowable
31.205-41	Taxes	May be allowable
31.205-42	Termination Costs	May be allowable
31.205-43	Trade, business, technical, and professional activity costs	May be allowable
31.205-44	Training and education costs	May be allowable

FAR Clause	Title	Allowability
31.205-45	Transportation costs	Allowable
31.205-46	Travel costs	May be allowable
31.205-47	Costs related to legal and other proceedings	May be allowable
31.205.48	Deferred research and development costs	May be allowable
31.205-49	Goodwill	Unallowable
31.205-51	Costs of alcoholic beverages	Unallowable
31.205-52	Asset valuations resulting from business combinations	Unallowable

Appendix D

Example of City of Long Beach Contract for Consulting Services

OFFICE OF THE CITY ATTORNEY
ROBERT E. SHANNON, City Attorney
333 West Ocean Boulevard, 11th Floor
Long Beach, CA 90802-4664

CONTRACT FOR CONSULTING SERVICES

BETWEEN THE CITY OF LONG BEACH AND

NAME
STREET AND P.O. BOX ADDRESS
CITY, STATE, ZIP
TELEPHONE NO.
FAX NO.

THIS CONTRACT is made and entered into, in duplicate, as of the date executed by the Executive Director of the Long Beach Harbor Department ("Executive Director"), by and between the CITY OF LONG BEACH, a municipal corporation, acting by and through its Board of Harbor Commissioners ("City"), pursuant to authority granted by said Board [by its Ordinance No. HD-1818] [at its meeting of [_____________, 2008; and [__________________________], a [_______________] corporation ("Consultant").

1. This contract is made with reference to the following facts and objectives:

1.1 City[, from time to time,] has the need for [____ ____].

1.2 Consultant represents that it has in its employ [licensed and] experienced personnel who are qualified to render these services.

1.3 City wishes to employ Consultant upon the following terms and conditions to render such services as City shall [from time to time] request.

2. Consultant shall provide, in accordance with generally accepted professional and technical standards currently in effect, such services [within the scope of work] as may be requested in writing [from time to time during the term of this contract] by City's Director of Planning. [The anticipated scope of work is set forth in the ______________________________ dated _____________________, 20__, attached hereto as Exhibit "A" and incorporated by this reference.]

3. The term of this contract shall [be deemed to have] commence[d] on

[____________________] and, subject to the provisions of paragraph [_____], shall terminate on [__________________________].

4. In requesting the services of Consultant, the Director of Planning shall identify the project for which such services are requested and shall establish the maximum amount to be charged by Consultant on such project, the time limit within which Consultant is to complete the work, and the charge point to be used by Consultant in billing City. Consultant's charges on any project shall not exceed the maximum amount so established without the express written approval of the Director of Planning.

5. Charges made by Consultant for such services shall be based on Consultant's [__________________], attached hereto as Exhibit "[___]" and incorporated by this reference.

6. Consultant shall submit a separate statement not later than the tenth day of each month for [each project upon which] services [which] have been performed during the immediately preceding month, referring in each of said statements to the charge point for such project previously furnished by the Director of Planning and detailing the services performed and expenses, if any, incurred. All payments to Consultant shall be made by City in due course, not to exceed thirty (30) days, after approval of invoice by the Director of Planning.

7. [Subject to the provisions of subparagraph 7.1,] T[t]he total amount which shall be payable by City to Consultant for Consultant's services[on all projects] during the term of this contract shall not exceed [$_______________].

[7.1 If, during the course of the described services, additional work beyond the scope of services described in Exhibit "A" is, in the opinion of the Director of Planning, required or desired, the Director of Planning may authorize such additional work by Consultant; provided, total compensation to be paid hereunder, including compensation for such additional services, shall not exceed [$_______________].

8. All designs, sketches, drawings, specifications, data and other

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information, in whatever form or medium, compiled or prepared by Consultant in performing its services or furnished to Consultant by City shall be the property of City and City shall have the unrestricted right to use or disseminate same without payment of further compensation to Consultant. Copies of Consultant's work product may be retained by Consultant for its own records.

9. City shall have the right to terminate this contract at any time upon ten (10) days' written notice to Consultant. If this contract is so terminated prior to the expiration of the term, Consultant shall be paid for those charges which have accrued but not been paid through the effective date of termination. Consultant agrees to accept such amount, plus all amounts previously paid, as full payment and satisfaction of all obligations of City to Consultant.

10. Neither City nor any of its employees shall have any control over the conduct of Consultant, or employees of Consultant, except as herein set forth, and Consultant and employees of Consultant shall not, at any time or in any manner, represent that Consultant or employees of Consultant, or any of them, are the officers, agents, or employees of City. It is expressly understood and agreed that Consultant is, and shall at all times remain, as to City a wholly independent contractor, and each party's obligations to the other party are solely such as are set forth in this contract. Consultant shall be free to contract for similar services to be performed for others during this contract. [Consultant acknowledges and agrees that: (i) City will not withhold taxes of any kind from Consultant's compensation; (ii) City will not secure workers' compensation or pay unemployment insurance to, for or on Consultant's behalf; and (iii) City will not provide and Consultant is not entitled to any of the usual and customary rights, benefits or privileges of City employees.]

11. Consultant agrees, subject to applicable laws, rules, and regulations, not to discriminate in the performance of this contract against any employee or applicant for employment on the basis of race, color, national origin, religion, sex, sexual orientation, AIDS, HIV status, age, disability, handicap, or veteran status. Consultant

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shall ensure that applicants are employed and that employees are treated during employment without regard to any of these bases, including but not limited to employment, upgrading, demotion, transfer, recruitment, recruitment advertising, layoff, termination, rates of pay or other forms of compensation, and selection for training, including apprenticeship. Consultant agrees to post in conspicuous places available to employees and applicants for employment notices to be provided by City setting out the provisions of this nondiscrimination clause. Consultant shall in all solicitations or advertisements for employees state that all qualified applicants will receive consideration for employment without regard to these bases. Compliance with the Americans with Disabilities Act of 1990 shall be the sole responsibility of Consultant, and Consultant shall defend and hold the City harmless from any expense or liability arising from Consultant's non-compliance therewith.

12. Any notices to be given under this contract shall be given in writing. Such notices may be served by personal delivery, facsimile transmission or by first class regular mail, postage prepaid. Any such notice, when served by mail, shall be effective two (2) calendar days after the date of mailing of the same, and when served by facsimile transmission or personal delivery shall be effective upon receipt. For the purposes hereof, the address of City, and the proper person to receive any such notices on its behalf, is: Executive Director, Long Beach Harbor Department, P.O. Box 570, Long Beach, California 90801, FAX number (562) 901-1733; and the address and FAX number of Consultant as indicated above.

13. This contract contemplates the personal services of Consultant and its employees, and it is recognized by the parties hereto that a substantial inducement to City for entering into this contract was, and is, the professional reputation and competence of Consultant and key employees [_______________ (Project Principal) and ____________________ (Project Manager)] and any change in personnel employed on City projects shall be approved in advance by the Director of Planning. Neither this contract nor any interest therein may be assigned or delegated by Consultant except

upon the prior written consent of the Executive Director. Any attempted assignment or delegation without such consent shall be void, and any assignee or delegate shall acquire no right or interest by reason of such attempted assignment or delegation. [Furthermore, except for the subcontract with Meyer, Mohaddes Associates, Inc., Consultant shall not subcontract any portion of the performance contemplated and provided for hereunder without the prior written approval of the Director of Planning.] Nothing herein shall prevent Consultant from employing or hiring as many employees as Consultant may deem necessary for the proper and efficient execution of this contract.

14. Consultant covenants that both itself, in its corporate capacity, and its principals presently have no interest and shall not acquire any interest, direct or indirect, which would conflict in any manner or degree with the performance of services required to be performed under this contract.

15. Consultant shall indemnify, hold, protect and save harmless the City of Long Beach, the Board of Harbor Commissioners, [the United States] and their officials, commissioners, employees, and agents ("Indemnified Parties") from and against any and all actions, suits, proceedings, claims, demands, damages, losses, liens, costs, expenses or liabilities, of any kind or nature whatsoever ("Claims") which arise out of, pertain to, or relate to the negligence, recklessness or willful misconduct of Consultant, its officers, employees, subcontractors or agents. Independent of the duty to indemnify and as a free-standing duty on the part of Consultant, Consultant shall defend the Indemnified Parties from and against any and all Claims which arise out of, pertain to, or relate to Consultant's work under this contract, and Consultant shall continue the defense until such Claim is resolved, whether by settlement, judgment or otherwise. City shall notify Consultant of any such Claim, shall tender its defense to Consultant, and assist Consultant, as may be reasonably requested, in such defense. Consultant shall provide such defense immediately upon notification and tender to Consultant of a Claim. If a court of competent jurisdiction determines that a Claim had causes other than the negligence, recklessness or willful misconduct of Consultant, Consultant's costs of

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indemnity and defense shall be reduced to the percentage of Consultant's negligence, recklessness or willful misconduct. Payment of a Claim shall not be a condition precedent to an Indemnified Party's right to indemnity, or to an Indemnified Party's right to defense.

16. As a condition precedent to the effectiveness of this contract, Consultant shall procure and maintain in full force and effect during the term of this contract the following types and levels of insurance:

(a) Commercial General Liability Insurance which affords coverage at least as broad as Insurance Services Office "occurrence" form CG 00 01 with minimum limits of at least $1,000,000 per occurrence, and if written with an aggregate, the aggregate shall be double the per occurrence limit. The policy shall contain no provisions or endorsements limiting coverage for (1) products - completed operations; (2) contractual liability; (3) independent contractors; (4) third party action over claims; (5) explosion, collapse or underground hazard (XCU); and (6) defense costs shall be excess limits.

(b) Automobile Liability Insurance with coverage at least as broad as Insurance Service Office Form CA 0001 covering "Any Auto" (Symbol 1) with minimum limits of $1,000,000 each accident.

[ADD AIRCRAFT LIABILITY IF APPROPRIATE]

[(c) Ocean Marine Liability Insurance, including Protection and Indemnity, with minimum limits of [$5,000,000] per occurrence, Jones Act for employees performing services covered by the Act, and pollution liability. Pollution liability shall include coverage for bodily injury (including death and mental anguish), property damage, defense costs and cleanup costs with minimum limits of [$5,000,000] per loss and [$10,000,000] total losses.]

[(d) Contractor's Pollution Liability Insurance covering all of Consultant's operations, including onsite and offsite for bodily injury (including death and mental anguish), property damage, defense costs and cleanup costs

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with minimum limits of [$5,000,000] per loss and [$10,000,000] total all losses. Non-owned disposal site coverage shall be provided if handling, storing or generating hazardous materials or any material/substance otherwise regulated under environmental laws/regulations.]

(c) Workers' Compensation Insurance, as required by the State of California and Employer's Liability Insurance with a limit of not less than $1,000,000 per accident for bodily injury and disease, and any required coverage under the U.S. Longshoremen's and Harbor Workers' Act, Federal Employers Liability Act, and Jones Act for employees performing services covered by these Acts.

(d) Professional Liability Insurance with minimum limits of $1,000,000. Covered Professional Services shall include all work to be performed under the contract and without any exclusions that may potentially affect the work to be performed under the contract. The policy shall contain provisions or endorsements extending coverage to contractual liability.

Insurance policies will not be in compliance if they include any limiting endorsement that has not been approved in writing by City.

The policy or policies of insurance for Commercial General Liability and Automobile Liability [Ocean Marine Liability, Aircraft Liability, Contractor's Pollution Liability] shall contain the following provisions or be endorsed to provide the following:

(1) The Indemnified Parties shall be additional insureds with regard to liability and defense of suits or claims arising out of the performance of the Contract. Additional insured endorsements shall not:

i. Be limited to ongoing operations;

ii. Exclude contractual liability;

iii. Restrict coverage to the sole liability of Consultant;

iv. Contain any other exclusion contrary to the contract.

(2) This insurance shall be primary and any other insurance,

deductible, or self-insurance maintained by the Indemnified Parties shall not contribute with this primary insurance.

(3) The policy shall not be canceled or the coverage reduced until a thirty (30) day written notice of cancellation has been served upon the Executive Director of the Harbor Department except notice of ten (10) days shall be allowed for non-payment of premium.

The policy or policies of insurance for Workers' Compensation shall be endorsed, as follows:

(1) A waiver of subrogation stating that the insurer waives all rights of subrogation against the Indemnified Parties.

(2) The policy or policies shall not be canceled or the coverage reduced until a thirty (30) days written notice of cancellation has been served upon the Executive Director of the Harbor except notice of ten (10) days shall be allowed for non-payment of premium.

The policy or policies of insurance required for Professional Liability shall be endorsed as follows:

(1) The policy or policies shall not be canceled or the coverage reduced until a thirty (30) day written notice of cancellation has been served upon the Executive Director of the Harbor except notice of ten (10) days shall be allowed for non-payment of premium.

Any deductible or self-insured retention must be approved in writing by the Executive Director and shall protect the Indemnified Parties in the same manner and to the same extent as they would have been protected had the policy or policies not contained a deductible or self-insured retention.

Consultant shall deliver either certified copies of the required policies or endorsements on forms approved by the City ("evidence of insurance") to the Executive Director for approval as to sufficiency and as to form. At least fifteen (15) days prior to the expiration of any such policy, evidence of insurance showing that such insurance

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coverage has been renewed or extended shall be filed with the Executive Director. If such coverage is canceled or reduced, Consultant shall, within ten (10) days after receipt of written notice of such cancellation or reduction of coverage, file with the Executive Director evidence of insurance showing that the required insurance has been reinstated or has been provided through another insurance company or companies.

The coverage provided shall apply to the obligations assumed by the Consultant under the indemnity provisions of this contract but this insurance provision in no way limits the indemnity provisions and the indemnity provisions in no way limit this insurance provision.

Consultant agrees to suspend and cease all operations hereunder during such period of time as the required insurance coverage is not in effect and evidence of insurance has not been approved by City. City has the right to withhold all payments due Consultant until Consultant has complied fully with this insurance provision.

Each such policy shall be from a company or companies with a current A.M. Best's rating of no less than A:VII and authorized to do business in the State of California, or otherwise allowed to place insurance through surplus line brokers under applicable provisions of the California Insurance Code or any federal law.

If coverage is written on a claims-made basis, the retroactive date on such insurance and all subsequent insurance shall coincide with or precede the effective date of the contract and continuous coverage shall be maintained or Consultant shall obtain and submit an extended reporting period endorsement of at least three (3) years from termination or expiration of this contract. Upon expiration or termination of coverage of required insurance, Consultant shall procure and submit to City evidence of "tail" coverage or an extended reporting period endorsement of at least three (3) years from termination or expiration of this contract.

Consultant shall require all subconsultants to purchase the appropriate insurance in compliance with the terms of this contract [in compliance with Exhibit ___]. If Consultant does not obtain evidence of the required insurance from all subconsultants,

the limits of liability listed above shall be increased by 50%.

17. Consultant shall obtain and maintain any necessary licenses and permits required under Title 3 and Title 5 of the Long Beach Municipal Code. City may withhold any payment to Consultant until Consultant comes into compliance with such licensing and permitting requirements.

[18. This contract shall be deemed made in the State of California and shall be governed by the laws of said State (except those provisions of California law dealing with conflicts of law), both as to interpretation and performance.]

19. In the event of any conflict or ambiguity between this written agreement and any exhibit hereto, the provisions of this agreement shall govern.

20. If there is any legal proceeding between the parties to enforce or interpret this contract or to protect or establish any rights or remedies hereunder, the prevailing party shall be entitled to its costs and expenses, including reasonable attorneys' fees.

21. This contract shall not be amended, nor any provision or breach hereof waived, except in writing signed by the parties which expressly refers to this contract.

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OFFICE OF THE CITY ATTORNEY
ROBERT E. SHANNON, City Attorney
333 West Ocean Boulevard, 11th Floor
Long Beach, CA 90802-4664

22. This contract, including all exhibits, constitutes the entire understanding between the parties and supersedes all other agreements, oral or written, with respect to the subject matter herein.

[________________________________]

________________________, 2008 By: ________________________
Name: ________________________
Title: ________________________

________________________, 2008 By: ________________________
Name: ________________________
Title: ________________________

CONSULTANT

CITY OF LONG BEACH, a municipal corporation, acting by and through its Board of Harbor Commissioners

________________________, 2008 By: ________________________
Richard D. Steinke
Executive Director
Long Beach Harbor Department

CITY

The foregoing document is hereby approved as to form.

ROBERT E. SHANNON, City Attorney

________________________, 2008 By: ________________________
Principal Deputy/Deputy

DTH/CMG/TLS: [date] #
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DTH:rjr revised 1/16/08

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Master Agr. - Alternate 1 - Paragraph 2.

2. Consultant shall provide, in accordance with generally accepted professional and technical standards currently in effect, such environmental documentation services as may be requested in writing from time to time during the term of this contract by City's Director of Planning. All services shall be provided in a manner consistent with City’s Request for Qualifications to Provide Environmental Documentation Services dated [________________________________] (“Request”) and Consultant’s Statement of Qualifications dated [_______________________________] (“Statement”). The Request and Statement are on file with City’s Director of Planning and incorporated herein by this reference.

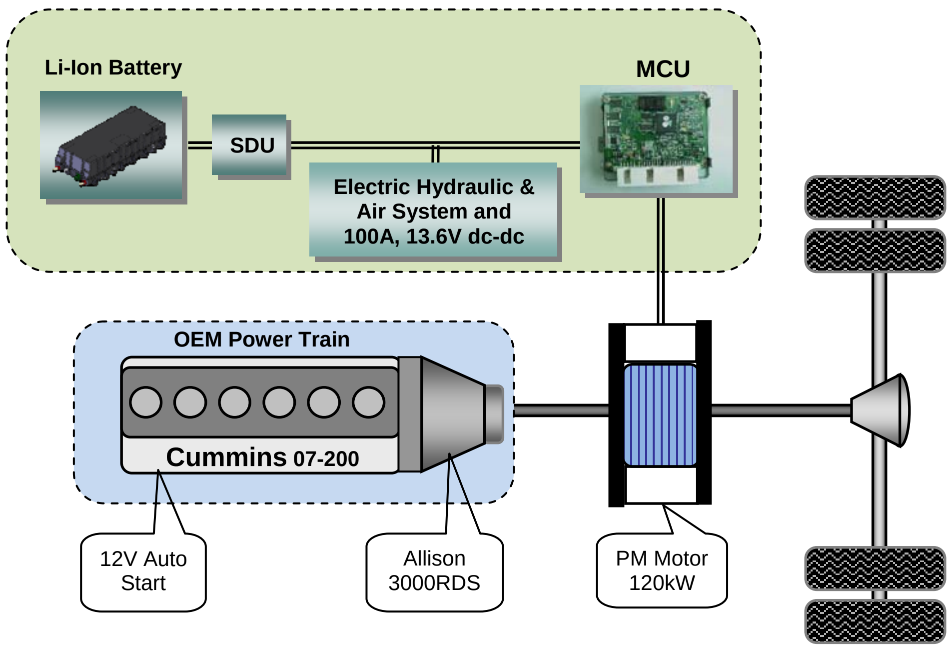
APPENDIX C

US Hybrid Yard Hostler Specification Sheet

Hybrid Port Truck

Hybrid Port Truck System Specification.

- Parallel Hybrid Post Transmission,
- 120kW Permanent Magnet Motor with Digital Controller and J1939 CAN
- Li-Ion Battery,
- 150A, 12V dc-dc converter
- Safety Disconnect Unit
- Electro-Hydraulic pump and controller
- Electric Air Compressor and controller
- CAN and PC based diagnostic, service and maintenance software
- Ottawa 50 with Cummins ISB 07-200 on-road Engine
- Engine Idle control.



APPENDIX D

Quantification of Yard Hostler Activity and the Development of a Representative Yard Hostler Duty Cycle

West Virginia University
Department of Mechanical & Aerospace Engineering
Center for Alternative Fuels, Engines & Emissions

09FFL-0284

Quantification of Yard Hostler Activity and the Development of a Representative Yard Hostler Cycle

David L. McKain, Nigel N. Clark, Richard J. Atkinson and Zac J. Luzader
Center for Alternative Fuels, Engines and Emissions
Mechanical and Aerospace Engineering, West Virginia University

Brad Rutledge
CALSTART, Inc.

ABSTRACT

Yard hostlers are tractors (switchers) used to move containers at ports and storage facilities. While many speed-time driving cycles for assessing emissions and performance from heavy-duty vehicles exist, a driving cycle representative of yard hostler activity at Port of Long Beach, CA was not available. Activity data were collected from in-use yard hostlers as they performed ship loading/unloading, rail loading/unloading and other yard routines, primarily moving containers on trailers or carts. The activity data were then used to develop two speed-time driving cycles with durations of 1200 seconds, representing medium-heavy and heavy-heavy ship activities and medium-heavy and heavy-heavy load rail activities. These cycles were constructed using actual speed-time data collected during activity logging and the cycles created were statistically comparable to each subset of activity data.

INTRODUCTION

Yard hostlers (switchers) serve to transfer cargo, primarily in containers, at marine and inland cargo terminals. They are also used to position over-the-road semi-trailers at warehousing operations. They are specialized single-axle fifth wheel tractors, and are the main source of non-marine emissions at the ports of Long Beach and Los Angeles in California (1). While there was a variety of driving schedules (2-6) available for use in evaluating emissions from heavy-duty vehicles prior to this research, none was known to be representative of the activity of yard hostlers. Additional complexity in evaluating yard hostlers arises since vehicle loading is highly variable. The vehicles typically transfer cargo containers of various sizes and weights between ships, rail cars, and storage yards. The researchers collected in-use global positioning system data, container information, and maintained physical logs with container loading status from two yard hostlers over a six day period. The data were then filtered and parsed to yield parameters including percentage of time spent at idle, amount of slow-speed creep, average trip speed, and standard deviation of trip speed. Fleet-average statistics were obtained: for example, the average “key-on” speed for the whole dataset was 7.5 mph and the average time spent idling was 40.1% of the key-on time. The data were then binned by vehicle activity (rail or ship) and by loading metrics. Two driving schedules, each having 1200 second duration, were developed, one representing medium-heavy (<20,000 kg) operation and the other representing heavy-heavy (>20,000 kg) operation where the mass was that of the vehicle and any trailer or load. The researchers used the method of joining microtrips (4) to create the cycles. Many candidate cycles were generated, with different microtrip combinations, and the cycles which most closely represented the database statistics were chosen for future use.

LITERATURE REVIEW

A large number of speed-time driving cycles have been developed for use in evaluating emissions and

performance of heavy-duty vehicles. One of the first driving cycles used for heavy-duty vehicle evaluation was the Urban Dynamometer Driving Schedule (UDDS). The UDDS, developed using Monte Carlo simulation based on average vehicle speed (1), has been used extensively in heavy-duty vehicle evaluation. Other driving cycles used during early heavy-duty vehicle evaluations include the Central Business District (CBD – SAE J1376) and WVU 5-Peak Truck cycles (3). These cycles were strictly geometric in nature and, as such, not representative of in-use vehicle behavior.

Techniques to create driving cycles that are more representative of specific vehicle operation in certain geographically defined regions have been developed to provide more accurate and localized assessment of vehicle emissions and performance. Examples of targeted cycles derived from actual in-use vehicle activity include the Manhattan cycle, the Washington Metropolitan Area Transit Authority (WMATA) cycle (4), and the Orange County Transit Authority (OCTA) cycle (5) for use with transit buses. An extensive review of previous heavy-duty driving cycles was presented by O'Keefe et al. (6). Three papers (7, 8, 9) have outlined the creation and use of cycles for medium- and heavy-duty trucks.

Lindjhem (10) presented information on intermodal yard activity for emissions inventory purposes from operations at the Port of Oakland, California.

VEHICLES, ACTIVITIES AND LOADING

The vehicles examined during this study were two identical Kalmar Ottawa YT-50 4x2 utility tractor rigs (UTRs or "yard hostlers"). Both vehicles were equipped with Cummins ISB-07 diesel engines (Power rating: 200 hp @ 2300 rpm, maximum torque: 520 lb/ft @ 1600 rpm).

Vehicle activity was classified into two major categories, namely that activity related to ship loading/unloading and that activity related to rail loading/unloading. Initially, a third category related to miscellaneous yard work was considered but was not included because both because the total percentage of time spent in this activity was below 5% of the total operating duration and the activity loading could not be tracked as accurately as the ship and rail related loading. Ship and rail related activity represented 77% and 23% of the observed activity duration after disregarding miscellaneous yard work activity. The total observed activity occurred over fourteen shifts from January 25th through January 30th, 2008.

Figure 1 - Yard hostler vehicles at Port of Long Beach utilized during data logging.

Vehicle loading was determined by combining the weight of the vehicle, the weight of the trailer if being towed, and the weight of the container when mounted on the trailer. Two different types of trailers, a simple chassis and a cornerless gathering chassis (CGC), were used in the port. The simple chassis was equipped with mounting points on the corners to receive a container and were typically used if the containers were to be transferred off-site using an over-the-road tractor. The cornerless gathering chassis, also known as a “bomb cart”, was used in cases where the containers were going to be transferred immediately to a rail car or if they were going to be stored at the yard while awaiting transfer. To simplify the data analysis process, loaded container data provided by the port operators was averaged to arrive at 17,450 kg for loaded 20 ft containers and 22,725 kg for loaded 40 foot containers. Table 1 contains the weights of individual components and the weights of the combinations considered from the observed data.

Table 1 - Component Masses

Component	mass (kg)
Tractor	6440
Simple Chassis	2950
CGC (Bomb-cart)	9750
Empty Container - 40 foot	3850
Empty Container – 20 foot	2200
Full Container - 40 foot	22725
Full Container – 20 foot	17450

Loading classification was defined as either medium-heavy or heavy-heavy with the medium-heavy classification generally covering those periods of activity where the vehicle was operating without a container and the heavy-heavy generally covering periods of activity with a container. From the data gathered during this program, the vehicles spent 64.1% of their time in medium-heavy duty activities and 35.9% in heavy-heavy activities.

DATA LOGGING

Data logging was accomplished by equipping individual yard hostlers with electronic logging devices that recorded positional data using a global positioning receiver and by manually recording vehicle, trailer and container information. Average container load data were estimated by the port operators and provided to the researchers. The GPS logger was a Race Technologies DL1 which was equipped to log data from external inputs in parallel with GPS data. External inputs included a driveshaft speed sensor and a sensor to record the state of the ignition system (on/off). Manual logs identified the activity, vehicle, trailer type, and container presence and load status.

For this effort, data were logged for a total duration of 54 hours and 4 minutes during which the vehicles traveled a distance of 288 miles.

DATA ANALYSIS

Vehicle speed data taken from the GPS receiver required quality audit and pre-processing prior to the activity analysis.

Data Filtering

Two basic filtering operations were required to remove inaccurate or insufficient data from the entirety of the logged activity data, removal of inaccurate data resulting from insufficient satellite tracking by the GPS and removal of data where the vehicle ignition was on but the engine had not been started. Periods where the ignition was on but the engine was not running were identified by monitoring the engine oil pressure switch. A more detailed examination of the data revealed periods where the vehicle was moving but overhead interference produced significant time gaps between accurately logged position data points. In cases where the period between accurately logged data points was small (less than two seconds) a spline interpolation was performed to bridge the gap, but larger gaps resulted in removal of that individual activity segment. Once these data filtering operations were performed, the data from observer logs and yard container weight logs were combined with the GPS/electronic data to form a complete data set.

Determination of Idle

Determining when the vehicle was stationary and idling was important since a large percentage of yard hostler activity was spent waiting to receive/deliver a load. Difficulty arose because noise in the GPS signals would always result in a finite near-zero speed indication. An algorithm was developed that established a GPS speed threshold based on the number of satellites in view. Threshold values ranged from 0.1 mph when the vehicles were idling in the yard and clear of any overhead obstructions but to 0.5 mph when the vehicles were under yard cranes. Any speed recorded that fell below this threshold was considered to be idle and set to zero miles per hour.

Microtrips

After the filtering operation, the data set was subdivided into individual microtrips with each microtrip consisting of a period where the vehicle was stationary at idle followed by an acceleration to speed then a deceleration back to a stop. The duration of the idle in the microtrip was the actual duration of idle from the end of the deceleration of the previous microtrip to the beginning of the acceleration for the microtrip in question. Individual microtrips were classified according to loading and activity with the summary of the entire dataset shown in Table 2.

Table 2 - Microtrip Summary

Activity Classification	Number of Microtrips	Average Load (kg)
All	4000	18,860
All Medium-Heavy	2764	12,897
All Heavy-Heavy	1236	32,193
All Rail	679	20,044
Medium-Heavy Rail	461	13,123
Heavy-Heavy Rail	218	34,678
All Ship	3321	18,618
Medium-Heavy Ship	2303	12,852
Heavy-Heavy Ship	1018	31,661

Each micrtotrip was classified into one of four groups, namely medium-heavy rail, heavy-heavy rail, medium-heavy ship and heavy-heavy ship such that a test cycle for one of these activities was generated using only microtrips classified in that activity.

Creep Mode

Creep mode was defined as operation where maximum microtrip speed did not exceed the tractor speed which corresponded to the first-gear operation with no depression of the accelerator pedal (~3.5 mph steady speed on level ground). More simply, creep operation occurred when the operator released the brake and the vehicle moved forward some distance while engine speed did not exceed the idle speed.

Comparative Metrics

Three different comparative metrics were determined for each non-creep microtrip, namely the percentage of time spent idling, the average speed excluding idle, and the standard deviation of speed excluding idle.

CYCLE GENERATION

The goal of the cycle generation process was to produce two driving cycles, one representing heavy-heavy activity and the other representing medium-heavy activity, each with a duration of 1200 seconds. For each cycle, the first 300 seconds was to be representative of rail related activity and the last 900 seconds representative of ship related activity. This 3:1 ratio of ship related activity to rail related activity corresponded closely to the ratio of ship to rail activity in the observed data set.

Candidate test cycles were generated by randomly selecting individual microtrips from the observed data set and joining them until a desired duration was reached. Durations of 300 seconds for rail related operation and 900 seconds for ship related operation were chosen to represent the makeup of yard hostler operation during the data logging period. Since it was difficult to randomly combine microtrips such that the duration would be exactly 300 or 900 seconds, combinations where the duration was within 25 seconds were considered and idle was added or subtracted to reach the desired duration. The idle added or subtracted was considered in the statistical comparisons. Once a candidate cycle was created, comparative metrics for that cycle were calculated and compared to metrics from the whole data sets as a whole using a minimization function. This approach has been used in the creation of previous test cycles (5, 11).

Minimization Function

A minimization function was used to determine how well each candidate cycle matched the overall characteristics of the data set from which it was selected. This minimization function combined four metrics including the average of the average microtrip speeds (v_{ave}), average of the standard deviation of microtrip speeds (σ_{ave}), the percentage of time spent at idle ($\%_{idle}$) and the percentage of time spent in creep mode ($\%_{creep}$). Once each of the metrics was determined for the candidate cycle, a minimization function was determined by determining the percent difference between the cycle metric and that of the data subset (Equations 1-4) and combining them into a minimization function (Equation 5).

$$m_v = \left[\frac{(v_{ave})_{Cycle} - (v_{ave})_{Dataset}}{(v_{ave})_{Dataset}}\right] \quad \textbf{Equation 1}$$

$$m_\sigma = \left[\frac{(\sigma_{ave})_{Cycle} - (\sigma_{ave})_{Dataset}}{(\sigma_{ave})_{Dataset}}\right] \quad \textbf{Equation 2}$$

$$m_{\%idle} = \left[\frac{(\%_{idle})_{Cycle} - (\%_{idle})_{Dataset}}{(\%_{idle})_{Dataset}}\right] \quad \textbf{Equation 3}$$

$$m_{\%creep} = \left[\frac{(\%_{creep})_{Cycle} - (\%_{creep})_{Dataset}}{(\%_{creep})_{Dataset}}\right] \quad \textbf{Equation 4}$$

$$m = \sqrt{m_V^{\,2} + m_\sigma^{\,2} + m_{\%idle}^{\,2} + m_{\%creep}^{\,2}} \quad \textbf{Equation 5}$$

The measure of how well the candidate cycle compared to those same metrics from the applicable subset of data was reflected in how close the resulting minimization function was to zero.

TEST CYCLES

Five hundred candidate cycles were generated representing each activity (medium-heavy rail, medium-heavy ship, heavy-heavy rail and heavy-heavy ship). Each candidate cycle was then compared to its respective activity data subset with that candidate cycle

having the lowest minimization function being chosen as the most representative cycle.

Table 3 shows the metrics for both the entire activity and for the selected candidate cycle as well as the minimization function for the selected candidate cycle.

The selected cycles were then combined to form two cycles, one representing medium-havy activity and the other heavy-heavy activity, each having a total duration of 1200 seconds. These test cycles are shown in Figure 2 and Figure 3.

Table 3 - Comparative metrics and minimization functions from the selected activity cycles.

	Average Speed (mph)	St. Dev Speed (mph)	% Creep	% Idle	Minimization Function (see eqn. 5)
Medium-Heavy Rail	9.101	4.290	19.7	43.6	
Selected Medium-Heavy Rail	9.177	4.415	21.5	47.3	0.0997
Medium-Heavy Ship	6.767	3.153	27.4	42.4	
Selected Medium-Heavy Ship	6.844	3.310	27.8	42.1	0.0576
Heavy-Heavy Rail	8.577	3.927	6.4	14.4	
Selected Heavy-Heavy Rail	8.377	3.933	6.7	14.3	0.0806
Heavy-Heavy Ship	7.391	3.279	16.0	27.3	
Selected Heavy-Heavy Ship	7.634	3.453	16.5	29.4	0.0861

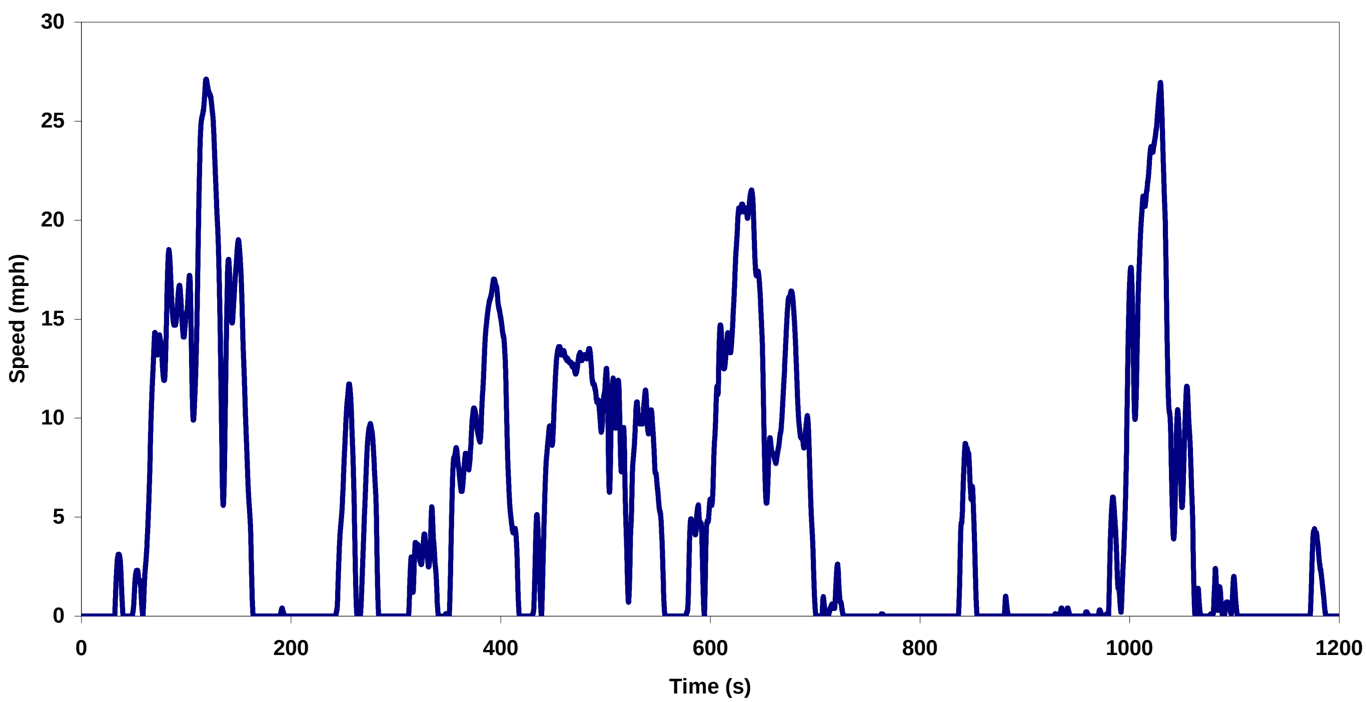


Figure 2 – Medium-Heavy Load Activity Yard Hostler Driving Schedule. The first 300 seconds represent rail activity while the last 900 seconds represent ship activity.

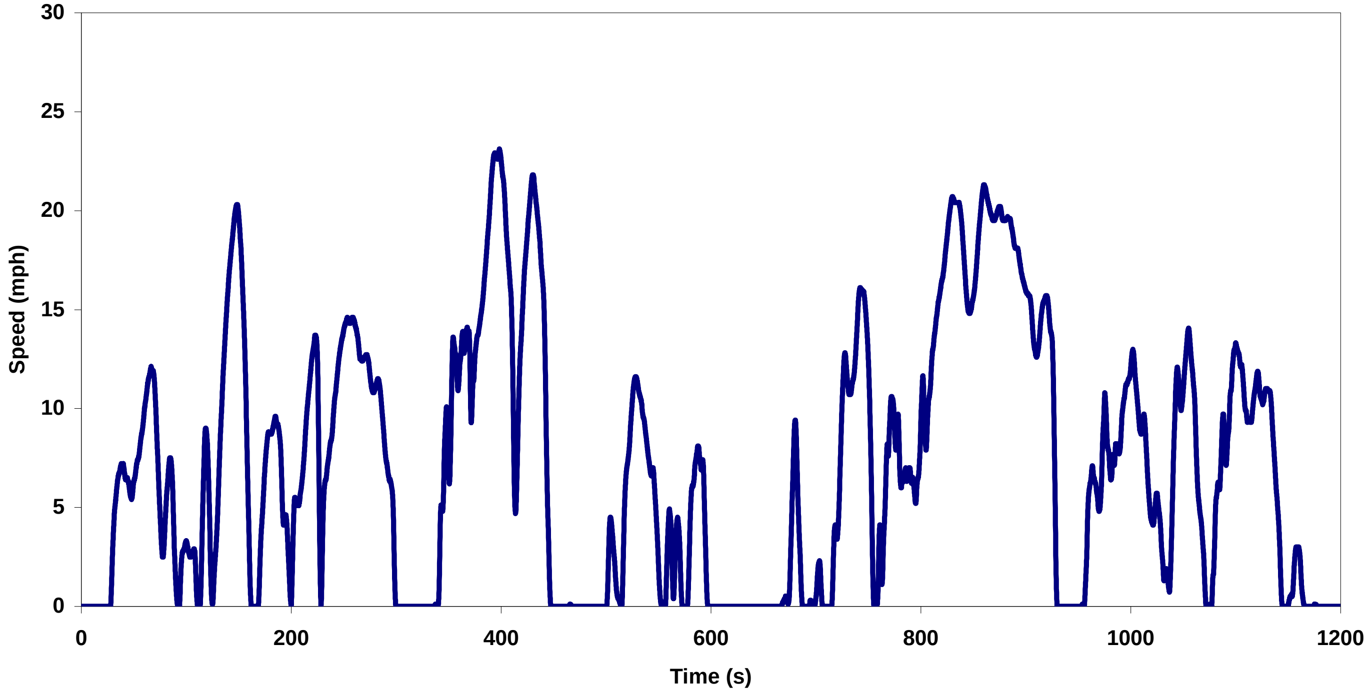


Figure 3 – Heavy-Heavy Load Activity Yard Hostler Driving Schedule. The first 300 seconds represent rail activity while the last 900 seconds represent ship activity.

Estimated Engine Loading

Instantaneous engine power was estimated by summing the positive inertial, aerodynamic and rolling resistance loads calculated using a road-load equation. Inertial load was a function of vehicle acceleration and mass where the medium-heavy operation assumed a mass of 11,888 Kg and the heavy-heavy operation assumed a mass of 32,837 Kg. Aerodynamic load was a function of vehicle speed and vehicle drag coefficient. A drag coefficient of 0.79, which is representative of heavy-duty vehicles, was used for aerodynamic drag calculation. Tire rolling resistance was a function of vehicle speed and the rolling resistance coefficient (μ) of the tires. A coefficient (μ) of 0.00938, typical of heavy-duty vehicles, was used in the calculations. An additional assumption made was that the automatic transmission and road-axle efficiency was 80%.

Based on the aforementioned vehicle assumptions, average engine powers of 29.7 and 67.9 hp were calculated, respectively, for the medium-heavy and heavy-heavy activity cycles. The total theoretical energy required to complete the medium-heavy activity cycle was 3.66 hp-hr and, for the heavy-heavy activity cycle, 10.50 hp-hr. Fan and auxiliary loads may increase the average power values but are difficult to quantify. Estimated continuous engine power is show in Figure 4 and Figure 5. The original data were obtained using 200 hp yard hostlers. Two power peaks in the estimated engine power for the heavy-heavy activity cycle exceed 200 hp, and these may be explained by the approximate nature of the engine power estimation and by the fact that the original microtrips were not all at a mass of 32,837 kg.

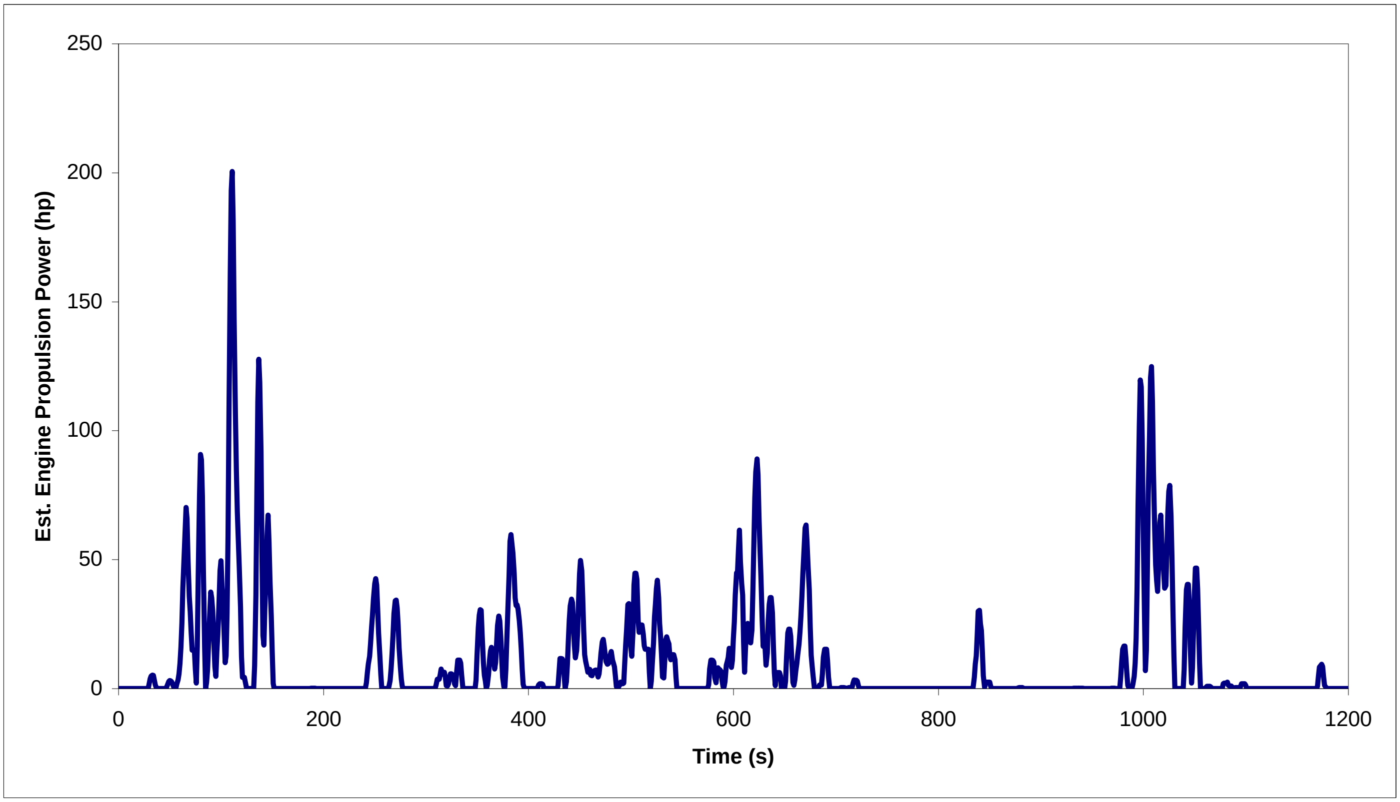


Figure 4 – Estimated engine loading for the medium-heavy duty activity cycle.

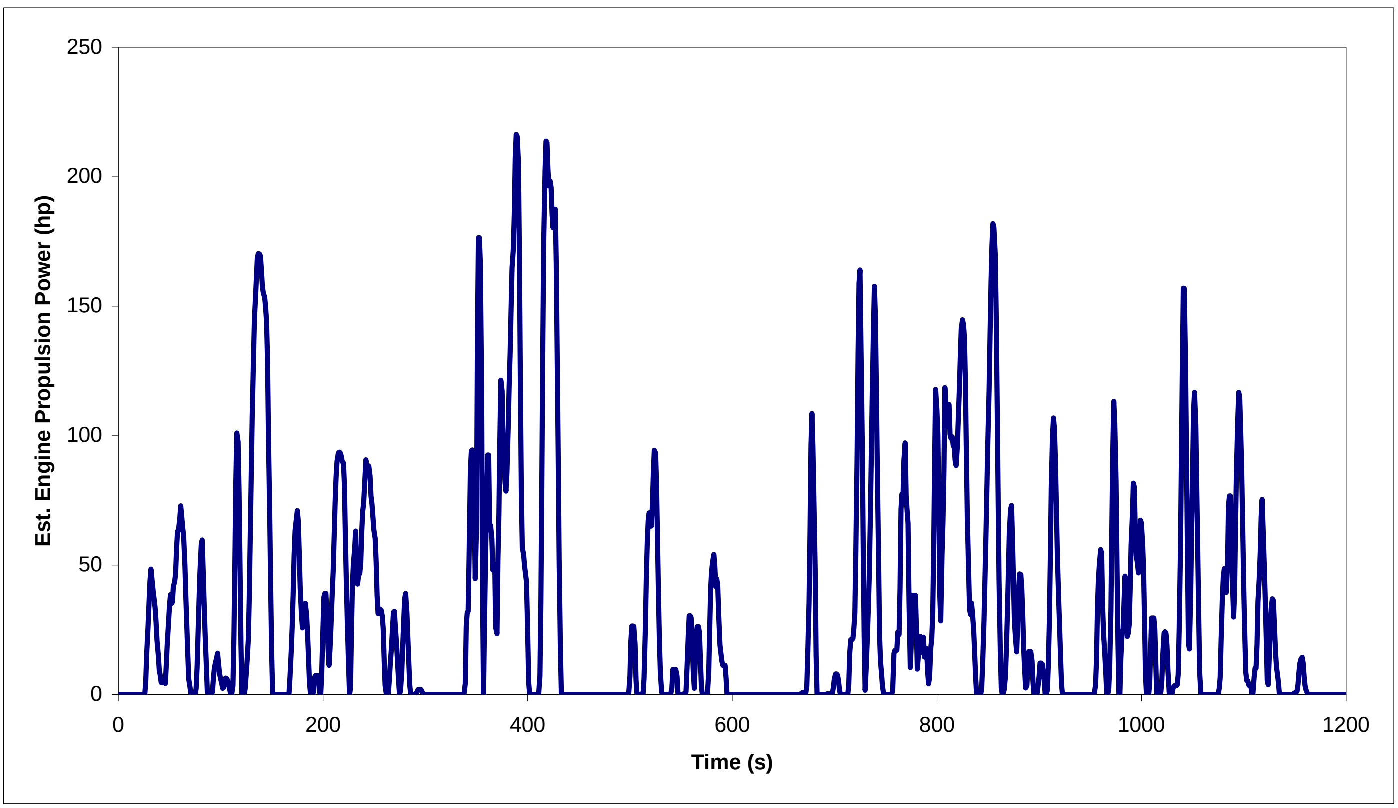


Figure 5 – Estimated engine loading for the heavy-heavy duty activity cycle

CONCLUSION

Driving cycles representative of in-use activities at the Port of Long Beach were developed from in-use activity data. The two driving cycles developed are representative of medium-heavy duty and heavy-heavy duty activity and each contain separate sections representative of rail related and ship related activities. These driving cycles will be appropriate for use in assessing the emissions and performance of yard hostlers in the current POLB container terminal fleet and in gauging the potential benefits of employing yard hostler vehicles with newer engine, propulsion and emissions control technologies.

ACKNOWLEDGMENTS

The authors thank Howard Mearns and “Major” Siddiq Khan for assisting in the data logging effort at POLB. The authors are also grateful to the assistance of the drivers at the POLB facility for their cooperation in this effort. The authors also thank CALSTART and POLB who provided funding for this research.

REFERENCES

1. Port of Long Beach, Addendum to 2002 Baseline Emissions Inventory: Ocean-Going Vessels, Harbor Craft, and Expanded Boundary for Rail Locomotives & Heavy-Duty Vehicles, Starcrest Consulting Group, September, 2007
2. Wysor, T., France, C., “Technical Report: Selection of Transient Cycles for Heavy-Duty Vehicles,” U.S. Environmental Protection Agency, U.S. Department of Commerce, National Technical Information Service PB-294 221, 1978.
3. Clark, N.N., Messer, J.T., McKain, D.L., Wang, W., Bata, R.M., Gautam, M., Lyons, D.W., “Use of the West Virginia University Truck Test Cycle to Evaluate Emissions from Class 8 Trucks,” SAE 951016, 1995.
4. Melendez, M., Taylor, J., Zuboy, J., Wayne, W.S., Smith, D., “Emission Testing of Washington Metropolitan Area Transit Authority (WMATA) Natural Gas and Diesel Transit Buses”, Technical Report NREL/TP-540-36355, December 2005.
5. Nine, R.D., Clark, N.N., Daley, J.J. and Atkinson, C.M., “Development of a heavy-duty chassis dynamometer driving route”, Proc. Inst. Mech. Engrs. Part D., Jour. of Automobile Eng., Vol. 213 pp. 561-574.
6. O’Keefe, M., Hendricks, T., Zou, Z., Davis, S., Beaty, K., Weissner, S., Sharma, V.K., “A New Composite Drive Cycle for the Evaluation and Test of Heavy Duty Hybrid Electric Class 4-6 Urban Delivery Vehicles”, 2003 International Truck and Bus Meeting and Exhibition, Fort Worth, Texas, November 12th, 2003. (Also presented in SAE Paper 2004-01-1052)
7. Gautam, M., Clark, N.N., Riddle, W., Nine, R., Wayne, W.S., Maldonado, H., Agrawal, A. and Carlock, M, “Development and Initial Use of a Heavy Duty Diesel Truck Test Schedule for Emissions Characterization”, SAE Spring 2002 Fuels & Lubricants Meeting, Reno, NV, SAE Paper 2002-01-1753.
8. Clark, N.N., Gautam, M., Wayne, W.S., Nine, R.D., Thompson, G.J., Lyons, D.W., Maldonado, H., Carlock, M. & Agrwal, A., “Creation and Evaluation of a Medium Heavy-Duty Truck Test Cycle” SAE Powertrain Conf., Pittsburgh, Oct. 2003, SAE Paper 2003-01-3284.
9. Clark, N.N., Gautam, M., Riddle, W., Nine, R.D., and Wayne, W.S., “Examination of a Heavy-Duty Diesel Truck Chassis Dynamometer Schedule,” SAE Powertrain Conference, Tampa, Fla., Oct 2004, SAE Paper 2004-01-2904.
10. Lindhjem, C., “Intermodal Yard Activity and Emissions Evaluations,” 17th Annual International Emission Inventory Conference, Portland Oregon, 2008.
11. McKain, D., Atkinson, R., Clark, N., Páramo, J.V.H., Hernández, S.Z., Gálvez, C.F., Rivero, E., Perrusquía, R., León, D., “Development of a Driving Schedule to Mimic Transit Bus Behavior in Mexico City,” SAE 2006-01-3394.

APPENDIX E

Driver Survey Form

Hybrid Yard Hostler Driver Survey

Dates of Operation: __________________________

Equipment ID: __________________________

Applicable Shifts Hybrid Yard Hostler Driven by Operator (circle all that apply):

Day Shift: Sun. Mon. Tues. Wed. Thurs. Fri. Sat.

2nd Shift: Sun. Mon. Tues. Wed. Thurs. Fri. Sat.

Assignment (circle all that apply): Ship Dock Rail N/A

Rate the hybrid yard hostler performance compared to typical diesel yard hostlers at LBCT.	*Better*	*Same*	*Worse*	Comments
1. Maneuverability for connection to chassis				
2. Pulling power with full container				
3. Acceleration with no container				
4. Smoothness of shifting under acceleration				
5. Steering (turning radius, ease of parking, negotiating tight places and steering effort)				
6. In-cab visibility (no blind spots, rear view)				
7. Ride comfort (vibration and shocks, feel of seat)				
8. In-cab controls (convenience and functioning of switches, controls, etc.)				
9. Braking (stops load quickly and smoothly)				
10. Interior noise level				
11. Exterior noise level				
12. HVAC system (heating, ventilation, A/C)				
13. Cab entry and exit				
14. Overall vehicle rating				

15. Any problems with the hybrid drive system (e.g. faults, shutdowns)? Yes No
If yes, explain. ____

<u>Comments:</u> ____

____

Month: June 2010

Number of Responses: 9

	BETTER	SAME	WORSE
1. Maneuverability for connection to chassis	0.0%	55.6%	44.4%
2. Pulling power with full container	11.1%	55.6%	33.3%
3. Acceleration with no container	66.7%	33.3%	0.0%
4. Smoothness of shifting under acceleration	0.0%	55.6%	44.4%
5. Steering	0.0%	22.2%	77.8%
6. In-cab visibility	0.0%	55.6%	44.4%
7. Ride comfort	0.0%	55.6%	44.4%
8. In-cab controls	0.0%	66.7%	33.3%
9. Braking	0.0%	33.3%	66.7%
10. Interior noise level	11.1%	33.3%	55.6%
11. Exterior noise level	0.0%	44.4%	55.6%
12. HVAC system	0.0%	66.7%	33.3%
13. Cab entry and exit	0.0%	77.8%	22.2%
14. Overall vehicle rating	0.0%	22.2%	77.8%

Month: July 2010

Number of Responses: 11

	BETTER	SAME	WORSE
1. Maneuverability for connection to chassis	0.0%	90.9%	9.1%
2. Pulling power with full container	45.5%	54.5%	0.0%
3. Acceleration with no container	63.6%	9.1%	27.3%
4. Smoothness of shifting under acceleration	27.3%	27.3%	45.5%
5. Steering	0.0%	72.7%	27.3%
6. In-cab visibility	9.1%	81.8%	9.1%
7. Ride comfort	0.0%	27.3%	72.7%
8. In-cab controls	0.0%	90.9%	9.1%
9. Braking	0.0%	63.6%	36.4%
10. Interior noise level	0.0%	36.4%	63.6%
11. Exterior noise level	0.0%	45.5%	54.5%
12. HVAC system	9.1%	81.8%	9.1%
13. Cab entry and exit	0.0%	100.0%	0.0%
14. Overall vehicle rating	0.0%	63.6%	36.4%

Month: August 2010

Number of Responses: 21

	BETTER	SAME	WORSE
1. Maneuverability for connection to chassis	4.8%	85.7%	9.5%
2. Pulling power with full container	0.0%	90.5%	9.5%
3. Acceleration with no container	5.0%	75.0%	20.0%
4. Smoothness of shifting under acceleration	0.0%	90.5%	9.5%
5. Steering	9.5%	76.2%	14.3%
6. In-cab visibility	9.5%	85.7%	4.8%
7. Ride comfort	0.0%	71.4%	28.6%
8. In-cab controls	4.8%	90.5%	4.8%
9. Braking	0.0%	81.0%	19.0%
10. Interior noise level	4.8%	71.4%	23.8%
11. Exterior noise level	0.0%	76.2%	23.8%
12. HVAC system	9.5%	81.0%	9.5%
13. Cab entry and exit	0.0%	90.5%	9.5%
14. Overall vehicle rating	0.0%	14.3%	85.7%

Month: September 2010

Number of Responses: 6

	BETTER	SAME	WORSE
1. Maneuverability for connection to chassis	0.0%	83.3%	16.7%
2. Pulling power with full container	0.0%	100.0%	0.0%
3. Acceleration with no container	0.0%	66.7%	33.3%
4. Smoothness of shifting under acceleration	0.0%	66.7%	33.3%
5. Steering	0.0%	66.7%	33.3%
6. In-cab visibility	0.0%	100.0%	0.0%
7. Ride comfort	0.0%	83.3%	16.7%
8. In-cab controls	0.0%	100.0%	0.0%
9. Braking	0.0%	66.7%	33.3%
10. Interior noise level	0.0%	83.3%	16.7%
11. Exterior noise level	0.0%	83.3%	16.7%
12. HVAC system	0.0%	100.0%	0.0%
13. Cab entry and exit	0.0%	100.0%	0.0%
14. Overall vehicle rating	0.0%	0.0%	100.0%

APPENDIX F

Mechanic Survey Form

Hybrid Yard Hostler Mechanic Survey

Mechanic: ____________________

Date: ____________________

Purpose: To solicit maintenance and service personnel feedback on the hybrid yard hostlers compared to conventional diesel yard hostlers.

1. Describe any hybrid yard hostler problems observed during the early part of the demonstration period that were subsequently corrected by the manufacturer:

   ____

   ____

   ____

   ____

Please rate the following issues related to hybrid yard hostler maintenance and service on a scale of 1 to 5 where 1 means unacceptable and 5 means excellent (circle the appropriate number):

	Unacceptable				*Excellent*
2. Hybrid Systems and Component Training:	1	2	3	4	5
3. Design for Maintainability:	1	2	3	4	5
4. Design for Serviceability:	1	2	3	4	5
5. Vehicle Manufacturer Support:	1	2	3	4	5
6. Hybrid System Manufacturer Support:	1	2	3	4	5

7. Describe any trends observed regarding non-routine service actions associated with the hybrid yard hostlers including the long-term effectiveness of corrective actions:

   ____

   ____

   ____

Additional Comments:

____

____

____

____

APPENDIX G

Modeling Analysis of Rear Axle Differential Ratios

US Hybrid

The following is the modeling analysis for the Ottawa 50 port UTR truck with Differential ratio of 10.62 and 12.28. The conventional UTR trucks at POLB are using the Arvin Meritor (Formerly Rockwell) RS-30-380 rear axle with 10.62:1 ratio, where as the hybrid UTR tractor was made using Sisu axle with 12.28:1. The reason for the use of such high rear differential for hybrid UTR is not clear, however there two emails dated 8/24/09 and 9/1/09 from Dean Newton of Kalmar that references a request from David Shore for 148,000 GCW thus requiring the use if Sisu differentials with 12.28:1. Kalmar also utilizes the RS-24-16, with lower ratio and GCW. The use of 148,000 GCW is rare.

There is no problem with such high ratio rear differentials; however POLB has been testing the lower differential ratio conventional UTR truck with the hybrid UTR with the 12.28:1 higher ratio. The actual fuse use data for the Hybrid UTR operating in hybrid mode vs. conventional diesel (Control via dashboard switches disabling the hybrid system) shows much more fuel saving when compared with the conventional UTR and the main difference is the use of different engine and the higher rear differentials. This is comparing apple and oranges.

Upon request from Calstart, US Hybrid has performed modeling of the conventional UTR with different rear differentials ratios. The result of such modeling is presented. In general the UTR engine is over power for the truck operation as such the higher ratio differential will force the engine to operate at higher rpm and lower torque (same power), thus it will result in operation at lower BSFC fuel economy for the same work. The transmission is locked at 4th gear, therefore the engine speed will be higher for the higher differential ratio, when the transmission reaches 4th gear, at low speed the transmission will shift to higher gear faster with the higher differential ratio.

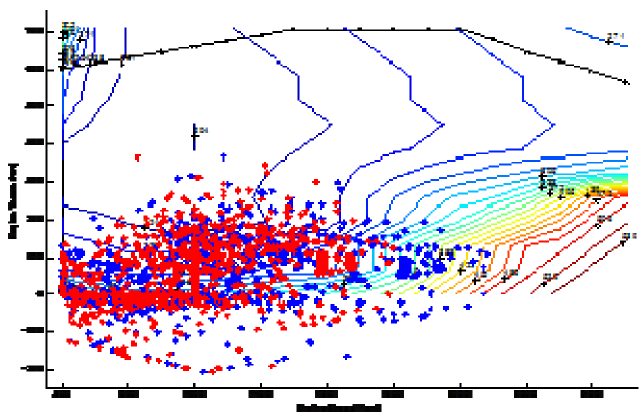


Figure 1: Engine Operation Map with GVWR=26,000 lb. Red shows operation with 10.62 gear ratio and Blue shows engine operation with 12.28 gear ratio.

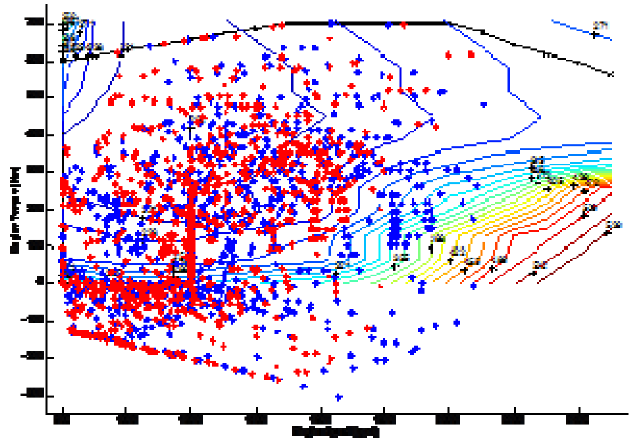


Figure 2: Engine Operation Map with GVWR=72,000 lb. Red shows operation with 10.62 gear ratio and Blue shows engine operation with 12.28 gear ratio.

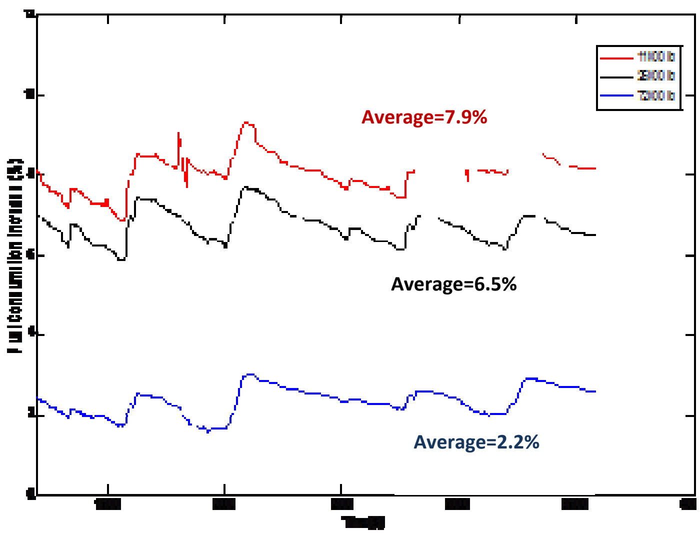


Figure 3: Fuel efficiency reduction due to higher rear ratio with UCR dyno test cycle.

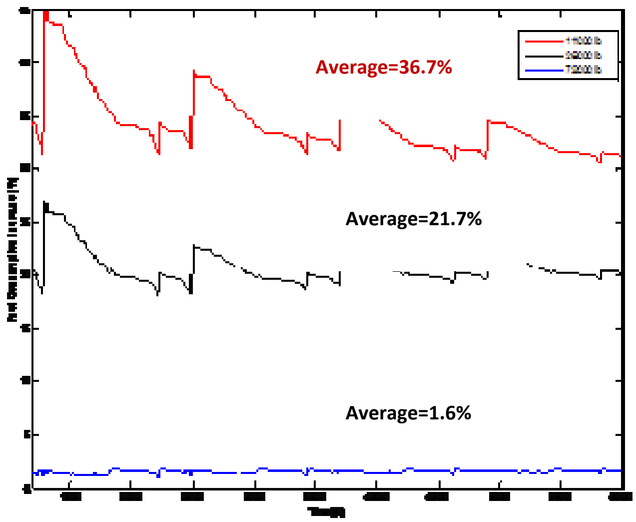


Figure 4: Fuel efficiency reduction due to higher rear ratio with Calstart Drive Cycle.

As it can be seen from Figure 1 and 2, the engine will operate less efficiently due to higher rear axle differentials ratio, the lower the load the worst the fuel economy. At higher load the engine efficiency contours are not as different, therefore the operation deficiencies is much less. The fuel efficiency difference is given in figure 3 and 4.

The fuel efficiency difference can be as low as 1.6% at 72,000Lb load and as high as 21.7% at 26,000Lb and 36.7% when running empty.

The port operation is a combination of above with light load and heavy load, however at least half time is operating empty after the container is un-loaded from the trailer.

Notes:

We have used the engine map of ISB200 for both molding and the ISB 240 engine map is assumed to be similar with scaled torque. US Hybrid does not have the detailed engine fuel map for the ISB240. Variation in engine map and drive cycle will impact the final results, however such impact will not change the basic trend of the results.

US Hybrid has asked Kalmar to allow the Allison Transmission to operate at higher gear with US Hybrid governor to enhance the fuel economy of the hybrid UTR, however such request has been put on hold by Kalmar due to other operation issues that need to be reviewed and considered.

APPENDIX H

Emissions Test Report
Comparing Criteria and Greenhouse Gas Emissions from a Conventional Diesel and a Prototype Hybrid Yard Tractor

University of California, Riverside
Bourns College of Engineering
Center for Environmental Research and Technology

Comparing Criteria and Greenhouse Gas Emissions from a Conventional Diesel and a Prototype Hybrid Yard Tractor

Final Report
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Disclaimer

This report was prepared as the result of work sponsored by the Port of Long Beach and the Port of Los Angeles, and carried out with Tetra Tech with test units provided by US Hybrid. As such the report does not necessarily represent the views of any of the participants, the Ports of Long Beach and Los Angeles, the US EPA, Tetra Tech, US Hybrid or their employees. Further the collective participants, its employees, contractors and subcontractors make no warrant, expressed or implied, and assume no legal liability for the information in this report; nor does any party represent that the uses of this information will not infringe upon privately owned rights. This report has neither been approved nor disapproved by the collective group of participants nor have they passed upon the accuracy or adequacy of the information in this report.

Acknowledgements

The author expresses appreciation to the following associates who contributed much to the success of the project and the furtherance of knowledge of emissions from cargo handling equipment at the Long Beach Container Terminals (LBCT) with help from Tetra Tech, Inc. and TIAX, LLC. We very much appreciated the financial support of the Ports of Long Beach and Los Angeles and the US EPA throughout the project and the assistance of CalStart and Tetra Tech in managing the selection and acquisition of the yard tractors and for conveying the contract.

Port of Long Beach

- Ms. Heather Tomley
- Ms. Allyson Teramoto

Port of Los Angeles

- Mr. Kevin Maggay

Long Beach Container Terminal, Inc.

- Mr. Kevin Hayes
- Mr. Hal Burkey

US Hybrid

- Dr. Abas Goodarzi
- Mr. Jeff Kohne
- Dr. Don Kang
- Mr. Christophe Salgues

Kalmar

- Mr. Mikko Vuojolainen
- Mr. Jay Hayes
- Mr. Dean Newton

Tetra Tech

- Dr. Eddy Huang
- Dr. Charng-Ching Lin
- Ms. Tunisia Hardy

Tiax, LLC

- Mr. Jon Leonard
- Mr. Patrick Couch

Calstart

- Mr. Michael Ippoliti
- Mr. Patrick Chen

University of California, Riverside

- Mr. Don Pacocha
- Mr. Edward O'Neil
- Mr. Joe Valdez

Table of Contents

List of Tables

List of Figures

Executive Summary

Background: Yard tractors (YTs) are the workhorse of the cargo handling equipment (CHE) in the Ports of Los Angeles and Long Beach. Due to the high numbers and frequent use, they are also the primary contributor to the emissions inventory from cargo handling equipment. Based on these facts, the San Pedro ports are always exploring new options to reduce and control the emissions from yard tractors. One new option was the use of a diesel-battery hybrid system. US Hybrid offered conversion kits and Kalmar made three hybrid yard tractors. The goal of this project was to determine the difference in the inventory contributions of criteria pollutants and greenhouse gases emissions from the hybrid and conventional diesel yard tractors.

Methods: The research project was built on the application of a transient cycle, specifically developed for the yard tractors and the use of the UCR heavy-duty chassis dynamometer. Emissions were measured with UCR's Mobile Emission Lab and state of battery charge monitored while the vehicle followed the transient cycle. Analysis compared the results for both the case of a light load and a heavy load for hybrid and diesel yard tractors.

Results: The hybrid was tested first and UCR learned that the as-supplied transient cycle had to be operated with the peak speeds clipped since the hybrid YT did not allow a speed above about 18 mph. Both YTs were tested on the same modified cycle and the results at two different loads are shown in the figure below. The results indicate that at low loads the hybrid consumed about 7% more fuel and at high loads the hybrid saved about 3% fuel. NO_x emissions were reduced 3% and 8% at the low and high loads, respectively. State of battery charge did not change much in the testing.

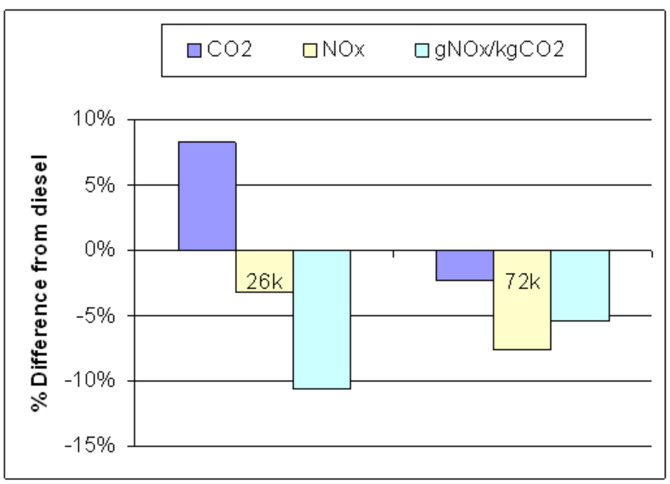

Figure E0-1 Comparative Emissions Factors for Various Yard Tractor Engines

Conclusions:

- The modified transient cycle had the same emissions as the originally supplied transient cycle.
- The hybrid fuel economy was only better than the conventional diesel at higher loads.
- The hybrid failed to achieve the expected fuel savings of about 30%, possibly related to the difference in rear-end gear ratio, to the small state-of-charge changes during the test cycle; or to another cause. The finding of less fuel economy needs further investigation.

Recommendations:

- Review the power management strategy for the hybrid system to assess whether a higher utilization of the batteries would have resulted in reduced tailpipe emissions compared to the conventional (baseline) YT.
- Use a chassis dynamometer to tune the power management module of the hybrid unit for optimal fuel consumption before putting the unit into demonstration service and emissions testing.
- Consider investigating behavior of the exhaust gas recirculation (EGR) system and gear ratio in the rear axle if modifying the power management strategy does not provide the desired results.

1 Introduction

1.1 Motivation

The San Pedro Bay Ports of Long Beach and Los Angeles are committed to reducing emissions from port related operations. In 2006, their Clean Air Action Plan[1] (CAAP) was adopted at a historic joint meeting of Harbor Commissioners. The 2006 CAAP specified the emissions reductions and focused primarily on reducing health risks to the local communities and reducing emissions of DPM, NO_x and SOx. Specific goals, relative to 2005, included:

- **Health Risk Reduction Standard**. Reduce the population-weighted cancer risk of ports-related DPM emissions by 85% in port communities by 2020.
- **Emissions Reduction Standard** 1) By 2014, reduce emissions by 22% for NO_x, 93% for sulfur oxides (SO_x), and 72% for DPM and 2)by 2023, reduce emissions for NO_x, SO_x and DPM by 59%, 93% and 77%, respectively.

The CAAP laid out a specific program to deal with the five major sources of criteria pollutant and greenhouse gas emissions at the ports: 1) ocean going vessels, 2) heavy on-road duty-vehicles (trucks), 3) harbor craft, 4) locomotives, and 5) cargo handling equipment. Inventory by Starcrest[2] shows the combined emissions contribution by source category. Although ocean going vessels are the largest source, the plan called for all sources to be reduced.

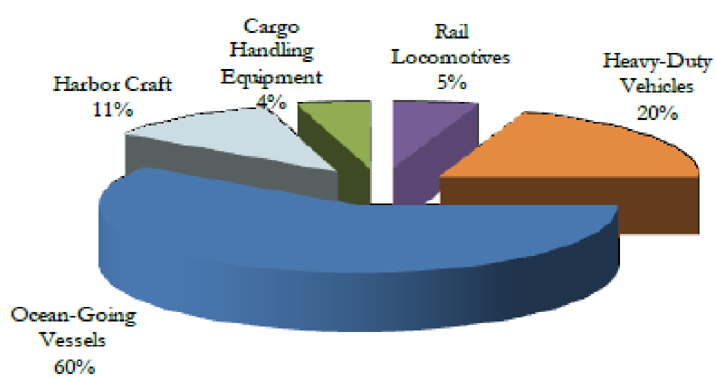

Figure 1-1 Combined Port DPM Emissions Contributions by Source Category in 2009

[1] Ports of Los Angeles and Long Beach, 2010 Update: San Pedro Bay Ports Clean Air Action Plan, October 2010

[2] Starcrest Consulting Group, LLC, *Port Of Long Beach Air Emissions Inventory – 2009*, June 2010

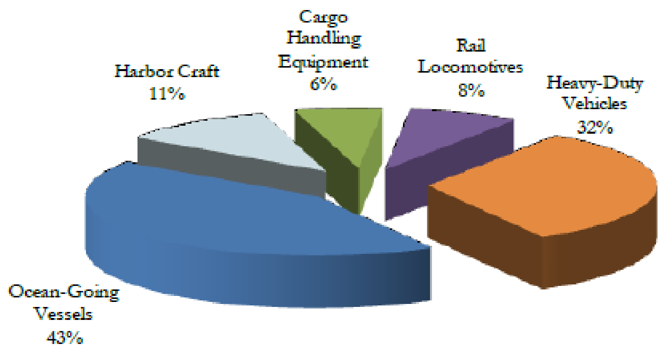

Figure 1-2 Combined Port NO_x Emissions Contributions by Source Category in 2009

1.2 Cargo Handling Equipment (CHE)

Cargo handling equipment includes equipment used to move cargo (containers, general cargo, and bulk cargo) to and from marine vessels, railcars, and on-road trucks. The equipment typically operates at marine terminals or at rail yards and not on public roadways or lands. Typical types of CHE are powered by 25 hp or greater size engines using diesel, gasoline, or propane. Due to the diversity of cargo, there is a wide range of equipment types. The majority of the non-electric cargo handling equipment can be classified into one of the following equipment types: forklift, rubber tired gantry (RTG) crane, side handler, sweeper, top handler, yard tractor and other. As the Starcrest report[2] shows, yard tractors are the dominant CHE type in numbers and emissions of PM and NO_x.

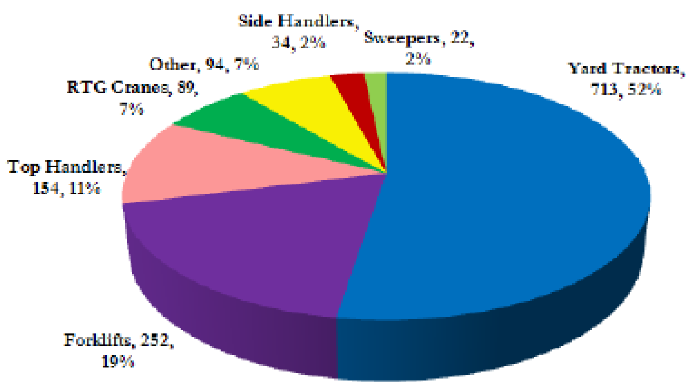

Figure 1-3 Distribution of Port CHE by Equipment Type in 2009

1.3 Cargo Handling Equipment (CHE) Control Measures in the CAAP

Even with increased imported cargo, emissions from cargo handling equipment are projected to decline due to the implementation of regulations adopted by CARB and the CAAP that further encourage new technologies and standards as they become commercially available. Although CHE emissions are much lower than those of the other port sources, the CAAP was designed to aggressively reduce air pollution from all sources associated with goods movement. This is clear from specific CHE-related control measures defined in the CAAP, as summarized below.

CAAP Control Measure CHE 1 defines potential improvements for CHE:

- Beginning 2007, all CHE purchases will meet one of the following performance standards:
  - Cleanest available on-road or off-road NO_x standard alternative-fueled engine, meeting 0.01 g/bhp-hr DPM, available at time of purchase, or
  - Cleanest available on-road or off-road NO_x standard diesel-fueled engine, meeting 0.01 g/bhp-hr DPM, available at time of purchase.
  - If there are no engines available that meet 0.01 g/bhp-hr DPM, then must purchase cleanest available engine (either fuel type) and install cleanest CARB verified diesel emission control strategy (VDECS) available.
- By the end of 2010, all yard tractors will meet, at a minimum, the USEPA 2007 on-road or Tier 4 off-road engine standards.
- By the end of 2012, all pre-2007 on-road or pre Tier 4 off-road top picks, forklifts, reach stackers, RTGs, and straddle carriers </=750 hp will meet, at a minimum, the USEPA 2007 on-road engine standards or Tier 4 off-road engine standards.
- By end of 2014, all CHE with engines >750 hp will meet at a minimum the USEPA Tier 4 off-road engine standards. Starting 2007 (until equipment is replaced with Tier 4), all CHE with engines >750 hp will be equipped with the cleanest available CARB VDECS.

Put in perspective, CARB's CHE regulation adopted in December 2005 requires the replacement or retrofit of existing engines with the cleanest available VDECS and requires, beginning January 1, 2007 that newly purchased, leased or rented CHE meet low DPM and NO_x limits. CARB's regulation is phased-in, first focused on 2002 and older engines in the 2007–2013 timeframe and later the 2003–2006 engines and equipment in the 2010-2016 timeframe. The CAAP control measure, CHE 1, further accelerates the CHE modernization schedule, by requiring the replacement of all engines on a faster timeline. According to the CAAP[1], emissions will be reduced by nearly 600 tons of NO_x and more than 70 tons of diesel PM, or 24% and 50%, respectively. These reductions occurred even while cargo tonnage increased by 30%.

1.4 Yard Tractors

Yard tractors, the focus of the measured emissions for this report, are also known as terminal tractors, yard trucks, yard hustlers and yard goats. In any case, these are the units that are typically powered with diesel engines and designed for the movement of containers: to/from ships/trains, on/off terminals, to/from RTG cranes or on/off stacks. The important perspective is that yard tractors are numerous, about 1,500 in the Ports of Los Angeles and Long

Beach, or 2,300 in California, and are frequently used. Given the large population and frequent use, it is not surprising that yard tractors contribute over 50% of the emissions associated with cargo handling equipment (CHE). Thus the control and reduction of emissions from yard tractors should be given a high priority in any plan to reduce emissions from port sources.

1.4.1 Hybrid Yard Tractors

In addition to CARB regulations, the ports' joint CAAP has encouraged new and emerging approaches to be tested in demonstration programs, even before commercial introduction of the equipment and technology. The main thrust of this project was to assess and compare emissions from a prototype diesel-electric or hybrid powered unit to a conventional diesel unit. A schematic of the hybrid power system installed on the two test YTs is shown in Figure 1-4. In a hybrid, the yard tractors are fitted with a Parallel Hybrid Drive system that converts power from on-board batteries to an electric motor for propulsion through the rear axle. The batteries are charged by the diesel engine/alternator system or by the regenerative braking system.

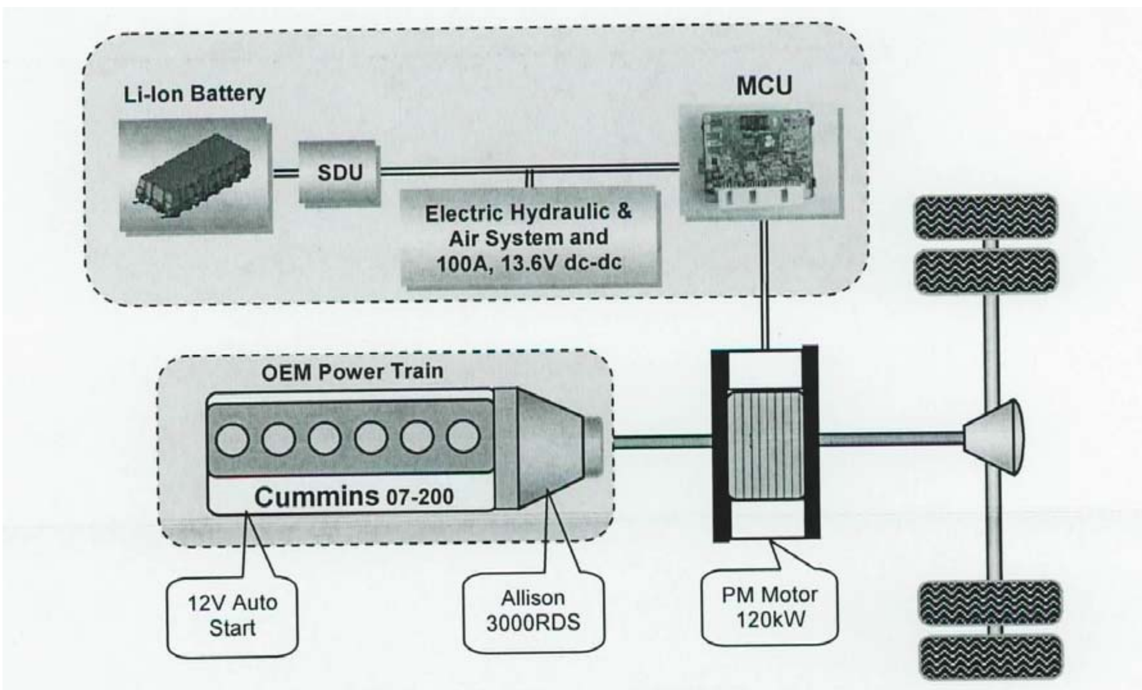

Figure 1-4 Schematic of the Multiple Power Systems on the Hybrid Yard Tractor

1.5 Emission Test Methods for Diesel Engines and Yard Tractors

1.5.1 Dynamometer Testing.

Dynamometers (dynos) are essential equipment for the accurate measurement of emission factors. These very useful tools are designed to measure torque and rotational speed (rpm) from which the power produced by an engine can be calculated from the product of torque (τ) and angular velocity (ω) values or force (F) and linear velocity (v). Dynamometers (dynos) come in various configurations. A dyno directly coupled to an

engine is known as an engine dyno. An engine dynamometer measures power and torque directly from the engine's crankshaft (or flywheel) and does not need to account for power losses in the drive train, such as the gearbox, transmission or differential as the engine values are directly measured. An engine dyno can either be a power absorbing or motoring type. The power absorbing-type is limited to steady-state cycles while a dyno with a motoring design can test either steady-state or transient cycles.

A chassis dyno measures torque and power delivered by the power train at the wheels of a vehicle without removing the engine from the vehicle. With a chassis dyno the vehicle operates with its wheels on the rollers where the output power from the engine is measured. While engine dynamometers provide the most accurate results of an engine operation, a chassis dynamometer is often the most practical approach as it measures the power and torque of an engine without removing the engine, thus saving time and money. The main issue with the chassis dynamometer is the measured power and torque at the wheels is less than the values at the engine flywheel (e.g. brake horsepower) due to the various frictional and mechanical losses in the various components; for example, drive train transmission and gearbox, tire friction and other factors. The rear wheel brake horsepower is generally estimated to be 15-25 percent less than the brake horsepower due to frictional losses. Fortunately many current engines have an Electronic Control Module that is calibrated by the engine manufacturer to report brake power so you measure both the power at the wheels and at the fly wheel.

An important distinction for the chassis dyno is the type of motor/driver or power absorption unit used in the design. Motoring/driving dynos are useful when testing the torque and power requirement for transient and steady-state cycles, while an absorbing dyno only acts as a load and can only be used with steady-state cycles.

1.5.2 Testing Approach for Steady-State Cycles

For emissions certification using steady-state cycles, the heavy-duty diesel engines are mounted on an engine dyno instead of being tested in the chassis of the vehicle type(s) for which they are designed. One example of a steady-state certification cycle is the CARB 8–Mode Steady-State Cycle, normally used for certifying off-road vehicles and diesel-powered off-road industrial equipment. It is the same as ISO-8178-C1[3]. The off-road equipment mentioned in ISO 8178-4 include: industrial drilling rigs, compressors, construction equipment including wheel loaders, bulldozers, crawler tractors, crawler loaders, truck-type loaders, off-highway trucks, hydraulic excavators, agricultural equipment, rotary tillers, forestry equipment, self-propelled agricultural vehicles (including tractors), material handling equipment, fork-lift trucks, road maintenance equipment (motor graders, road rollers, asphalt finishers), snow-plough equipment, airport supporting equipment, aerial lifts, and mobile cranes. The original certification cycle for off-road equipment is shown in Table 1-1.

Testing is carried out at with the engine operating at number of loads for the rated and intermediate speed as defined in ISO-8178. Generally speaking, rated speed is the

[3] International Standard Organization IS0 8178-4 *Reciprocating internal combustion engines - Exhaust emission measurement -Part 4:Test cycles for different engine applications*, First edition 1996-08-l 5

governed speed and near where the engine power begins to drop off on the lug curve while intermediate speed is near the peak torque. Either a water brake or motoring dyno can be used to hold the engine at the desired load and RPM values.

Table 1-1 Test Modes, Torque and Weighting Factors for the ISO-8178-C-1 Cycle

Mode number (cycle B)	1	2	3	4	5	6	7	8	9	10	11
Mode number (cycle C1)	**1**	**2**	**3**		**4**	**5**	**6**	**7**			**8**
Speed 1)	Rated speed					Intermediate speed					Low-idle speed
Torque 1), %	100	75	50		10	100	75	50			0
Weighting factor	0,15	0,15	0,15		0,1	0,1	0,1	0,1			0,15

1.5.3 Testing Approach for Transient Cycles

In the past decade, regulatory agencies have moved testing heavy-duty applications with steady-state cycles to testing heavy-duty applications using special use-specific driving cycles with testing on a chassis dyno. Since there was no chassis dynamometer test cycle designed specifically for typical operational parameters of yard tractors, CalStart contracted West Virginia University to develop a duty cycle for this project. The duty cycle was developed based on in-use yard hostler data collected at the Long Beach Container Terminal (LBCT) between January 25^{th} and January 30^{th}, 2008. The purpose of developing the transient cycle for the yard hostler was to allow comparative measurements of emissions and fuel economy for hybrid and diesel yard hostlers. Details are in Appendix C.

When testing an engine in a yard tractor with a transient cycle, a motored chassis dyno is required. A power absorbing dyno used with steady state cycles as described in the earlier section is not suited for transient cycles and test programs. For this project, UCR used their motored chassis dyno as further described in Section 2.2.

1.6 Project Objective

The project was viewed as a technology demonstration and evaluation program aimed at reducing emissions for cargo handling equipment. As part of the project, vehicle emissions and performance of the hybrid unit were evaluated and compared with a conventional diesel yard tractor. The same transient cycle designed for a yard tractor was used in both tests. The project was to test the emissions of a hybrid drive, supplied by U.S. Hybrid after integration into the hybrid drive system of a Kalmar Ottawa 4x2 yard hostler chassis and used in the field for several months. According to Jay Hayes, Vice President, Research and Development for Kalmar terminal tractors at Cargotec: "The trials should not only prove the hybrid concept with new terminal tractors, but also that used terminal tractors can be modified to hybrid power. We estimate that adding a hybrid kit may result in fuel savings of up to 30 percent."

2 Experimental Work Plan

This section provides information on the plan outlined in the contracted scope of work and does not include changes that occurred as the plan was carried out. Changes are included in Section 3 which details the results.

2.1 Yard Tractors and Fuel

In this project, we planned to test two Kalmar Ottawa 4x2 yard tractors, equipped with Cummins 6.7L ISB engines. Both engines used exhaust gas recirculation (EGR) for NO_x control, had a diesel particulate filter (DPF) for exhaust after treatment and were certified to meet USEPA and CARB 2007 emission standards. One yard tractor was Kalmar's typical diesel production. The other unit was fitted with a Parallel Hybrid Drive system developed by Kalmar's partner in hybrid technology, US Hybrid (USH) in Torrance, California. The USH unit converted power from on-board batteries to an electric motor for propulsion through the rear axle. The batteries were recharged by the diesel engine/alternator or from the regenerative braking system.

Fuel for the project was the same as normally used at LBCT, namely, CARB #2 diesel fuel with ultra-low sulfur content.

2.2 Heavy-duty Diesel Chassis Dynamometer Test Facility

Testing was carried out on UCR's new HDD transient dynamometer (see Appendix D for details). The new dynamometer was designed to handle a range of vehicles and vehicle loads at on-road driving conditions. It includes a 48" Electric AC Chassis Dynamometer with dual, direct connected, 300 horsepower motors attached to each roll set. The dynamometer applies appropriate loads to a vehicle to simulate factors such as the friction of the roadway and wind resistance that it would experience under typical driving. A driver accelerates and decelerates following a driving trace while the vehicle is chained to the dynamometer. Emissions were collected and measured with CE-CERT's Mobile Emissions Laboratory (MEL), as described later in this report.

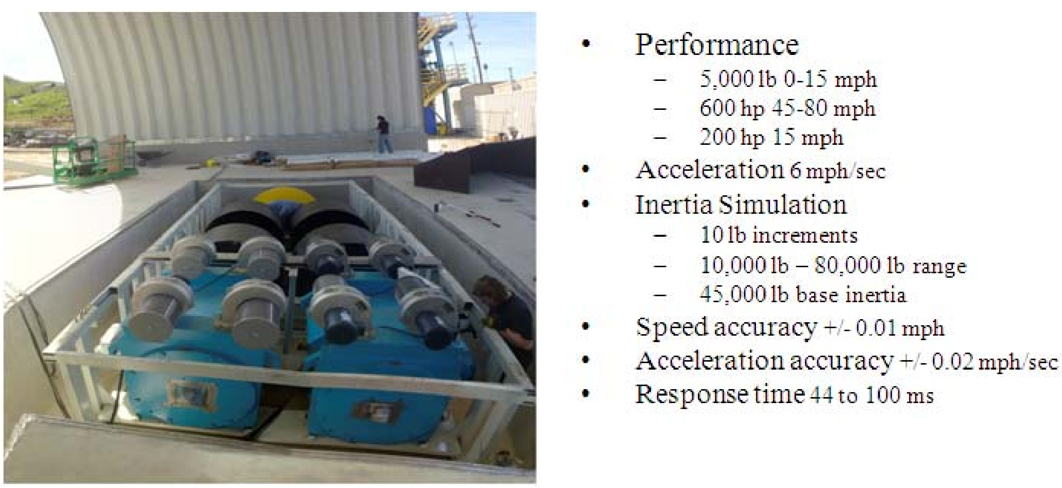

Figure 2-1 Selected Data for UCR HDD Chassis Dyno

Normally a coast down test would be carried out in which the vehicle to be emissions tested is accelerated up to a set speed in actual driving and then allowed to “coast down” to a lower speed. The time it takes to coast down from the higher to lower speed while the vehicle is coasting in neutral is used to determine the vehicle's drag coefficient C_d and coefficient of rolling resistance C_{rr}. However, for the yard tractor, top speed was about 25 miles per hours so vehicle drag (“wind resistance”) was assumed to be negligible. Accordingly in this project, we selected the rolling resistance for a similar weight bobtail tractor.

Table 2-1 Coast Down Coefficients for the Test

Load	A	B:	C:	HP@50
26k	152.267	3.2243	0.144607	47.01
76k	179.007	10.1079	0.0039308	92.56

2.3 Test Operating Schedule

The testing procedure begins by first securing the yard tractor with chains to tie-downs that are part of the heavy-duty chassis dynamometer equipment such that the rear (drive) wheels are on the dyno’s 48-inch rollers. Next, the vehicle was driven on the rollers for 30 minutes or more until gaseous emissions were stable. The vehicle operated at the engine power required to maintain the speed at 18mph with the higher load assigned to the dyno wheels. This approach allowed the engine and the mechanical equipment associated with the dyno to reach steady-state.

Emission testing included the measurement of the primary and dilution exhaust flow rates and the concentrations of carbon monoxide (CO), carbon dioxide (CO_2), NO_x and total hydrocarbons (THC). $PM_{2.5}$ mass was measured in this project but all filters did not shown any statistically significant weight gain in the transient cycle. In addition to measuring mass emissions for these pollutants, a number of engine parameters were recorded during the testing, including exhaust temperature, both dyno and engine RPM, horsepower at the wheels, engine exhaust pressure, electronic fuel delivery and electronic load Other measurements included: elevation, cycle duration, ambient temperature and pressure, humidity and ambient gas concentrations. A triplicate run was carried out for each of the test cycles

For this project, the plan was for the two yard tractors to be tested while following the two transient cycles supplied by CalStart and as shown in Figure 2-2 and Figure 2-3.

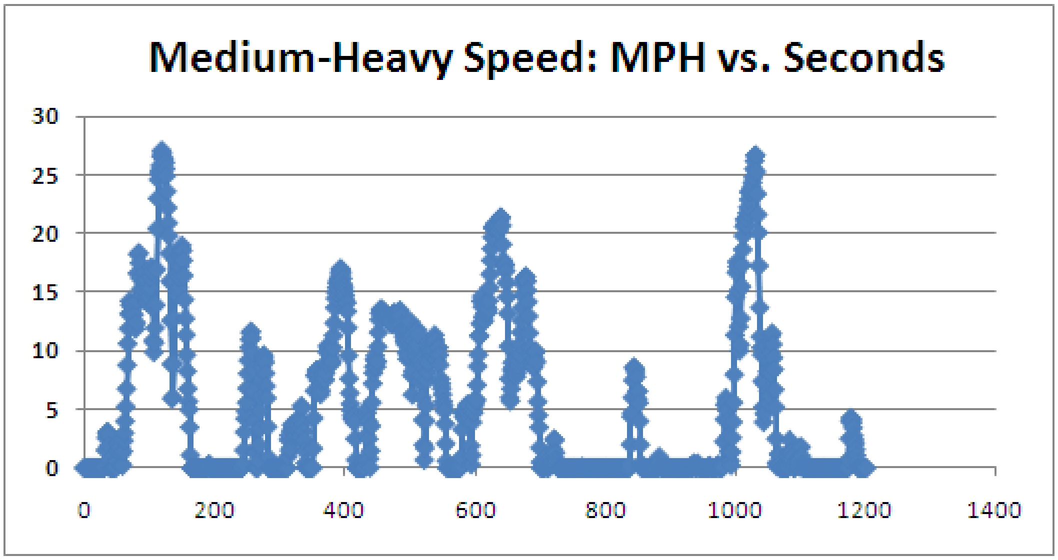

Figure 2-2 Transient Test Cycle for Medium Loads

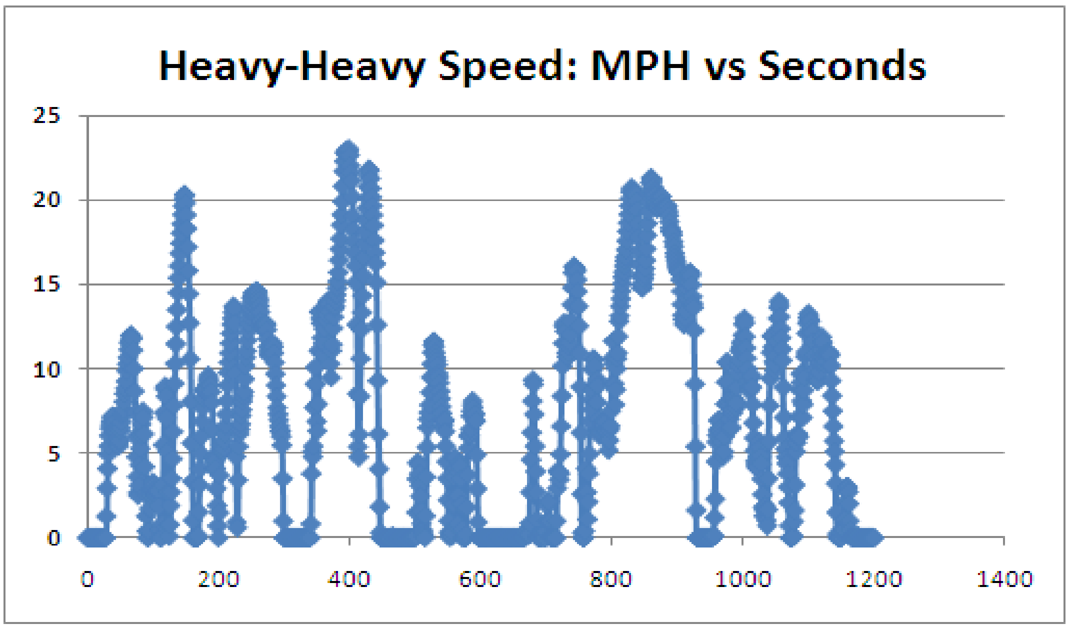

Figure 2-3 Transient Test Cycle for Heavy Loads

2.4 Measurement of State of Charge for the Hybrid Yard Tractor

One of the complications of testing hybrid systems is properly accounting for the multiple energy systems found in a hybrid vehicle. The hybrid yard tractor had both a diesel engine and batteries supplying power to the wheels so it was important that the batteries "State of Charge" (SOC) were returned at the end of test to within about 1% of the value at the beginning of the test. Fortunately the supplied hybrid system had an internal monitor of the state of charge and US Hybrid provided UCR with access to that metric. This allowed UCR to continuously monitor the state of charge.

2.5 Testing the Hybrid Yard Tractor with the Batteries Disconnected

One concern was properly accounting for the contribution of energy from the battery pack to the hybrid's power output. To address this concern, the test plan called for testing the hybrid yard tractor with and without the battery pack connected. US Hybrid showed UCR how to physically disconnect the battery pack so there would be no doubt that the batteries were not included in the measurements. One run was carried out on the transient yard tractor cycle in the mode of a disconnected battery pack.

2.6 Measurement of Gas Concentration and Flow Rates

The sampling and measurement methods of mass emission rates from heavy-duty diesel engines are specified in detail in Title 40 of the Code of Federal Regulations (CFR), *Protection of the Environment,* Part 1065 and described in detail an earlier report[4]. UCR's unique mobile, heavy-duty diesel laboratory (MEL) is designed and operated to meet those specifications. MEL is a complex laboratory that was verified against CARB's heavy-duty diesel lab, the DOE lab in Denver and the laboratory at Southwest Research (SwRI) in San Antonio. MEL routinely measures a wide range of gaseous species and particulate emissions from diesel engines. Design capabilities and details of the MEL design and specifications are described in Cocker[5]. MEL in combination with the heavy-duty chassis dynamometer at UCR became the platform to measure emissions from the yard tractors.

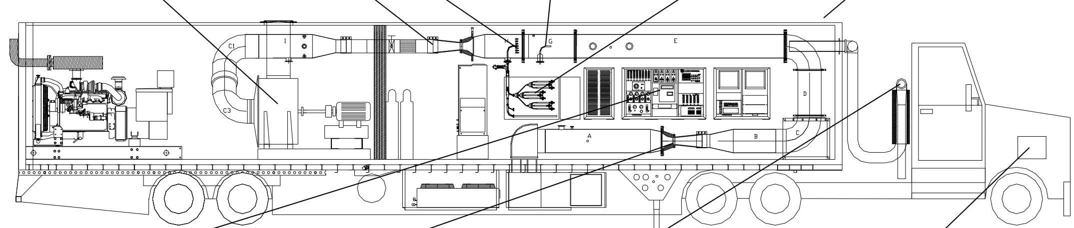

Figure 2-4 Major Systems within UCR's Mobile Emission Lab (MEL)

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[4] Miller, J. W. *A Study of Emissions from Yard Tractors Using Diesel and LNG Fuels*, prepared for the Port of Long Beach August 2007

[5] Cocker III, D. R., Shah, S., Johnson, K., Miller, J. W., Norbeck, J., *Development and Application of a Mobile Laboratory for Measuring Emissions from Diesel Engines. I Regulated Gaseous Emissions,* Environ. Sci. Technol.,**2004***,* 38,2182-2189

The total exhaust gases from the diesel engine entered the primary tunnel in the mobile emission lab where they were diluted with filtered ambient air. The primary dilution system is configured as a full-flow constant volume sampling (CVS) system with a smooth approach orifice (SAO) Venturi and dynamic flow controller. The SAO Venturi has the advantage of no moving parts and repeatable accuracy at high throughput with low-pressure drop. As opposed to traditional dilution tunnels with a positive displacement pump or a critical flow orifice, the SAO system with dynamic flow control eliminates the need for a heat exchanger. Tunnel flow rate is adjustable from 1,000 to 4,000 standard cubic feet per meter (scfm) with accuracy of 0.5% of full scale. It is capable of total exhaust capture for engines up to 600 kilowatts (kW). Colorado Engineering Experiment Station Inc. initially calibrated the flow rate through both SAOs used in the primary tunnel.

The mobile laboratory contains a suite of gas-phase analyzers on shock-mounted benches. The gas-phase analytical instruments measure NO_x, methane (CH_4), THC, CO, and CO_2 at a frequency of 10 hertz (Hz) and were selected based on optimum response time and on road stability. The 200 liter (L) Tedlar bags were used to collect tunnel and dilution air samples over a complete test cycle. In the design, eight bags were suspended in the MEL allowing four test cycles to be performed between analyses. Filling of the bags is automated with Lab View 7.0 software (National Instruments, Austin, TX). A summary of the analytical instrumentation used, their ranges, and principles of operation is provided in the table below. Each modal analyzer is time-corrected for tunnel, sample line, and analyzer delay time.

Table 2-2 Summary of Gas-Phase Instrumentation in MEL

Gas Component	Range	Monitoring Method
NO_x	10/30/100/300/1000 (ppm)	Chemiluminescence
CO	50/200/1000/3000 (ppm)	NDIR
CO_2	0.5/2/8/16 (%)	NDIR
THC	10/30/100/300/1000 & 5000 (ppmC)	Heated FID
CH_4	30/100/300/1000 (ppmC)	FID

Thus during the yard tractor testing we measured exhaust flow and concentrations of CO, CO_2, NO_x and THC. Gas phase samples were extracted and the diluted samples are analyzed second by second (modal data). Samples from the engine exhaust were also collected into sample bags over defined phases of the test cycles and analyzed later (integrated data).

2.7 Quality Assurance and Quality Control Requirements

From an overview perspective, there are numerous quality control (QC) and quality assurance (QA) procedures built into the operation of MEL, mainly due to the requirements of the CFR. A partial summary of routine calibrations performed by the MEL staff as part of the data QA/QC program follows and more detail is listed in

Appendix A of an earlier report[6]. The MEL uses precision gas blending to obtain required calibration gas concentrations. Calibration gas cylinders, certified to 1%, are obtained from Scott-Marin Inc. (Riverside, CA). By using precision blending, the number of calibration gas cylinders in the lab was reduced and cylinders needed to be replaced less frequently. The gas divider contains a series of mass flow controllers that are calibrated regularly with a Bios Flow Calibrator (Butler, New Jersey) and produces the required calibration gas concentrations within the required ±1.5 percent accuracy.

The CFR specifies a number of quality control and quality assurance requirements in order to meet their protocol in the measurement of emissions from heavy-duty diesel engines. For example Title 40 CFR includes many performance specifications and criteria including:

- sampling methods
- instrumental methods
- environmental controls
- calibration methods and frequencies
- QC check methods and frequencies
- QC check tolerances

Documentation of the program and its results include Standard Operating Procedures (SOPs), Checklists, Log Books, Data Files, Reports to Management, and Reports to Clients.

Standard Operating Procedures

- Safety Check: Truck and Trailer
- Generator start-up
- Analytical bench start-up
- Pre-test set-up
- Test operations
- Post test shutdown
- Shutdown: to ground power
- Shutdown: total

Balance Protocol

Checklists are maintained for:

- Start-up
- Calibration
- Shutdown
- Test operations
- Test QC

[6] Miller, J. W. *A Study of Emissions from Yard Tractors Using Diesel and LNG Fuels*, prepared for the Port of Long Beach August 2007

<u>Logbooks</u>:

- Environmental logbook recording environmental conditions during each test
- Filter sample identification logbook
- Equipment tested log (e.g., trucks, generators, etc)
- Project logs book: history of tests, checks, repairs, etc.
- Fuel log book: quantities and types of fuel, vehicle or generator
- Microbalance log book: recording all filter weight and balance QC data
- Filter Sampling Log: filter Ids and filter weight data associated with each test

<u>Computer Data Files</u>

Equipment test selections, configurations, and test sequences are automated by configuration files. Each configuration file specifies a complete sequence of test and QC operations. During the sequence of operations specified in a configuration files, the data from all channels were recorded at a rate of 1 Hz or faster in a raw test results data file. The configuration file and associated data file were identified by test identification (ID) number. The test ID numbers were assigned based on date and time of day. Each day of testing consists of a pre-test calibration and post-test calibration. When multiple tests were done in one day, the post-test calibration becomes the pre-test calibration for the next test. For example a typical triplicate test day will look like the following:

Pre-test calibration and QC configuration
Pre-test calibration and QC raw test original data

Test 1: equipment test configuration with integral post test calibration
Test 1: equipment test raw test original data with integral post test calibration

Test 2: equipment test configuration with integral post test calibration
Test 2: equipment test raw test original data with integral post test calibration

Test 3: equipment test configuration with integral post test calibration
Test 3: equipment test raw test original data with integral post test calibration

In addition to the files generated by the data acquisition system there were a particle Filter Log File and an environmental data check log. The Filter Log file that associates filter identification numbers with sampling locations and times throughout the test, and with filter weight gains. The environmental data log verifies barometric pressure, dew point temperature, ambient temperature, and RH with lab values for at least one point during a day of testing.

Raw test original data files were post processed to produce original quality control (QC) summaries and original data summaries for review by the Project Manager. The post-processed files include:

- one test file for 1-second modal data

- one test file for uncorrected integrated cycle data, calibration data, Mass Flow Control (MFC) data, etc

In addition to the individual test files, the QC data from each test and the integrated cycle data were each appended to a database containing all test results since the beginning of MEL operations. The following two database files were maintained from the raw data file post processing:

- database of integrated test results (emissions in grams per cycle, parts per million (ppm) and environmental)
- database of integrated test QC results (zeros, spans, and test specific data)

During data validation and review, comments and corrections are recorded by editing a copy of the raw test original data files. The edited, corrected files are called raw test validated data files, and these validated data files are used to generate and replace entries in the post processed files.

In addition to the databases of integrated results and test QC results, there were database files containing histories of QC checks not related to specific tests. These include:

- Propane injection mass balance
- CO_2 injection mass balance
- NO_x converter efficiency
- Blended gas calibration checks
- Analyzer linearity checks

In addition to the QA/QC steps required by the CFR, UCR took the data one more step in that our calculated emission factors were compared with manufacturer’s value and U.S. Environmental Protection Agency (USEPA)/CARB standards.

3 Results

This section discusses the test results, including any modification of the plan for testing that was described in Section 2

3.1 Yard Tractor: Engine Rating and Engine Map

The yard tractors both used Cummins ISB engines, although the engine used in the hybrid yard tractor had less power and torque at their rated speeds. Table 3-1 below provides some detail on the engines and more information is available in Appendix C, including the engine maps.

Table 3-1 Ratings for the Cummins 6.7L ISB Engines

- Hybrid (DB) engine
  - Cummins ISB 200
  - Displacement 6.7 liters
  - Rated 200 hp at 2300 rpm
  - Fuel at rated HP 99 mm3/stroke
  - EGR NOx Control
- FEL
  - NOx 1.75 g/hp-h
  - PM 0.01 g/hp-h

- Diesel engine
  - Cummins ISB 240
  - Displacement 6.7 liters
  - Rated 240 hp at 2300 rpm
  - Fuel at rated HP 100 mm3/stroke
  - EGR NOx Control
- FEL
  - NOx 1.75 g/hp-h
  - PM 0.01 g/hp-h

While both yard tractors used the same Alison C300 transmission system, the rear end ratio for the hybrid was 12.28:1 as compared with 10.62:1 for the diesel. Thus the hybrid engine runs about 20% higher as compared with the diesel and this could influence the measured fuel economy.

3.2 Transient Drive Cycle Modified for Hybrid Yard Tractor

Since the roll speed of the hybrid yard tractor was limited by the electronics within the hybrid power system to about 18 miles per hour and the CalStart cycles shown in Figure 2-2 and Figure 2-3 with a maximum speed of 28 miles per hour, we knew the peak speeds in the cycle would be clipped. Thus we first ran the hybrid yard tractor on the dyno with the CalStart provided operating cycles to establish a modified test cycle; one with a maximum speed determined by the hybrid yard tractor. The modified transient yard tractor cycle is shown in Figure 3-1 and was used when testing both the hybrid and diesel yard tractors to ensure a comparison of the two vehicles when undertaking the same amount of work.

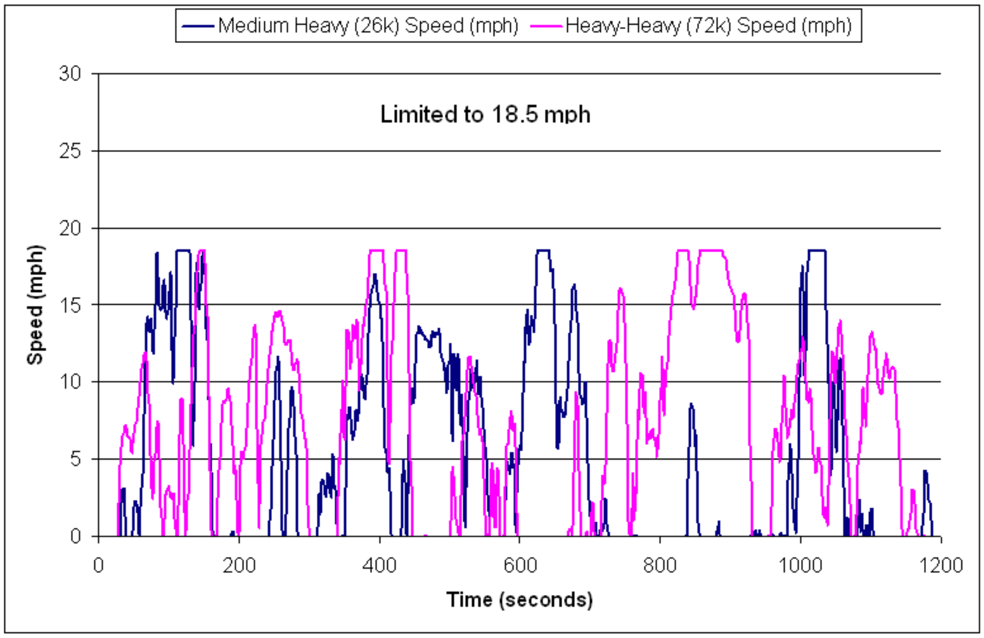

Figure 3-1 Modified Transient Yard Tractor Driving Cycles

3.3 Hybrid Yard Tractor and State of Charge (SOC)

The work carried out by a conventional diesel ICE yard tractor in the cycle can be measured simply from the diesel engine but with the hybrid diesel-electric tractor both the diesel engine and the batteries need to be figured in the final calculation. On the hybrid tractor, the energy from the batteries also had to be taken into account and could be calculated based on the difference in the state of charge multiplied by the total battery power and the seconds for the cycle. For the testing in this project there was a small difference in the initial and final State of Charge (SOC) as seen in the table below. The final state of charge of 72 was achieved, but when the system was initialized before the next test the initial state of charge had dropped to 65-68.

Table 3-2 Example of Change in State of Charge during Test

Testing	Start SOC	End SOC
conditioning	45.1	72.0
26k Test #1	65.5	72.0
26k Test #2	68.0	72.0
26k Test #3	65.5	72.0
conditioning	77.5	72.5
72k Test #1	73.5	72.5
72k Test #2	72.5	72.5
72k Test #3	72.0	72.0

Real time monitoring of the SOC is shown in Figure 3-2 and Figure 3-3 below and provides some insight into the range of the battery utilization. Interestingly the SOC quickly rises to 72 then stays in a range from 71% to 73% for the 26k load test, a rather limited range. For the 72k heavy loaded test the SOC only varied from 65 to 74, also a limited range.

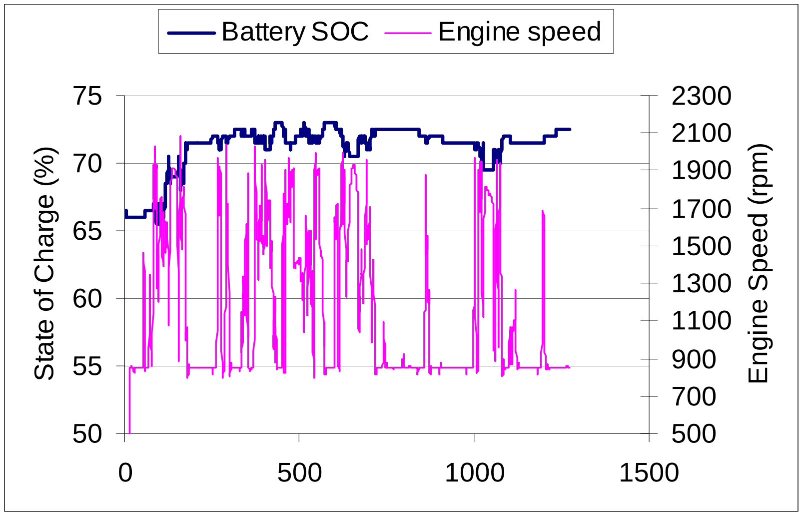

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Figure 3-2 Continuous State of Charge Readings during the 28k Testing

One of the observations was the SOC dropped from the end of the previous test to the beginning of the next test when the key was turned off then on after a ten-minute soak. The US Hybrid people were not surprised by this finding.

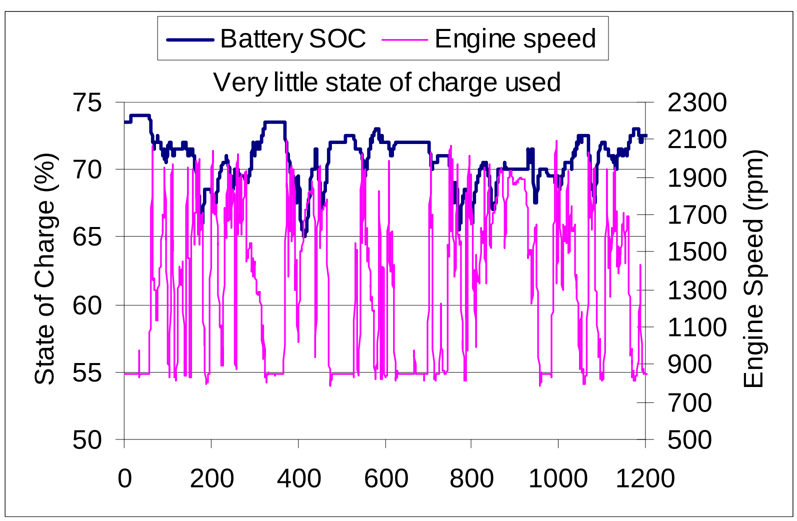


Figure 3-3 Continuous State of Charge Readings during the 72k Testing

3.4 Emissions Testing the Hybrid and Conventional Yard Tractors

Emissions and flow data were collected in triplicate for the hybrid and conventional yard tractors while running on the two transient cycles on the UCR dyno seen below.

Figure 3-4 Figure Showing the UCR HDD Chassis Dyno with YT and MEL

Testing went well as the driver was able to follow the modified transient cycles for both the hybrid and the conventional yard tractor without any difficulty. Simultaneously data was collected with the MEL, the chassis dynamometer and from the Electronic Control Module (ECM) on the yard tractor. The ECM data included percent load, fuel rate, temperatures and engine speed. A test of the hybrid with the batteries disconnected was also carried out without any problems. From these data, we calculated the mass emissions rate per unit time.

3.5 Carbon Dioxide as Surrogate for Fuel Comsumption

Previous projects with MEL showed a strong correlation between the ECM fuel rate and the measured carbon dioxide (CO_2) rate; mainly because over 99% of the fuel carbon is converted into CO_2. A carbon balance and correlation was carried out for this project and the results are presented in the figure below. As indicated in the figure the slope is linear and the coefficient of determination (R^2) is basically unity, an excellent quality check of the relationship between the fuel consumed and CO_2 emissions. This correlation was used to gauge the change in fuel consumption between the hybrid and conventional yard tractor in the data analysis.

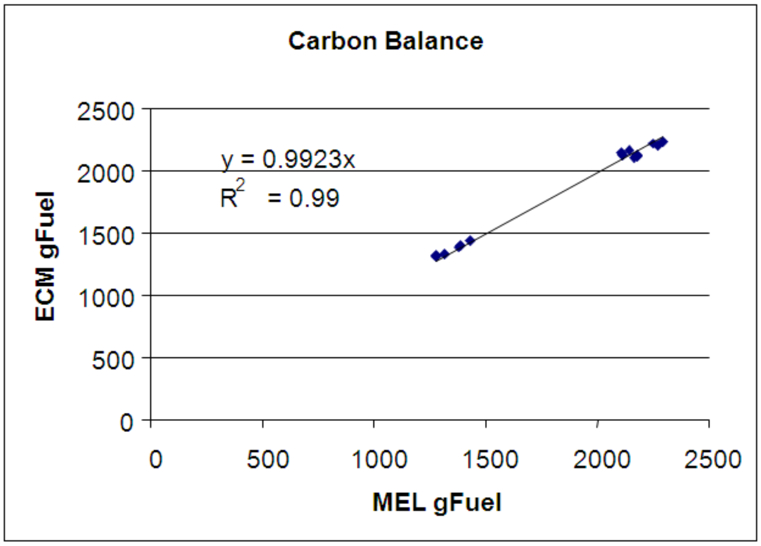


Figure 3-5 MEL Carbon Balance Matches ECM Fuel Rate

3.6 Comparing NO_x and CO_2 Emissions

The most important goal for this project was the comparison of the fuel consumption and the NO_x and CO_2 emissions for the hybrid and conventional yard tractor. Table 3-3 provides the comparative data of the total grams of NO_x and CO_2 measured during the same transient cycle for the two yard tractors and these data are shown graphically in the figure below. Values are shown as mass per cycle as this metric represented the best approach to comparing the two YTs on the transient cycle.

Table 3-3 Comparison of the NO_x and CO_2 Emissions over the Two Transient Cycles

	NOx g/cycle		CO_2 kg/cycle		gNOx/kgCO2	
	ave	stdev	ave	stdev	ave	stdev
Hybrid_26	21.8	0.9	4.4	0.1	4.9	0.3
Diesel_26	22.5	0.2	4.1	0.1	5.5	0.1
Hybrid_72	30.1	0.2	6.7	0.1	4.5	0.0
Diesel_72	32.5	0.6	6.9	0.0	4.7	0.1

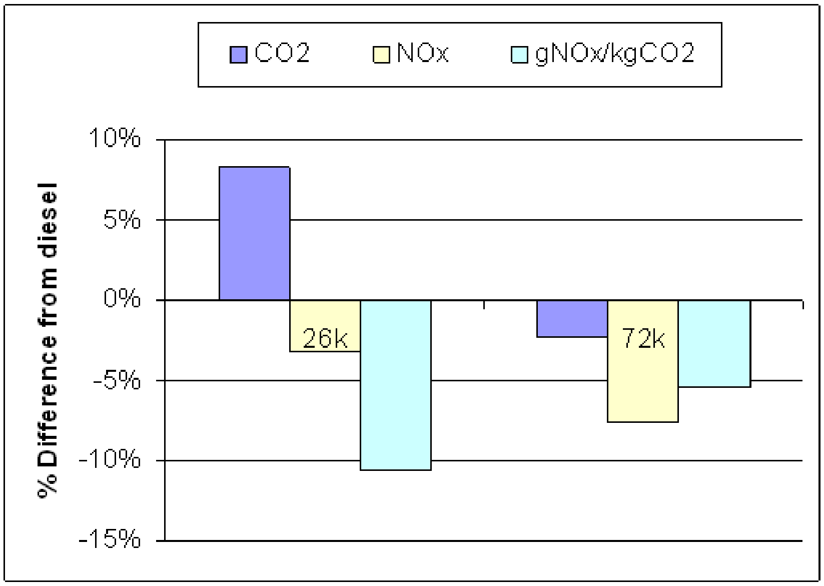


Figure 3-6 Graph of the NO_x and CO_2 Emissions over the Two Transient Cycles

The comparison shows that 1) at low loads, the hybrid actually uses about 8% more fuel and 2) at the higher loads, the hybrid is about 2% more fuel efficient and NO_x emissions are 8% lower compared to the conventional yard tractor.

3.7 Comparing Other Emissions: CO, THC, CH_4 and PM

Emission values of CO, THC, CH4 and PM are of lesser interest than the CO_2 and NO_x values presented earlier. The results show at high loads that the conventional yard truck emitted slightly higher levels of THC and CO. PM was near the detection limits of the reference method for all tests and well below the certification standards as expected for DPF-equipped diesel engines.

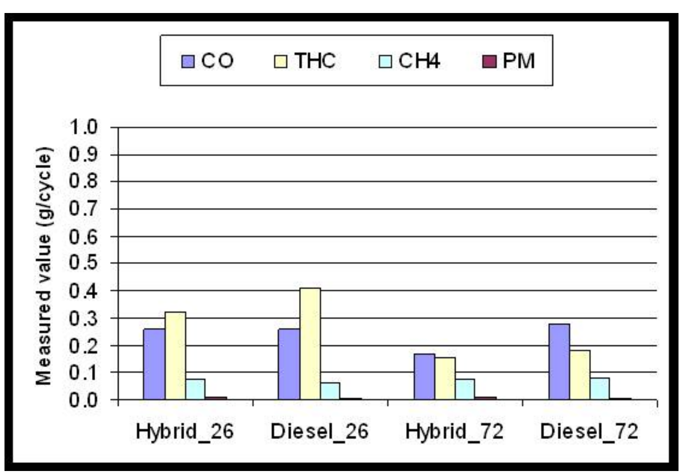


Figure 3-7 Graphical Differences of Other Emissions

3.8 Investigation of Engine Parameters for Causitive Effects

UCR made a deeper investigation of the engine parameters to learn if there was some obvious cause for the differences in performance of the hybrid and conventional yard tractors. The table and figure below show the result of the investigation.

Table 3-4 Engine Parameters Values show Differences in Yard Tractors

	speed (mph)		distance (mi)		dyn Load		eLoad (%)		throttle (%)		boost (kPa)		intake (F)		coolant (F)	
	ave	stdev	ave	stdev	ave	stdev	ave	stdev	ave	stdev	ave	stdev	ave	stdev	ave	stdev
Hybrid_26	5.02	0.03	1.69	0.01	27.7	0.1	26.3	0.6	17.3	0.6	10.1	0.3	105	1	190	0.1
Diesel_26	5.07	0.04	1.70	0.01	27.3	0.1	25.0	0.5	11.6	0.7	9.7	0.5	103	5	193	0.1
Hybrid_72	6.90	0.06	2.31	0.02	63.6	0.5	30.8	0.4	28.1	0.3	18.3	0.4	111	1	191	0.2
Diesel_72	6.98	0.03	2.33	0.01	63.6	0.2	28.4	0.3	20.8	0.7	19.9	0.6	112	3	194	0.2

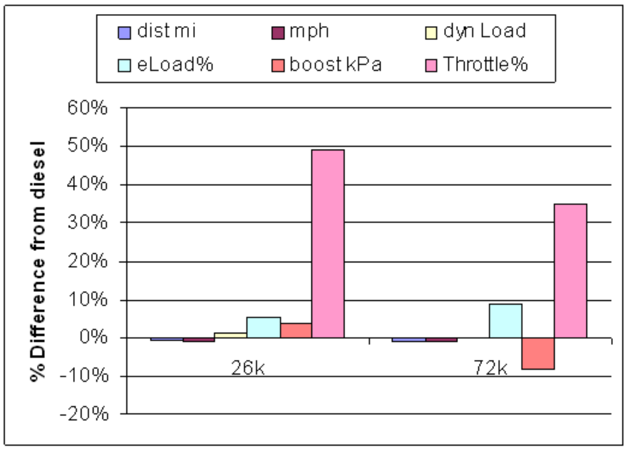


Figure 3-8 Graph Showing the Differences in Engine Parameters

It was clear from the investigation that the throttle for the hybrid operated about 40% higher than that of the conventional diesel. The average throttle position for the hybrid at 26k and 72k tests was 17% and 28% and for the conventional it was 12% and 21% respectively. The difference in actual average throttle between the hybrid and convention was fairly small. Whether the throttle position caused the observed differences in emissions is left for further study.

The engine percent load measured by the ECM was slightly higher for the hybrid compared to the conventional by 5% and 9% for the 26k and 72k tests. The increase for the hybrid is a result of the downsizing the engine. The hybrid engine is rated at 200 hp and the conventional is rated at 240 hp. Thus, it takes more percent load of 200 to perform the same work as 240. The difference in percent load is not a difference in work performed. The fact that the chassis dyno measured the same power at the wheels for both tests confirms this. The other parameters such as coolant temperature, intake temperature, distance and dyno load were within 1%. In general there was no significant differences identified suggesting the tests were performed in a repeatable manner.

Another question was whether the regeneration of the DPF during the test had anything to do with the observed differences. UCR noted there was a flag on the ECM

when the DPF regenerates and the data were purged from the one run where this flag was shown.

3.9 Special Case: Hybrid YT Operating in Full Diesel Mode or as Hybrid

US Hybrid explained that one of the features of their design was the opportunity to completely disconnect the batteries and allow the yard tractor to operate in either the full diesel or the hybrid mode. Given that opportunity, UCR had US Hybrid disconnect the batteries and UCR ran the YT while following the high-load transient cycle with 1) the original cycle with speeds to 24mph and 2) the modified-clipped cycle established when the hybrid electronic unit governed the speed to 18 mph. Comparative data were already available for the hybrid yard tractor. Charts below show the streaming and cumulative data for CO_2 and NO_x as a function of time during the test cycle.

After examining the data in this format, we made the following observations:

1. When operating in the diesel mode, the emissions were independent of whether the yard tractor followed the original transient cycle or the chopped version created by the hybrid unit.
2. The cumulative CO_2 emissions were lower for hybrid throughout the cycle as the data had indicated.

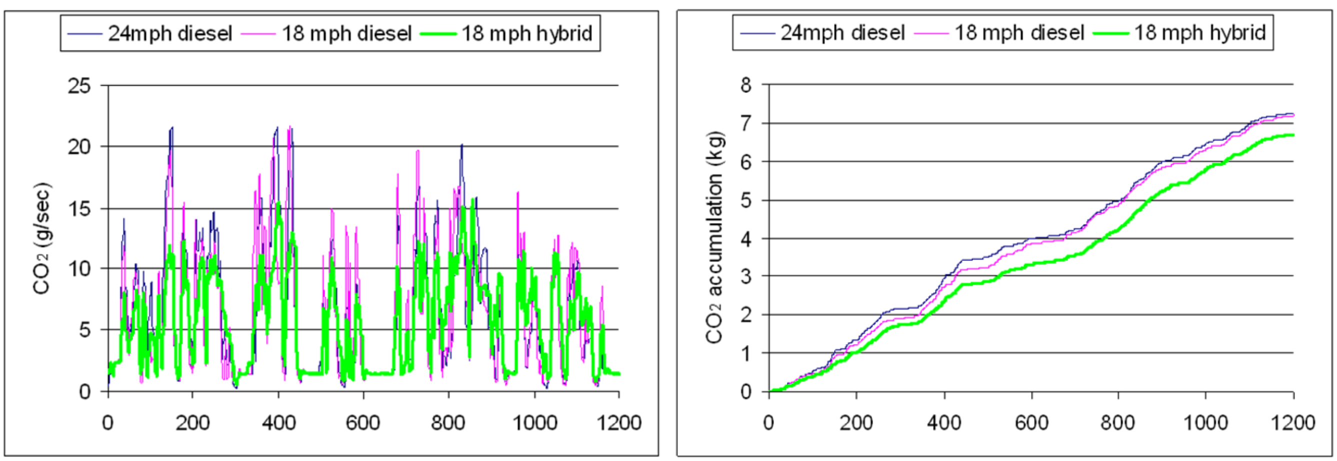
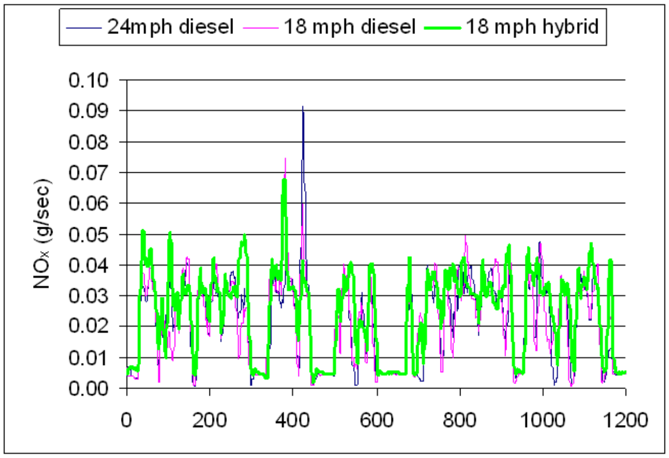


Figure 3-9 Integrated CO_2 Data for the Yard Tractors

A comparable measurement project was carried out for NO_x emissions during the various operating modes of the hybrid yard tractor and results are shown in the figures below. Analysis shows:

1. The emissions were the same for the hybrid unit operating in diesel mode and independent of whether it followed the original transient cycle or the chopped version created by the hybrid unit.
2. The cumulative hybrid NO_x emissions were higher throughout the cycle as the data had indicated. UCR speculates that the EGR operation differed in the two cases leading to the higher NOx but this hypothesis should be checked with further study.



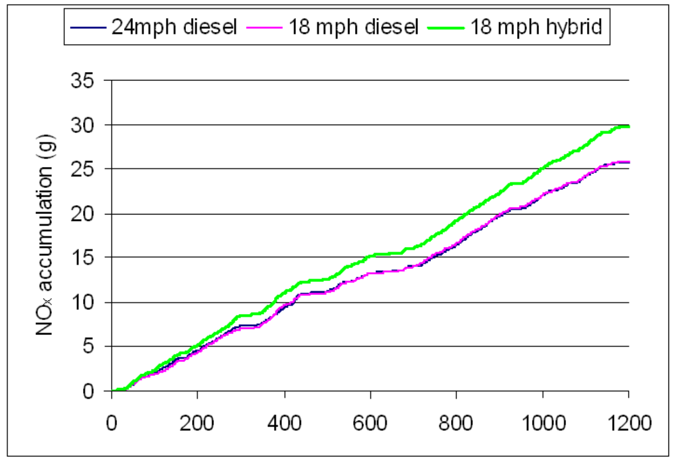


Figure 3-10 Integrated NO_x Data for the Yard Tractors

4 Findings and Recommendations

4.1 Findings

The goal of this project was to measure the emissions of a conventional and hybrid yard tractor following cycles developed from monitoring in-use activities. The cycle was modified to accommodate the hybrid tractor but subsequent results showed emissions were basically the same on both cycles. The results comparing the diesel and hybrid YTs at two different loads are shown in the figure below and indicate that at low loads the hybrid consumed about 7% more fuel and at high loads the hybrid saved about 3% fuel. NO_x emissions were reduced 3% and 8% at the low and high loads, respectively.

The findings were surprising since it was expected that the hybrid would show a fuel savings on the order of 30%. These authors speculate that since the state-of-charge did not change much in the test cycle that the power management strategy for the hybrid system has underutilized the batteries.

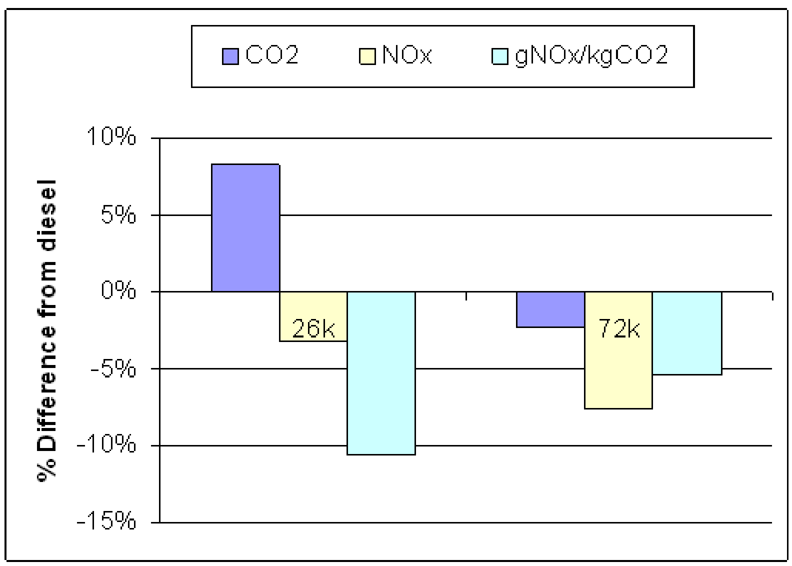


Figure 4-1 Comparative Emissions for the Hybrid and the Diesel Yard Tractors.

4.2 Recommendation

Based on the findings, UCR makes the following recommendations:

1. Review the power management system algorithms for the hybrid to determine if greater utilization of the batteries would improve fuel economy.
2. Use a chassis dynamometer to tune the power management module of the hybrid unit for optimal fuel consumption and then put the unit into service before testing. Repeat and confirm the modified strategies fuel savings.
3. Consider investigating EGR behavior if the modified strategy does not provide the desired results.

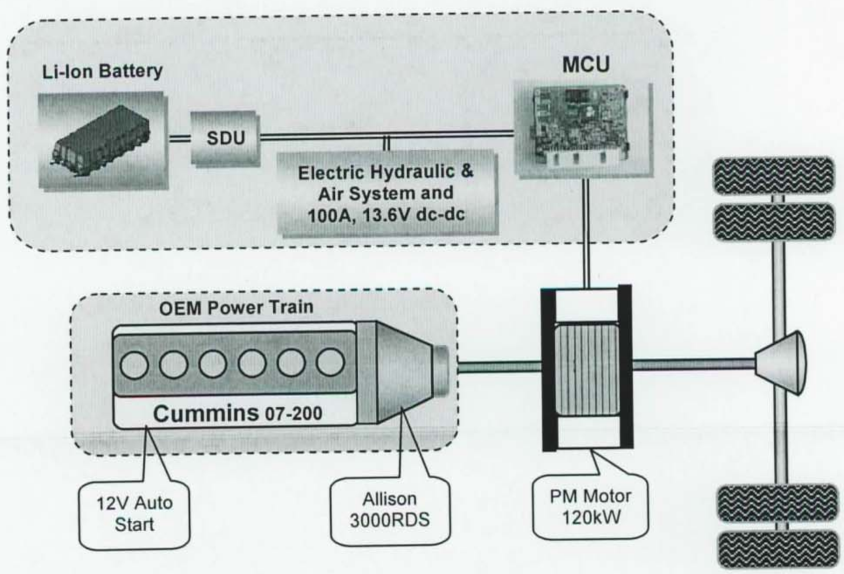
Appendix A

US Hybrid's Plug-In Hybrid Electric Terminal Tractor

Hybrid Port Truck

Hybrid Port Truck System Specification.

- Parallel Hybrid Post Transmission,
- 120kW Permanent Magnet Motor with Digital Controller and J1939 CAN
- Li-Ion Battery,
- 150A, 12V dc-dc converter
- Safety Disconnect Unit
- Electro-Hydraulic pump and controller
- Electric Air Compressor and controller
- CAN and PC based diagnostic, service and maintenance software
- Ottawa 50 with Cummins ISB 07-200 on-road Engine
- Engine Idle control.



4 X 2 YARD TRACTOR

STANDARD FEATURES

- Cummins ISB-07 200 HP @2300 RPM
  520 lb/ft torque @1600 RPM
  certified turbo diesel with primary fuel filter
- Allison 3000RDS Transmission (4 speed)
- Front Axle: Meritor FF-961, 12,000 lb
- Rear Axle: Meritor RS-24-160, 7.17:1 ratio, solid mount to frame
- 110" Wheelbase with "L" reinforcement
- Fifth wheel: Holland FW-3500, 70,000 lb plate rating
- Fifth wheel lift cylinders: 5" diameter, 60,000 lb rating
- Tires 11R22.5 Steel belted radials 14PR
- Wheels 22.5" X 8.25" 285 mm hub piloted, 10 hole steel disc
- Vertical exhaust system with heat shield
- Air cleaner, frontal inlet
- Back-up light, stop and turn signals
- Mud-flaps rear spring loaded
- Step - battery box 16" width
- Cab side vent (riveted)
- Drive shaft Spicer 1710 series
- Approximate Vehicle Weight 14,500 lb
- GCWR 80,000 lbs.

TRAILER EQUIPMENT

- Two (2) color coded, coiled air lines with glad hand receivers, 7 wire female receptacle at rear of cab, 7 wire coiled trailer light cable

STEERING

- Gearbox type integral power steering with mechanical back up
- Constant running PTO/pump with priority steering circuit

CAB FEATURES

- Cab air ride, 3-point mount suspension
- Cab with raised roof: 50" X 65" X 68" welded steel and drivers side door which has a full length piano hinge and an aluminum sliding rear door
- Cab insulation, for thermal protection and noise abatement
- Cab tilt: Electric 45° with 90° tilt capability
- Platform, rear of cab
- Air Ride Seat with isolator
- Seat belt with 2-point mount
- Tinted glass all windows
- 40,000 BTU fresh air heater/defroster
- West coast 16" X 7" mirrors
- See through sun visor
- ICC light package

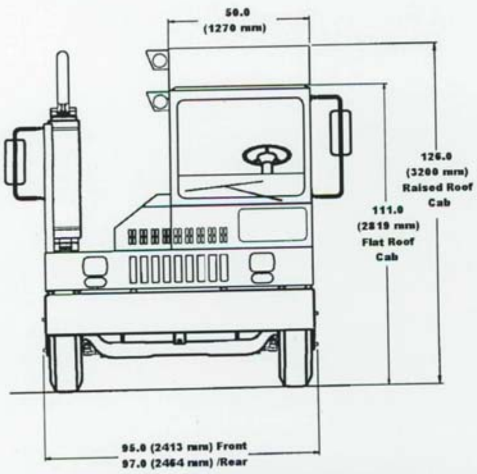
- **Cab gauges:**
  Volt meter, oil pressure, water temperature, fuel level, air pressure, speedometer and five digit hour-meter

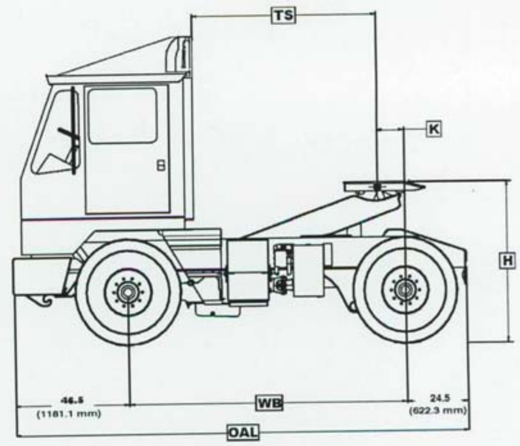
- **Cab controls:**
  Accelerator, tractor/trailer brakes, gear selector, fifth wheel elevation, steering wheel 18" soft touch, dash light controls, turn signals, electric horn, heater defroster, electric windshield washer, electric windshield wiper control, door locks, headlights, side and front clearance lights, rear flood light upper right side, 5th wheel unlatch

WARNING DEVICES

- Low air pressure light and alarm
- Transmission oil high temperature warning
- Headlight hi-beam indicator
- Electric backup alarm
- Engine temperature/oil pressure
- Engine protection warning system

Ottawa 4x2 DOT/EPA Certified





		BOOM POSITION STANDARD LIFT	
WB	DIM	UP	DOWN
110" (2794 mm)	TS	73.4 (1863 mm)	77.5 (1958 mm)
	K	10.2 (259 mm)	6.1 (154 mm)
	H	63 (1600.2 mm)	46 (1168.4mm)
	OAL	181 (4597.4 mm)	

HYDRAULIC SYSTEM

- 16 gallon tank with sight glass
- 10 GPM pump
- 5" hydraulic lift cylinders
- Hydraulic system fittings with "O" Ring
- Boom lift 17"

BRAKES

- FMVSS 121 Brake system with ABS
- Split Brake system
- Front:"S" Cam type 16.5" x 5" air actuated
- Rear: "S" Cam type 16.5" x 7" air actuated
- Automatic Slack Adjusters Front and Rear

FRAME FEATURES

- Welded 50,000 psi steel with 12" x 3 3/8" X 3/8" formed channel 43.25" wide frame with "L" frame reinforcement (1,835,000 in/lb RBM)
- 55° tapered deck curbside with reinforced removable bumper
- 50-gallon frame mounted round fuel tank, curbside
- Integral front and rear tow eyes

PNEUMATIC SYSTEM

- 15.2 CFM Wabco compressor with 3-tank air reservoir system total capacity 5688 cu. in.
- Color-coded air lines

ELECTRICAL SYSTEM

- 12 Volt neg. ground with circuit breakers, 130-amp minimum charge alternator, color coded wiring in separate removable harness, 12-volt starter with positive engagement, two (2) 12-volt low maintenance batteries, cab dome light

PAINT FINISH

- Cab: white DuPont Imron 5000
- Chassis and components powder coated primer, top coated with polyurethane, paint black
- Wheels: Paint "E" coat white
- Rubberized undercoating under cab and deck

Kalmar

Appendix B

Press Releases

US Hybrid's Plug-In Hybrid Electric Terminal Tractor to be Tested at Port of Long Beach Shipping Terminal

August 10, 2009 Palo Alto, California

A plug-in hybrid electric "terminal tractor" used to move shipping containers and cargo within the port will be tested at a Port of Long Beach shipping terminal. If this heavy-duty application of hybrid electric technology proves successful at Long Beach and other ports then it could replace diesel-powered tractors on a wide scale, reducing emissions of greenhouse gases and improving energy efficiency of port operations.

The Electric Power Research Institute is coordinating the project among several ports and will also compile and analyze project data related to the tractor's performance, including emissions, charging, diesel fuel reduction and other aspects. The equipment will be tested at SSA Container Terminal on Pier A at the Port of Long Beach for 3 months.

US Hybrid Corporation converted the diesel powered vehicle, which is similar in appearance to a tractor cab, into a hybrid which has the ability to be refueled from the electric grid. As a plug-in hybrid electric vehicle (PHEV) the tractor will be able to move containers weighing up to 95,000 pounds as its diesel counterparts can, but unlike diesels will not idle its engine when inactive. Over a year of full-time operation it is expected that the PHEV tractor would use 3,000 gallons of fuel per year less than a similar diesel and significantly reduce emissions.

"Terminal tractors are the most prevalent piece of equipment at container ports and they typically idle 50 percent to 80 percent of the time they're in use," said Andra Rogers, senior project manager of Electric Transportation at EPRI. "It's feasible that by converting their tractor fleets ports could reduce emissions from this source by 80 percent for nitrogen oxides, 50 percent for carbon dioxide and significant amounts of other criteria pollutants. These vehicles can make a big impact on lowering a port's overall emissions."

"One of the central directives in our Green Port Policy is the adoption of new, environmentally friendly technologies," said Heather Tomley, Port of Long Beach Assistant Director of Environmental Planning. "We encourage private industry to develop, test and evaluate technologies such as this hybrid-electric terminal tractor." Currently there are approximately 754 diesel tractors at the Port of Long Beach.

The three-month Port of Long Beach demonstration project is part of a one-year demonstration, during which the tractor will also be tested and evaluated at ports in Savannah, Ga., Mobile, Ala., Houston, and New York City.

EPRI will document the tractor's performance and operation including electric grid system impact, vehicle system efficiency, emissions, costs and vehicle performance. EPRI also will evaluate performance and benefits relative to conventional diesel vehicles. The research is part of a broader program EPRI conducts on "non-road" electric applications for transportation, which includes forklifts, airport vehicles and power supply options for ships at dock, airliners at the gate and trucks at truck stops.

SOURCE: greentechmedia

Port of Long Beach to test Kalmar hybrid terminal tractors

April 22, 2009

Cargotec's Kalmar business area has been awarded a contract to supply three new hybrid terminal tractors for technology trials being carried out by the Port of Long Beach, CA, USA.

The Port of Los Angeles and the Port of Long Beach are well-known as leaders in environmentally friendly, sustainable port operations.

The three hybrid terminal tractors will be based on Kalmar's well established Ottawa 4 X 2 terminal tractor, already proven in use at terminals across the world. They will be fitted with a Parallel Hybrid Drive system which converts power from on-board batteries, having been charged by the OEM Diesel engine or regenerative braking system, to an electric motor for propulsion through the rear axle. This technology is being developed by Kalmar's development partner in Hybrid technology, US Hybrid in Torrance California.

Jay Hayes, Vice President, Research and Development, Kalmar terminal tractors at Cargotec said: "The trials will commence in about a year and will last for a full twelve months. The trials should not only prove the hybrid concept with new terminal tractors, but also that used terminal tractors can be modified to hybrid power. We estimate that adding a hybrid kit may result in fuel savings of up to 30 per cent.

"We will start getting results as soon as the tests commence and will come to our final conclusions during and after the testing."

SOURCE: www.kalmarind.com

HYBRID YARD HOSTLER DEMONSTRATION PROJECT

Yard hostlers (also known as yard tractors, terminal tractors, or utility tractor rigs) are common at port terminals, rail yards, and distribution centers. Their function is to move containers around a facility. At a port, containers are loaded off a ship onto a bobtail rig that is pulled by the yard hostler to an intermodal point or to a storage facility. Yard hostlers are often idling as they wait in queues to pick up or drop off their loads.

The ports of Long Beach and Los Angeles (POLB and POLA) have contracted CALSTART to manage a project that will demonstrate 3 diesel-hybrid yard hostlers at the Long Beach Container Terminal (LBCT). This is a technology demonstration and evaluation program aimed at reducing emissions in (non-road) marine terminal environments. As part of this project, vehicle emissions and performance will be evaluated compared to baseline diesel yard hostlers. Following the testing and evaluation phase, a business case assessment will be performed for expanding the use of hybrid yard hostlers in marine terminals and similar applications.

The U.S. Environmental Protection Agency is also providing funds for the development of the hybrid drive system.

To date, a hybrid drive supplier—U.S. Hybrid—has been chosen and is currently completing its design and testing before integrating the hybrid drive system into a Kalmar Ottawa 4x2 yard hostler chassis. The yard hostlers will be put into service in early 2010 at LBCT for a demonstration period of six (6) to nine (9) months. A similar demonstration will be conducted at approximately the same time at the Port of New York and New Jersey.

http://www.calstart.org/consulting/What-We-Do/Recent-Projects/Hybrid-Yard-Hostler-Demo-Project.aspx

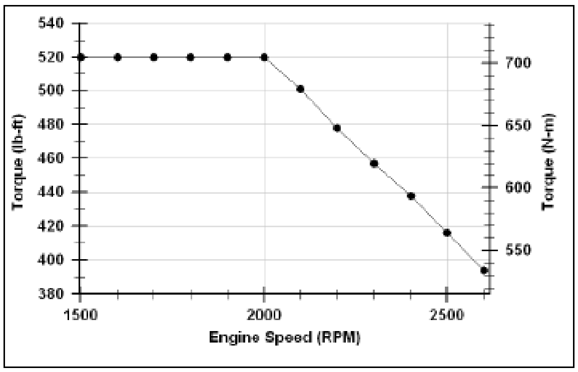
Appendix C

Cummins Engine Maps

Engine Performance Curve Cummins Inc Columbus, Indiana 47202-3005 http://www.cummins.com	ISB 200	200 hp (149 KW) @ 2300 RPM 520 lb-ft (705 N-m) @ 1600 RPM			Automotive Pg. No.
		Curve Number FR91655	CPL Code 0279	Date 10-May-2007	1

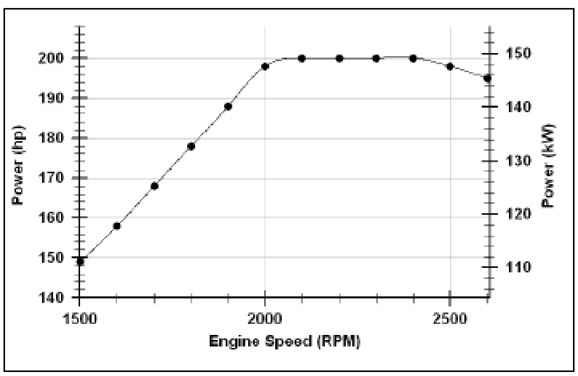
Compression Ratio:	17.3:1	Engine Configuration:	D313006BX03
Fuel System:	Bosch Electronic	Emission Certification:	EPA 2007, CARB 2007
Cylinders:	6	Aspiration:	Turbocharged and Charge Air Cooled
Bore:	4.21 in (107 mm)	Displacement:	409 in3 (6.7 L)
Stroke:	4.88 in (124 mm)		

Automotive Applications - DPF Required



Torque Output

RPM	lb-ft	N-m
1,500	520	705
1,600	520	705
1,700	520	705
1,800	520	705
1,900	520	705
2,000	520	705
2,100	501	679
2,200	478	648
2,300	457	620
2,400	438	594
2,500	416	564
2,600	394	534



Power Output

RPM	hp	kW
1,500	149	111
1,600	158	118
1,700	168	125
1,800	178	133
1,900	188	140
2,000	198	148
2,100	200	149
2,200	200	149
2,300	200	149
2,400	200	149
2,500	198	148
2,600	195	145

Curves shown above represent mature gross engine performance capabilities obtained and corrected in accordance with SAE J1995 conditions of 29.61 in Hg (100 kPa) barometric pressure [300 ft (90 m) altitude], 77 deg F (25 deg C) inlet air temperature, and 0.30 in Hg (1 kPa) water vapor pressure with No. 2 diesel fuel.

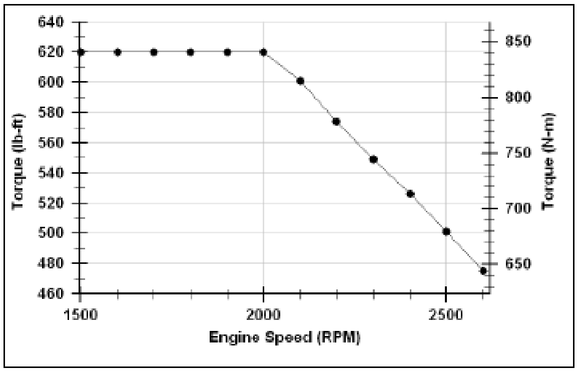
All data are based on the engine operating with fuel system, water pump, lubricating oil pump, air compressor (unloaded) and with inlet restriction and exhaust restriction at or below datasheet limits. Not included are alternator, fan, optional equipment and driven components.

Engine Performance Curve Cummins Inc Columbus, Indiana 47202-3005 http://www.cummins.com	ISB 240	240 hp (179 KW) @ 2300 RPM 620 lb-ft (841 N-m) @ 1600 RPM			Automotive Pg. No.
		Curve Number FR92166	CPL Code 0279	Date 10-May-2007	1

Compression Ratio: 17.3:1
Fuel System: Bosch Electronic
Cylinders: 6
Bore: 4.21 in (107 mm)
Stroke: 4.88 in (124 mm)

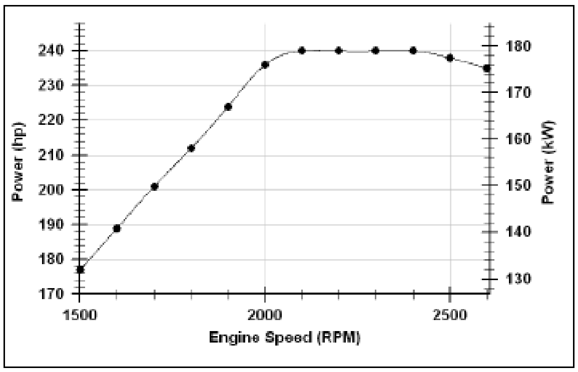
Engine Configuration: D313006BX03
Emission Certification: EPA 2007, CARB 2007
Aspiration: Turbocharged and Charge Air Cooled
Displacement: 409 in3 (6.7 L)

Automotive Applications - DPF Required



Torque Output

RPM	lb-ft	N-m
1,500	620	841
1,600	620	841
1,700	620	841
1,800	620	841
1,900	620	841
2,000	620	841
2,100	601	815
2,200	574	778
2,300	549	744
2,400	526	713
2,500	501	679
2,600	475	644



Power Output

RPM	hp	kW
1,500	177	132
1,600	189	141
1,700	201	150
1,800	212	158
1,900	224	167
2,000	236	176
2,100	240	179
2,200	240	179
2,300	240	179
2,400	240	179
2,500	238	177
2,600	235	175

Curves shown above represent mature gross engine performance capabilities obtained and corrected in accordance with SAE J1995 conditions of 29.61 in Hg (100 kPa) barometric pressure [300 ft (90 m) altitude], 77 deg F (25 deg C) inlet air temperature, and 0.30 in Hg (1 kPa) water vapor pressure with No. 2 diesel fuel.

All data are based on the engine operating with fuel system, water pump, lubricating oil pump, air compressor (unloaded) and with inlet restriction and exhaust restriction at or below datasheet limits. Not included are alternator, fan, optional equipment and driven components.

Appendix D

Yard Hostler Duty Cycle Summary

Brad Rutledge
Nov. 27, 2009

Introduction

A yard hostler duty cycle has been developed as part of the Hybrid Yard Hostler Demonstration and Commercialization Project funded by the Port of Long Beach (POLB), the Port of Los Angeles (POLA), and the U.S. Environmental Protection Agency (EPA). The purpose of developing a yard hostler duty cycle is to be able to compare the relative emissions and fuel economy of hybrid yard hostlers vs. diesel yard hostlers at the chassis level. Note that there is currently no standard, chassis-level duty cycle specifically for yard hostlers.

The Center for Alternative Fuels, Engines and Emissions at West Virginia University (CAFEE) was contracted by CALSTART to develop the yard hostler duty cycle for this project. The duty cycle was developed based on in-use yard hostler data collected at the Long Beach Container Terminal (LBCT), a POLB tenant, between January 25th and January 30th, 2008. LBCT is considered to be a “typical” small container handling terminal. (Note that container handling terminals can generally be grouped by size as either small, medium or large.)

This duty cycle was developed based on yard hostler operation in a marine terminal environment. It may also prove useful in representing other yard hostler applications, such as intermodal yards and/or distribution centers, however these applications have not been investigated sufficiently to make such a determination yet.

Technical Considerations

Yard hostlers are heavy-duty tractors used for moving cargo containers within port container terminals and other off-road areas. At any given time during the operation of a particular yard hostler, the physical load being pulled by the yard hostler can vary dramatically depending on the weights of the trailer and container connected to the tractor. In extreme cases, this weight difference can easily exceed 80,000 lbs. Therefore it is necessary to know both the vehicle speed and the physical load (weight) of the trailer and container being pulled by the yard hostler at any given time as both have a significant effect on how hard the engine has to work, (which in turn directly affects emissions and fuel consumption). While the use of data loggers to collect vehicle speed vs. time data is common, determination of the vehicle physical load (weight) vs. time added significant complexity to the real-time data collection procedures.

Another technical issue associated with the yard hostler application is that yard hostlers spend a significant portion of their operation in “creep” mode. “Creep” mode is informally defined as forward movement at speeds below 4 mph. (Note that 4 mph is approximately the lowest speed where the transmission can directly couple the engine speed to the drive train speed.) This frequently occurs while yard hostlers are waiting in a queue to have a cargo container loaded or unloaded. Since GPS-based data loggers

typically do not have the resolution to distinguish "creep" operation vs. a stopped or idling vehicle, additional vehicle instrumentation was necessary to identify real-time "creep" operation to ensure that it would be adequately represented in the final yard hostler duty cycle. Note that the loads on the vehicle's propulsion and auxiliary systems can be significantly different during "creep" vs. idle operation, which may in turn affect emissions and fuel consumption.

Yard Hostler Duty Cycle Statistics

There are three main categories of work that yard hostlers perform: ship work, rail work and dock work (sometimes called yard work). Ship work and rail work involve a high degree of repetitive activities while dock work tends to involve more non-repetitive activities. In addition, ship and rail work constitute the vast majority of all yard hostler activities at LBCT (about 95%). For these reasons, in-use data collection at LBCT focused on ship and rail activities, purposely excluding dock work activities. A summary of the key statistics associated with the yard hostler in-use data collected at LBCT is given below:

Parameter	*All Activities*	*Rail Only*	*Ship Only*
Avg. Speed	7.5 mph	8.9 mph	7.0 mph
Std. Dev. Speed	3.4 mph	4.2 mph	3.2 mph
Creep	21.4%	15.1%	23.3%
Idle	40.1%	31.7%	41.8%
Creep + Idle	61.5%	46.8%	65.1%

Yard Hostler Weight Categories

As a result of the significant variability in physical load (weight) of the yard hostler during operation and the constraints of typical heavy-duty chassis dynamometers, the yard hostler duty cycle was split into two (2) sub-cycles. Each sub-cycle corresponds to that portion of the yard hostler duty cycle associated with yard hostler operation in one of two (2) weight categories: medium-heavy duty and heavy-heavy duty. The "dividing line" between the medium-heavy duty and heavy-heavy duty weight categories was chosen as a Gross Combined Vehicle Weight (GCVW) of 20,040 kg. (44,181 lbs.). The choice of this "dividing line" was based on an analysis of the combined vehicle, trailer and container weights of all potential tractor/trailer combinations. Average weights for each category were then calculated based on actual data as the number of pound-trips in each category divided by the total number of trips in each category. The results are as follows:

Average weight for medium-heavy duty category: 11,888 kg. (26,209 lbs.)
Average weight for heavy-heavy duty category: 32,837 kg. (72,393 lbs.)

From the yard hostler in-use data collection, the actual percentage of time spent in each weight category was as follows:

Percentage of time in medium-heavy duty category: 64.1%
Percentage of time in heavy-heavy duty category: 35.9%

A summary of the key statistics associated with each weight category (i.e., combining rail and ship activities in each weight category) vs. the statistics for all activities is given below:

Parameter	*All Activities*	*Medium-Heavy (Rail + Ship)*	*Heavy-Heavy (Rail + Ship)*
Avg. Speed	7.5 mph	7.3 mph	7.7 mph
Std. Dev. Speed	3.4 mph	3.4 mph	3.4 mph
Creep	21.4%	25.6%	13.9%
Idle	40.1%	44.4%	30.6%
Creep + Idle	61.5%	70.0%	44.5%

Yard Hostler Sub-Cycles

The time-speed traces for the medium-heavy duty and heavy-heavy duty sub-cycles can be found in the file, "Yard Hostler Driving Cycles.xls". Each sub-cycle is composed of individual micro trips taken directly from the data collected during in-use yard hostler operation. A micro trip was defined as a distinct activity starting with the vehicle at rest (idling or stopped), then accelerating to a speed greater than creep speed (i.e., greater than 4 mph), and then coming to rest again. There are two sub-cycles, one representing medium-heavy duty operation and the other representing heavy-heavy duty operation. Each sub-cycle is 1200 sec. in duration with the first 300 seconds consisting of rail micro trips followed by the last 900 seconds of ship micro trips. This corresponds to the estimated split between yard hostler rail (25%) vs. ship (75%) activities at LBCT. A summary of the key micro trip statistics (excluding creep and idle) associated with each portion (rail vs. ship) of the sub-cycles is as follows:

Parameter	*Medium-Heavy Rail*	*Medium-Heavy Ship*	*Heavy-Heavy Rail*	*Heavy-Heavy Ship*
Duration	300 sec.	900 sec.	300 sec.	900 sec.
Avg. Speed	9.2 mph	6.8 mph	8.4 mph	7.6 mph
Std. Dev. Speed	4.4 mph	3.3 mph	3.9 mph	3.5 mph
Creep	21.5%	27.8%	6.7%	16.5%
Idle	47.3%	42.1%	14.3%	29.4%
Creep + Idle	68.8%	69.9%	21.0%	45.9%

A summary of the overall statistics (including creep and idle) associated with the medium-heavy duty sub-cycle is as follows:

Parameter	*Medium-Heavy Rail*	*Medium-Heavy Ship*	*Medium-Heavy Combined*
Duration	300 sec.	900 sec.	1200 sec.
Avg. Speed	6.1 mph	5.0 mph	5.3 mph
Std. Dev. Speed	7.8 mph	6.4 mph	6.8 mph
Creep	13.7%	16.9%	16.1%
Idle	44.5%	41.2%	42.0%
Creep + Idle	58.2%	58.1%	58.1%

A summary of the overall statistics (including creep and idle) associated with the heavy-heavy duty sub-cycle is as follows:

Parameter	*Heavy-Heavy Rail*	*Heavy-Heavy Ship*	*Heavy-Heavy Combined*
Duration	300 sec.	900 sec.	1200 sec.
Avg. Speed	7.1 mph	7.1 mph	7.1 mph
Std. Dev. Speed	5.2 mph	6.9 mph	6.5 mph
Creep	17.6%	13.9%	14.9%
Idle	13.3%	28.4%	24.6%
Creep + Idle	30.9%	42.3%	39.5%

Chassis Dynamometer Testing

Since actual yard hostler operations includes activities in both the medium-heavy duty and heavy-heavy duty weight categories, chassis dynamometer testing of yard hostlers must include tests of both the medium-heavy duty and heavy-heavy duty sub-cycles. Results from both cycles can then be combined mathematically to produce a single, aggregate result for yard hostler emissions and fuel economy. The medium-heavy duty sub-cycle is tested at the average weight for the medium-heavy duty weight category while the heavy-heavy duty sub-cycle is tested at the average weight for the heavy-heavy duty weight category. The results for each sub-cycle are then weighted according to the overall percentage of time spent in each weight category.

Since both sub-cycles have the same overall duration and ratio of rail to ship activity (time), it is not necessary to scale the results before combining them. Given that testing is performed at the chassis (vs. engine) level, emissions results are reported in grams/hour (g/hr) rather than grams/brake horsepower-hr (g/bhp-hr). Due to the significant percentage of idle and creep in the yard hostler duty cycle, fuel economy results are reported in gallons/hour (gal/hr) rather than miles per gallon (mpg). Note that this is consistent with standard practice in the yard hostler industry where fuel economy is

generally reported in gal/hr and vehicles are typically equipped with engine-hour meters rather than odometers.

Example Calculation of Emission Factors

Emissions from medium-heavy duty rail: 12 g/hr
Emissions from medium-heavy duty ship: 15 g/hr
Emissions from heavy-heavy duty rail: 20 g/hr
Emissions from heavy-heavy duty ship: 22 g/hr

Emissions Factor =

$((\text{emissions}_{\text{medium-heavy rail}}) \times (\%_{\text{rail}}) \times (\%_{\text{medium-heavy}})) +$
$((\text{emissions}_{\text{medium-heavy ship}}) \times (\%_{\text{ship}}) \times (\%_{\text{medium-heavy}})) +$
$((\text{emissions}_{\text{heavy-heavy rail}}) \times (\%_{\text{rail}}) \times (\%_{\text{heavy-heavy}})) +$
$((\text{emissions}_{\text{heavy-heavy ship}}) \times (\%_{\text{ship}}) \times (\%_{\text{heavy-heavy}})) =$
((12 g/hr) x (0.25) x (0.641)) +
((15 g/hr) x (0.75) x (0.641)) +
((20 g/hr) x (0.25) x (0.359)) +
((22 g/hr) x (0.75) x (0.359)) =
(1.92 g/hr + 7.21 g/hr + 1.78 g/hr + 5.92 g/hr) =
16.83 g/hr

Note that it is also possible to mathematically adjust the emissions factors calculations for different ratios of rail vs. ship activities.

Example Calculation of Fuel Economy

Fuel consumption from medium-heavy duty rail: 0.75 gal/hr
Fuel consumption from medium-heavy duty ship: 1.0 gal/hr
Fuel consumption from heavy-heavy duty rail: 2.0 gal/hr
Fuel consumption from heavy-heavy duty ship: 2.2 gal/hr

Fuel Economy =

$((\text{fuel}_{\text{medium-heavy rail}}) \times (\%_{\text{rail}}) \times (\%_{\text{medium-heavy}})) +$
$((\text{fuel}_{\text{medium-heavy ship}}) \times (\%_{\text{ship}}) \times (\%_{\text{medium-heavy}})) +$
$((\text{fuel}_{\text{heavy-heavy rail}}) \times (\%_{\text{rail}}) \times (\%_{\text{heavy-heavy}})) +$
$((\text{fuel}_{\text{heavy-heavy ship}}) \times (\%_{\text{ship}}) \times (\%_{\text{heavy-heavy}})) =$
((0.75 gal/hr) x (0.25) x (0.641)) +
((1.0 gal/hr) x (0.75) x (0.641)) +
((2.0 gal/hr) x (0.25) x (0.359)) +
((2.2 gal/hr) x (0.75) x (0.359)) =
(0.12 gal/hr + 0.48 gal/hr + 0.18 gal/hr + 0.59 gal/hr) =
1.37 gal/hr

Note that it is also possible to mathematically adjust the fuel economy calculations for different ratios of rail vs. ship activities.

Appendix E

Specifications for UCR's Motored Chassis Dynamometer

From Mustang Publication "Project Spotlights" March 2010

Mustang Advanced Engineering delivers a newly designed 48" Electric AC Heavy-Duty Truck Chassis Dynamometer with dual, direct-connected 300-hp AC motors to The University of California - Riverside, College of Engineering - Center for Environmental Research and Technology (CE-CERT).

The science of measuring emissions from mobile and other sources has evolved significantly over the past several years. The most important changes in the nature of emissions measurement science has been a shift to examining emissions from diesel sources and to understanding emissions under in-use driving conditions.

The Bourns College of Engineering – Center for Environmental Research and Technology (CE-CERT) at The University of California Riverside has recently installed a heavy-duty tandem axle truck chassis dynamometer in the facility's research area. Designed and manufactured by Mustang Advanced Engineering, the development of this chassis dynamometer design was based on targeting vehicles in the medium to heavy-duty diesel vehicle range. Heavy-duty applications that can be tested at the facility include on-highway trucks, buses, waste haulers, yard tractors, and more - under test conditions representative of their specific in-use operations. The facility couples the new heavy-duty chassis dynamometer from Mustang Advanced Engineering with CE-CERT's Mobile Emissions Laboratory (MEL), to perform precise vehicle simulation and in-operation emissions measurements.

The first research conducted on the new facility will be a comparison of federally mandated diesel fuel formulas versus the stricter formulation required in California. The program calls for 10 heavy-duty trucks to be tested with several different fuels.

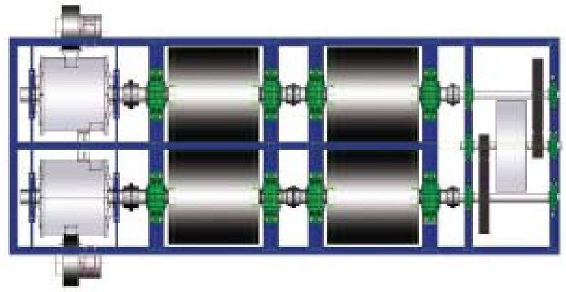
The new dynamometer will simulate on-road driving conditions for any big rig using its 48" precision rollers with dual, direct connected, 300 horsepower motors attached to each roll set. The dynamometer applies the appropriate loading to a vehicle to simulate factors such as the friction of the roadway and wind resistance that it would experience under typical driving conditions. An additional large inertia weight was incorporated into the dynamometer to increase the base mechanical inertia and enable the dynamometer to provide precise on-road simulation for a wide range of vehicle weights. The driver accelerates and decelerates according to a driving trace which specifies the speed and time over a wide range of vehicle simulation cycles. As the on-road driving conditions are being simulated on the dynamometer, emissions measurements will be collected with CE-CERT's Mobile Emissions Laboratory (MEL).

"This adds new capabilities in California that are only available at a limited number of facilities around the country," said Tom Durbin, who with J. Wayne Miller, are the principle investigators for the project. At both the state and federal levels, scientific requirements for emissions testing are trending away from steady state engine testing in favor of transient conditions found in typical driving, Durbin explained. "This addition will significantly expand our laboratory and measurement capabilities and help us continue our role as leading experts in the field of emissions research," said CE-CERT Director Matthew Barth.

CE-CERT's new heavy-duty chassis dynamometer will allow the testing of a variety of heavy vehicles under loaded and transient in-use conditions with corresponding emissions measurements. The dynamometer configuration is capable of meeting the inertia simulation range requirements of 10,000 to 80,000 lb for each of the cycles listed below. This includes acceleration rates up-to 6 mph/sec, as found in the UDDS Section D Drive Schedule and deceleration rates of up to 7 mph/sec as required for the WHM Refuse Drive Schedule. The dynamometer can also provide a load in excess of 600 HP @ 70 mph. The dynamometer also has the ability to continuously handle 200 Hp @ 15 mph for applications such as yard tractors.

The Dynamometer system is designed to meet the Heavy Duty Drive Schedules for diesel trucks in the weight range of 10,000 to 80,000 lb with acceleration rates for the following cycles:

- CARB HHDDT Cruise Mode Drive Schedule
- UDDS (Urban Dynamometer Drive Schedule)
- CARB 50 mph HHDDT Cruise Cycle
- HHDDT Transient Mode Drive Schedule
- WHM Refuse Drive Schedule
- Bus cycles such as, the CBD, OC Bus cycle, NY bus cycle
- In-use cycles for applications such as yard tractors.



"As part of our strategic plan, Mustang has developed a cost effective series of diesel, petroleum and hybrid certification grade dynamometer systems to address the needs of the global emissions and R&D market. There is a clear and present demand for a full performance cost effective dynamometer systems that offer all of the capabilities and confidence of a certification system at a price point that makes it no longer cost-prohibitive for organization to perform critical emissions studies, hybrid system calibration development, performance evaluation and other cutting edge research technologies. Researchers are in need of dynamometer systems to develop the next generation technologies which mimic the capabilities of the certification requirements, but at a fraction of the cost of a true certification system. That is what we are developing with this series of dynamometers and universities are lining up for them", said Executive Vice President, Donald Ganzhorn.

Appendix F

Summarized emissions, ambient, engine and chassis dyno data

					Chassis Dyno Information				ECM Data				
File Name	Comment	Trace	Vehicle	Mode	ave speed	max speed	dist	drum load	Load%	Pos%	Boost_kPa	Intake_F	Coolant_F
201010050800	okay	YT_26k_18mph	hybrid YT	hybrid	5.05	18.8	1.69	2.8	25.8	16.7	10.0	104	190
201010050833	okay	YT_26k_18mph	hybrid YT	hybrid	5.02	19.3	1.69	2.6	27.0	17.2	10.4	105	190
201010050909	okay	YT_26k_18mph	hybrid YT	hybrid	4.99	18.9	1.68	2.6	26.1	17.8	9.8	106	190
201010051015	okay	YT_72k_18mph	hybrid YT	hybrid	6.94	18.9	2.32	13.3	30.8	28.0	17.8	109	191
201010051046	okay	YT_72k_18mph	hybrid YT	hybrid	6.94	18.9	2.32	13.2	30.5	27.8	18.4	112	191
201010051120	okay	YT_72k_18mph	hybrid YT	hybrid	6.84	18.6	2.29	14.2	31.3	28.4	18.5	112	191
201010051307	okay	YT_72k_18mph	hybrid YT	diesel	7.21	19.8	2.41	12.7	30.4	21.2	21.7	115	191
201010051338	okay	YT_72k_24mph	hybrid YT	diesel	7.48	22.2	2.50	13.4	30.7	21.5	21.7	113	191
201010070739	okay	YT_26k_18mph	diesel YT	diesel	5.05	18.9	1.69	2.3	24.5	11.2	9.1	99	193
201010070810	okay	YT_26k_18mph	diesel YT	diesel	5.11	19.5	1.71	2.2	25.3	12.4	9.9	103	193
201010070842	okay	YT_26k_18mph	diesel YT	diesel	5.06	18.7	1.70	2.4	25.3	11.1	10.0	108	193
201010070950	okay	YT_72k_18mph	diesel YT	diesel	6.99	19.3	2.34	13.5	28.7	21.6	19.3	109	194
201010071319	okay	YT_72k_18mph	diesel YT	diesel					28.3	20.7	20.2	114	194
201010071350	okay	YT_72k_18mph	diesel YT	diesel	6.96	19.1	2.32	13.8	28.1	20.2	20.3	114	194
201010080713	okay	YT_72k_24mph	diesel YT	diesel	7.09	22.0	2.37	14.0	29.1	20.9	20.7	95	193
201010071052	regen	YT_72k_18mph	diesel YT	diesel					35.3	23.3	17.6	105	194
201010071020	regen	YT_72k_18mph	diesel YT	diesel	7.16	19.0	2.39	14.0	33.2	22.1	16.9	104	194

	Battery SOC		Emissions g/cycle							NO_CO2 ratio	Carbon Balance	
File Name	SOC i	SOC f	THC	CH4	NMHC	CO	NOx	CO2	PM	gNOx/kgCO2	gfuel emis	gfuel ECM
201010050800	65.5	72.0	0.23	0.07	0.16	0.14	22.3	4.38	0.003	5.09	1382	1386
201010050833	68.0	72.0	0.34	0.07	0.27	0.24	20.8	4.53	0.016	4.59	1431	1441
201010050909	65.5	72.0	0.39	0.08	0.32	0.41	22.3	4.40	0.013	5.06	1388	1400
201010051015	73.5	72.5	0.17	0.08	0.09	0.26	29.8	6.71	0.010	4.44	2117	2131
201010051046	72.5	72.5	0.13	0.05	0.08	0.08	30.1	6.67	0.006	4.52	2104	2138
201010051120	72.0	72.0	0.16	0.09	0.08	0.16	30.2	6.79	0.008	4.45	2144	2165
201010051307	n/a	n/a	0.14	0.10	0.05	0.45	25.9	7.20	0.004	3.59	2273	2209
201010051338	n/a	n/a	0.14	0.08	0.06	0.25	25.8	7.26	0.005	3.55	2291	2230
201010070739	n/a	n/a	0.50	0.07	0.44	0.34	22.3	4.06	0.000	5.49	1281	1306
201010070810	n/a	n/a	0.41	0.06	0.36	0.13	22.7	4.17	0.012	5.44	1316	1335
201010070842	n/a	n/a	0.32	0.05	0.28	0.31	22.6	4.06	0.003	5.56	1282	1321
201010070950	n/a	n/a	0.20	0.06	0.14	0.32	33.1	6.90	0.002	4.80	2177	2120
201010071319	n/a	n/a	0.16	0.08	0.09	0.40	32.5	6.90	0.011	4.71	2177	2128
201010071350	n/a	n/a	0.19	0.10	0.09	0.12	32.0	6.85	0.005	4.67	2161	2102
201010080713	n/a	n/a	0.23	0.08	0.16	0.23	28.2	7.13	0.000	3.95	2249	2224
201010071052	n/a	n/a	2.36	0.98	1.44	6.65	37.3	10.24	0.031	3.64	3239	3400
201010071020	n/a	n/a	0.77	0.33	0.46	0.26	36.0	8.76	0.093	4.11	2767	2850

APPENDIX I

Potential Funding Sources
Grants, Incentives, and Tax Credits

APPENDIX I
Potential Funding Sources
Grants, Incentives, and Tax Credit Programs

There are several potential funding sources for hybrid yard hostlers in California. In general, these programs require proposed projects to provide verified emissions reductions above and beyond what is required by regulations. Each of the possible programs has different rules and guidelines that are subject to change.

AB 118 Air Quality Improvement Program

There will be approximately $2 million available for demonstration projects for agricultural and off-road equipment through the California Air Resources Board's (CARB) Air Quality Improvement Program (AQIP) in FY 2010-2011.

While this funding cycle will be focused on hybrid construction equipment, it does signal a willingness on CARB's part to look at off-road incentives in future years. Furthermore, CARB has indicated that the purpose of this demonstration project is to "lay the groundwork for a potential hybrid off-road equipment voucher project in future AQIP funding years." The specifics of this future voucher project are not clear at this time, and a hybrid yard hostler may or may not qualify. The success of the on-road Hybrid Truck and Bus Voucher Program (HVIP) may lead CARB to develop similar off-road and agricultural programs.

The AB 118 AQIP program is funded through 2015. Funding plans are different year to year, and staff may choose to focus additional attention on the off-road sector in future funding plans.

Carl Moyer Memorial Air Quality Standards Attainment Program

The Carl Moyer Program provides funding for cleaner-than-required engines and other equipment. Emissions must be real, surplus, quantifiable, and enforceable. Funded projects cannot be required by any federal, state, or local regulation. Opportunities are therefore limited by existing regulations, especially for CHE. As mentioned above, the current performance of the prototype hybrid yard hostlers would not qualify them for Moyer funding.

CARB is in the process of "retooling" the Carl Moyer program. Information on the retooling effort, along with DRAFT versions of the guidelines to be considered, can be found on CARB's Moyer Retooling website (http://www.arb.ca.gov/msprog/moyer/retooling.htm)

Within the guidelines set by CARB, Carl Moyer funds are controlled by local air districts. Information on the South Coast Air Quality Management District's Moyer funding can be found at the South Coast AQMD website: (http://www.aqmd.gov/tao/Implementation/carl_moyer_program_2001.html).

Proposition 1B Goods Movement Emission Reduction Program

In November 2006, the people of California approved Proposition 1B, the Highway Safety, Traffic Reduction, Air Quality and Port Security Bond Act of 2006.[1] Proposition 1B includes $1 billion in funding for projects to reduce emissions associated with goods movement through California ports. Proposition

[1] Proposition 1B, Highway Safety, Traffic Reduction, Air Quality and Port Security Bond Act of 2006, November 6, 2007, www.sos.ca.gov/elections/vig_06/general_06/pdf/proposition_1b/entire_prop1b.pdf.

1B is similar to AB 118 in that it does not specifically allocate money for individual projects, however the availability of funding could have a positive impact on the demand for hybrid yard hostlers.

$100 million of the Proposition 1B funding is intended to be used for Shore Power for Cargo Ships at Berth, and Cargo Handling Equipment. The current guidelines allow partial funding of up to the lower of 50% of the eligible cost or $50,000/truck to replace a yard truck equipped with a model year 2004-2006 off-road diesel engine with a new electric or zero-emission yard truck. A hybrid truck would therefore not qualify under the current guidelines.

Like the Carl Moyer program, Proposition 1B funds are managed by local air districts. Information on the South Coast Air Quality Management District's programs can be found on their website (http://www.aqmd.gov/tao/Implementation/Prop1B.htm).

Off-road Hybrid Vehicle Tax Credits

Currently there are no tax credits available for off-road hybrid vehicles. The focus of policy-makers has been on-road vehicles. There is little indication this will change.

APPENDIX J

Regulatory and Policy Considerations

APPENDIX J
Regulatory and Policy Considerations

Summaries of current legislation and policies which may have an impact on the market for hybrid yard hostlers either directly or indirectly are provided herein.

San Pedro Bay Ports Clean Air Action Plan

In November, 2006, POLB and POLA jointly released the San Pedro Bay Ports Clean Air Action Plan (CAAP).[1] The CAAP describes the goals and measures that POLB and POLA will take to significantly reduce emissions related to port operations during the five year period ending in 2011. Section 5.3 of the CAAP Technical Report describes CHE control measures. Control Measure SPBP-CHE1, Performance Standards for CHE, specifies that beginning in 2007, all new CHE purchases (including yard hostlers) must meet the cleanest available NOx alternative fuel or diesel fuel engine with PM emissions of 0.01 grams per break horsepower-hour (g/bhp-hr) or better. From a practical point of view, this means that new yard hostlers must have either a 2007 on-road natural gas or 2007 on-road diesel engine. Furthermore, by the end of 2010, all yard hostlers must either meet 2007 on-road engine standards or Tier 4 off-road engine standards. On November 22, 2010, an updated version of the Clean Air Action Plan was approved, which maintained the same standards for cargo handling equipment.

Clearly one of the intents of this measure is to encourage the usage of cleaner CHE such as hybrid yard hostlers. However the extent to which the control measure actually results in an increased demand for hybrid yard hostlers is highly dependent on the incremental cost of the hybrid yard hostlers. The CAAP does not currently provide any buy-down or incentive funds for the hybrid yard hostlers. It is unlikely that the business case for hybrid yard hostlers alone will spur a significant increase in hybrid yard hostler usage since the life cycle cost of the hybrid yard hostler is much greater than the baseline vehicle.

CARB Cargo Handling Equipment Regulations

In December 2006, CARB adopted regulations for mobile CHE at ports and intermodal rail yards.[2] The purpose of the regulations is to reduce PM and other criteria pollutant emissions from diesel CHE operating at ports and intermodal rail yards in California. The regulations require that all yard hostlers purchased after January 1, 2007 and operated in California ports or intermodal rail yards include either an on-road certified engine meeting the emissions requirements of the year it was purchased, or meet Tier 4 off-road emissions standards. The regulations also require that yard hostler fleet operators begin phasing out an increasing percentage of their older (pre-2007) yard hostlers according to a compliance schedule commencing in 2008. Yard hostler fleet operators can comply with the regulations by using advanced technologies such as the hybrid drive system but this is not required. Therefore by themselves, the CARB regulations are not expected to spur a significant increase in hybrid yard hostler demand.

California Assembly Bill 118 – Alternative Fuels and Vehicle Technologies Bill

Please see Appendix I for a discussion of how AB118 could influence funding for hybrid yard hostlers.

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[1] San Pedro Bay Ports – Clean Air Action Plan (http://www.cleanairactionplan.org)

[2] California Air Resources Board Final Regulation Order, Regulation for Cargo Handling Equipment at Ports and Intermodal Railyards. (Amended, effective December 3, 2009).

In October 2007, the California state legislature adopted Assembly Bill 118 (AB 118), the Alternative Fuels and Vehicle Technologies Bill.[3] AB 118 authorizes $200M in combined annual funding for the California Energy Commission and CARB to support clean vehicles and fuels in California through 2015; total funding will therefore be $1.5 billion. The primary goals of the bill are to help reduce GHG emissions, smog and reduce California's dependence on oil. While AB 118 does not specifically allocate money for individual projects, there are no restrictions that would prevent the funds from being used to support projects involving hybrid yard hostlers. Given the large amounts of funding available and the focus on reducing port emissions in California, it is not unreasonable to expect that some of the AB 118 funding could be allocated to port projects involving CHE such as hybrid yard hostlers. In fact, given the reductions in CO_2 emissions (CO_2 is one of the primary GHGs contributing to climate change) and oil consumption associated with hybrid yard hostlers compared to the vehicles they replace, hybrid yard hostlers may be considered a good candidate for AB 118 funding. In general, the availability of AB 118 funding could have a positive impact on the demand for hybrid yard hostlers; however the magnitude of that potential impact is not quantifiable at this time.

[3] AB 118, Alternative Fuels and Vehicle Technologies Bill, Nunez, October, 2007.