Pluggable Hybrid Electric Terminal Truck (PHETT™) Demonstration at the Port of Los Angeles

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Technical Report: Fuel Consumption and Emissions Estimates

FINAL

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The Port of Los Angeles

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Executive Summary

The Port of Los Angeles, in conjunction with Capacity and Yusen Terminals, Inc. (YTI), conducted a three-week field trial of the Capacity PHETT™ at the YTI terminal from December 8th to December 29th, 2009. The goal of this project was to evaluate the performance and emissions of the Capacity Pluggable Hybrid Electric Terminal Truck (PHETT) in operation at the Port of Los Angeles. Testing included an assessment of the PHETT's™ fuel economy; a characterization of its load factors; and a review of the host site personnel's opinions regarding operation.

This test consisted of simultaneous operation of a diesel terminal tractor and the PHETT™. Both tractors were equipped with a multi-channeled data logging system to record available data on the vehicle communications bus. Fuel use and operating time information were recorded and supplied by YTI. TIAX then estimated the fuel economy and emissions of both the PHETT™ and the baseline diesel terminal tractor. Additionally, TIAX reviewed the results of operator surveys administered by YTI to assess the overall capability and performance of the PHETT™.

Key findings in this report are:

- The load factor for the PHETT™ was determined by measuring the diesel generator output over the entire operating time of the PHETT™. During the demonstration period, the PHETT™ load factor was calculated to be 0.54; equivalent to an average engine load of 21.7 horsepower.

- Based on the CARB OFFROAD 2007 methodology, the PHETT™ is expected to achieve:
  1. A 44% reduction in NOx, 56% reduction in PM, and a 53% reduction in CO compared to a 2009 diesel yard tractor using a CARB-approved load factor.
  2. Emissions rates that are comparable to the 2009 diesel yard tractor tested in this demonstration.
- Fuel economy improvements were estimated to be 34% over the baseline fleet.
- Survey data from the vehicle operators involved with the PHETT™ demonstration were very positive and indicated no significant problems with the PHETT™ and comparable or better performance to diesel yard tractors.

1. Introduction / Test Program Objective

Terminal tractors (also known as utility tractor rigs, yard hostlers, drayage trucks, and yard goats) are categorized as cargo handling equipment[1] (CHE) -- one of five major types of diesel-powered equipment commonly used to move cargo at sea ports. Terminal tractors are primarily off-road vehicles that are specifically used to move cargo containers within and around terminals in three applications: 1) to and from cargo ships (ship work), 2) to and from cargo trains (rail work), and 3) within terminal yards (yard work).

Terminal tractors and other types of CHE are essential elements of the goods movement infrastructure. However, they also consume large volumes of diesel fuel and generate significant levels of harmful diesel emissions within the ports they serve. Development and deployment of low-emissions, high-efficiency terminal tractors (and other CHE) are high priorities for the Port of Los Angeles under its Clean Air Action Plan.

In response to the need for environmentally friendly yard hostlers, Capacity of Texas, Inc. has developed and is now testing its Pluggable Hybrid Electric Terminal Tractor (PHETT™). According to Capacity, this diesel-electric hybrid terminal tractor (see Figure 1) is a "charge sustaining series hybrid that utilizes a constant and efficient rate generator to supply power, reducing fuel consumption by 60 percent and audible db by 30 percent."[2]

The Port of Los Angeles, in conjunction with YTI, conducted a three-week field trial of the PHETT™ from December 8th to December 29th, 2009. The Port tasked TIAX with helping to plan and oversee this testing, with the objective of evaluating certain elements of the PHETT's™ performance. To make as accurate comparison as possible, within the constraints of the demonstration, this evaluation was conducted relative to conventional diesel-fueled terminal tractor operated in parallel with the PHETT™ during the demonstration period. The testing included an assessment of the PHETT's™ fuel economy; a characterization of its load factors; and a review of the host site personnel's opinions regarding operation.

[1] Other types of cargo handing equipment include cranes, top handlers, side handlers, forklifts and loaders.

[2] Capacity News Release. March 18, 2009. "Capacity Launches Pluggable Hybrid Electric Terminal Tractor"

Figure 1. PHETT™ and diesel terminal tractor in YTI bay

2. Test Methodology

The PHETT™ is a diesel-electric plug-in hybrid terminal tractor that uses a small diesel generator and a large lead-acid battery pack to provide power for vehicle operation. Table 1 summarizes the PHETT™'s powertrain specifications. As a plug-in hybrid, the PHETT™ offers a modest all-electric range and higher overall efficiency, which can significantly reduce fuel consumption and emissions compared to a conventional diesel-fueled terminal tractor. To estimate these potential environmental benefits relative to the conventional (baseline) counterpart, TIAX developed a test plan. A conventional diesel terminal tractor and the PHETT™ were placed into "ship service" (moving containers from ship cranes to the container stacks on the terminal) during the demonstration period, providing a reasonable "apples to apples" comparison within the constraints of the demonstration period. Both terminal tractors were equipped with a multi-channel data logging system to record operational data from the vehicle Engine Control Unit (ECU). Additionally, YTI recorded daily fuel consumption and chassis hour meter data. Based on this data, TIAX was able to estimate the fuel economy of the PHETT™ and compare it to the baseline diesel terminal tractor with respect to average fuel economy and emissions. Additionally, YTI managers administered surveys to operators to assess the overall capability of the PHETT™ as compared to a traditional diesel terminal tractor.

Table 1. Test Vehicles powertrain specifications

Feature	Diesel UTR	PHETT
Make/Model	Ottawa C50	Capacity PHETT
Unit Number	H221	-
Gross Combined Weight Rating	130,000 lbs	130,000 lbs
Hybrid Configuration	N/A	Charge sustaining
All-electric Operation	N/A	All electric operation while in battery mode
On-board generator	N/A	Cummins Onan diesel, 40 HP, Tier 4i emissions
Traction Motor	Cummins ISB07, 240 HP/ 620 ft.lb @1600 RPM	225 HP, 3 phase AC
Diesel Fuel Capacity	50 gallons	40 gallons
Battery Type	N/A	Lead Acid
Battery Capacity	N/A	65 kW-hr @ C/8 rate

2.1 Duty Cycle and Load Factor

The California Air Resources Board (CARB) estimates emissions from off-road equipment through its OFFROAD model. To estimate emissions from a particular equipment group, such as yard tractors, the model makes certain assumptions about how the equipment is typically operated. An important parameter in the model is the equipment's load factor, which is defined as the "average operation level in a given application as a percent of the engine manufacturer's maximum horsepower rating."[3] In other words, load factor is the engine's average horsepower divided by its maximum horsepower.

In December, 2008, the Port of Long Beach and the Port of Los Angeles released the "San Pedro Bay Ports Yard Tractor Load Factor Study Addendum."[4] The purpose of the study addendum was to determine if the average load factors used by CARB reasonably represent the activity of conventional diesel ICE yard tractors at the Port of Long Beach and the Port of Los Angeles. The study determined that CARB's load factor of 65% is too high for yard tractors typically used at the two ports. A revised load factor of 39% was proposed and eventually approved by CARB.

To determine the load factor for a non-conventional yard tractor like the PHETT™, it is important to consider the operation of the series hybrid drive system with plug-in capability. To actuate the electric drive system, the PHETT™ can draw power simultaneously from the diesel generator and the energy stored in the batteries from grid charging. To remain consistent with CARB's definition of load factor, the energy produced by the diesel generator must be separated from the total energy used by the vehicle in operation. Based on information provided by Capacity and previous testing of the PHETT, it is known that the diesel generator runs at near maximum load whenever it is operating. Using this information in conjunction with separate chassis and generator hour meter data collected over 21 days, the relative contribution of the energy produced by the diesel generator to the total energy used by the PHETT™ over the course of the demonstration was determined.

2.2 Fuel Economy

Determination of the fuel economy for the PHETT™ requires recording or estimating both the volume of diesel fuel consumed and the vehicle operating time. Because terminal tractor operational parameters are generally measured in hours of operation rather than miles traveled, energy per hour is an appropriate measure of terminal tractor activity and allows comparison on a fuel-equivalent basis.

Diesel fuel use was tracked by YTI staff using special terminal tractor refueling logs created for this project. Each morning, prior to the beginning of the shift, gearmen would top off the fuel tanks and record the current chassis hour meter reading for both the PHETT™ and the diesel. The fueling logs provide a daily accounting of the fuel consumed during the previous day as well as the chassis hour meter reading at the end of the shift.

[3] California Air Resources Board, Technical Mailout MSC# 99-32, 1999

[4] San Pedro Bay Ports Yard Tractor Load Factor Study Addendum, Starcrest LLC, 2008

2.3 Operator Acceptance

In addition to estimating the duty cycle and fuel economy of the PHETT™, an objective of this abbreviated testing program was to assess the overall capability of the PHETT™ in terminal service, and its acceptance by host fleet personnel compared to conventional diesel-fueled tractors. To make a fair comparison of fuel economy and emissions between the two technologies, the PHETT™ must be capable of performing the same work as a typical, comparable conventional terminal tractor. TIAX reviewed and approved a standard operator survey used by YTI in previous yard tractor demonstration projects. YTI then administered the survey at the end of each shift to the operator who worked with the PHETT™ during that shift. The survey asked respondents to rate the PHETT™ in several key areas of design and performance as "Better, Same, or Worse" compared to a standard, comparable diesel terminal tractor. Additionally, the survey provides a free-response section for additional comments. A copy of the survey is provided in Appendix B.

3. Experimental Setup

3.1 PHETT™ Configuration

The PHETT™ operates as a series diesel-electric hybrid. In this configuration, all of the energy demands of the vehicle are supplied through the battery; regardless of whether the energy is stored in the battery by a grid-connected charger or the on-board diesel generator[5]. Given a fully charged battery, the PHETT™ will operate entirely from battery power, providing a limited "all-electric range" with zero tailpipe emissions. Once the battery has been depleted to a predetermined state of charge, the diesel generator will start and attempt to sustain the current level of charge in the battery.

There are three electrical inverters that are used to supply the vehicle subsystems with power. The inverters convert the DC voltage of the battery pack into AC voltage that is better suited to operate the numerous AC electrical motors in the PHETT™. The three electrical inverters are:

1. Traction Motor Inverter – provides power to the drive motor for propulsion. Nominally rated at 150 kW.

2. Hydraulics Inverter – provides power to the hydraulic pump. Hydraulics are used primarily for operation of the fifth wheel that connects to the container chassis. Nominally rated at 15 kW.

3. Cooling Fan Inverter – provides power to the cooling fan; used to dissipate heat from the inverters and other subsystems. Nominally rated at 1.5 kW.

Additionally, several systems on the vehicle use a 12VDC auxiliary power supply including the safety light, radios, and cabin HVAC fan. Capacity estimates a fixed power draw of 500 watts, assumed to be constant while the vehicle is in use.

To record when the vehicle was in use, the ignition system voltage was monitored. Specifically, certain accessory systems are only powered when the ignition switch is in the "Run" position. By monitoring when these systems are powered, the position of the key can be determined and, by extension, whether or not the vehicle was in operation.

[5] Capacity uses the Cummins Onan 20HDKAW-2008A. Datasheet available at http://www.cumminsonan.com/www/pdf/specsheets/a-1538.pdf

3.2 Data Logging Equipment

To support this study, TIAX (on the Port's behalf) purchased a J1939 capable AVIT[6] data logger with analog inputs and the associated DAWN software package from HEM Data[7]. A second, identical logger was provided on loan from the Port of Long Beach. These data loggers are capable of simultaneously recording engine operating parameters from J1939 compatible vehicles along with analog signals that can be used to control the data logger. To interface each data logger to the vehicle and provide for long term data logging, several additional hardware changes were required and are shown in Figure 2. These changes included the following:

1. Addition of a 55 amp-hour rechargeable deep cycle battery. Required to ensure the data logger energy demand did not affect the PHETT's propulsion battery systems.

2. Custom cable to interface the analog signal wires on the PHETT™ with the serial port connector on the data logger.

3. Extended J1939 cable to allow the logger to be appropriately positioned on the vehicle.

4. Hard case to protect the data logger during the extended field deployment.

Figure 2. AVIT Data Logger with Added Equipment

[6] http://www.drewtech.com/products/avit.html

[7] http://hemdata.com/products/dawn

The data logger also includes a voltage input that will place the logger into a low power "sleep" mode when the voltage signal drops below a certain threshold. This input was connected to the vehicle ignition circuit so that the logger would enter sleep mode when the key to the vehicle was turned to the off position. The battery pack is required for proper operation of the logger because the logger will lose data if power is disconnected before it is sent a shutdown command.

3.3 Test Parameters

During the three week demonstration, the PHETT™ and a diesel UTR were operated by YTI in ship loading/unloading service. Table 2 summarizes the test parameters that were recorded while the terminal tractors were in operation. The test plan originally anticipated that the PHETT™ would be equipped with analog signal connections that would allow TIAX to monitor the power output of the individual electrical subsystems. These connections were not available for the demonstration. J1939 data were also not recorded from the PHETT™ due to the PHETT's partial implementation of the J1939 standard. However, neither the lack of J1939 data nor electrical subsystem data had any significant impact on the analysis of the PHETT™ load factor or fuel economy; as TIAX was able to determine the load factor from generator and chassis hour meter data.

Table 2. Test parameters

Test Parameter	Source	Purpose
Vehicle data	Data logger	Measure duty cycle, energy splits
Fuel use	Terminal fueling logs	Record total fuel consumption
Hours of operation	Terminal service/operations logs	Determine rate of fuel consumption
Vehicle performance*	Operator surveys	Assess overall vehicle capability

*PHETT™ only

4. Results

Data were recovered from both data loggers on three occasions during the demonstration period. TIAX inspected the data loggers twice while the demonstration was in progress and downloaded all available data. All remaining data were recovered at the end of the test when the data logger was removed from the PHETT™ and diesel terminal tractor.

4.1 Duty Cycle and Load Factor Measurements

Duty cycle and load factor were calculated for the PHETT™ and compared to CARB approved load factors for diesel terminal tractors as well as the load factor calculated from engine torque and engine speed data for the diesel terminal tractor, recorded by the data logger.

4.1.1 PHETT™ Duty Cycle and Load Factor Calculations

The design of the PHETT™ hybrid control system requires the diesel generator to run at close to maximum electrical power output whenever the generator is operating. During a previous demonstration of the PHETT, TIAX calculated the average diesel generator electrical output was 18.44 kW, or 92.2% of the rated 20kW output. Discussions with Capacity support this estimate and allow TIAX to calculate the load on the diesel generator's engine.

Once the average power produced by the generator is known, the average load on the generator can be calculated from the following equation:

$$EngineLoad_{Average} = P_{electric} * \frac{1}{\eta_{electric}} * \frac{T_{genset}}{T_{Vehicle}}$$

Figure 3. Equation to calculate Average Engine Load of PHETT™

Where:
$EngineLoad_{Average}$ is the average engine load in kW
$P_{electric}$ is the average power produced by the diesel generator
$\eta_{electric}$ is the mechanical-to-electrical conversion efficiency of the diesel generator's alternator
T_{genset} is the total operating time of the diesel generator
$T_{Vehicle}$ is the total operating time of the vehicle

The average power produced by the generator is taken as 18.44 kW as described above. Using an estimated 83% alternator efficiency[8], a generator operating time of 44.3 hours,

[8] Estimate provided by Capacity engineers, based on conversations with Cummins.

and a vehicle operating time of 60.9 hours, the average engine load is 16.16 kW or 21.66 HP.

Once the average engine load is known, it is straightforward to calculate the load factor. As described in Section 2.1, load factor is determined by the following equation:

$$LoadFactor = \frac{Load_{Average}}{Load_{Maximum}}$$

Figure 4. Definition of Load Factor

The PHETT™'s diesel generator is rated for a maximum load of 40 HP. An average load of 21.66 HP results in a calculated load factor of 0.54.

Based on the collected data, it is also possible to determine the amount of time the PHETT™ operated in all-electric mode and charge-sustaining mode (generator operating). While the impact of all-electric operation on emissions is captured in the load factor, knowing the relative amount of time in all-electric mode may be of interest in future assessments of all-electric drayage truck designs. This information is summarized in Table 3 below.

Table 3. Summary of duty cycle and load factor data

Parameter	Units	Value	Notes
Vehicle Operating Time	Hours	60.9	Total ignition-on time
Generator Operating Time (Charge-sustaining)	Hours	44.3	Total time the generator operated
All-Electric Operating Time	Hours	16.6	Total Generator-off time
Charge-Sustaining Operation	%	72.7	
All-Electric Operation	%	27.3	
Average Generator Load (Generator-on Only)	kW	18.4	Average electrical load based on time generator was running
Average Generator Load (Ignition-on)	kW	13.4	Average electrical load based on total vehicle operating time
Alternator Efficiency	%	83	
Load Factor	--	0.54	

4.1.2 Diesel Terminal Tractor Duty Cycle and Load Factor Calculations

Data recorded from the J1939 bus of the diesel terminal tractor include the percentage of maximum engine torque and the engine speed. If engine torque and speed are known, engine load can be calculated from the following equation:

$$EngineLoad_{Average} = \frac{\sum_{i=1}^{n} \tau_{i,engine} * \omega_{i,engine}}{n}$$

Figure 5. Equation to calculate Average Engine Load of diesel terminal tractor

Where:
$EngineLoad_{Average}$ is the average engine load in kW
$\tau_{i,engine}$ is the instantaneous engine torque
$\omega_{i,engine}$ is the instantaneous engine speed
n is the total number of data points

Based on the 160,274 data points collected at 1Hz from the J1939 bus, the average engine load is estimated to be 33.8 HP. Load factor is calculated as given in Figure 4. Using the rated maximum of 240 HP for the diesel UTR, the load factor is calculated to be 0.14. This load factor is far less than the currently accepted 0.39 used by CARB. However, recent reviews of load factor data from the joint Port of Los Angeles and Port of Long Beach Load Factor Study[9] suggest that the average load factor for the fleet is approximately 0.20. This would be in much better agreement with the current test data. It is also important to note that the current test data are for a single terminal tractor in ship loading/unloading service only. Therefore, the current test data cannot be considered representative of the entire terminal tractor fleet.

4.2 Fuel Economy Estimates

Fuel economy improvement was determined by comparing the average fuel use rate for the PHETT™ to the diesel terminal tractor. Fuel rate, in gallons per hour, is the total fuel used divided by the vehicle's operating time. Ideally fuel usage data are obtained directly from the host fleet's fueling records over a substantial period of time. Due to the limited duration of the demonstration and available work at the YTI terminal, fuel use and operating time data were available for eight days for the diesel terminal tractor and ten days for the PHETT. Table 4 summarizes the fuel log data and calculated fuel use rates for both the diesel terminal tractor and the PHETT™. The PHETT™ achieved a 34% fuel economy improvement over the baseline diesel terminal tractor. Additionally, the calculated fuel rate of 1.89 gallons per hour for the diesel terminal tractor is nearly identical to the 1.9 gallons per hour fuel rate reported in the ports' Load Factor Study.

[9] San Pedro Bay Ports Yard Tractor Load Factor Study Addendum, Starcrest LLC, 2008

Table 4. Fuel economy data and comparisons

Record Date (Morning of)	Diesel UTR		PHETT	
	Fuel (gal)	Hour Meter	Fuel (gal)	Hour Meter
9-Dec		1361		35.8
10-Dec	5	1364	3	41
11-Dec	6.4	1367	10.1	45
12-Dec	16.9	1374	11	53
13-Dec	8.7	1380	7.5	58
14-Dec	10	1386	8.2	64
15-Dec		1386		64
16-Dec		1386	7	70.6
18-Dec	5.2	1389	2.7	73.3
24-Dec	14.4	1398	9.2	81.9
27-Dec	18.5	1406	12.2	91.7
29-Dec		1406	5.4	96.7
Subtotal	85.1	45	76.3	60.9
Avg. Fuel Rate (gal/hour)	1.89		1.25	
Fuel Rate (% of Baseline)	100%		66.3%	

Black bars indicate no data available

Based on the available data and calculations, the PHETT™ showed significant improvements in fuel economy compared to the existing diesel terminal tractor. This is in part due to the high levels of idle and low power operation measured in the current study, which is believed to be typical of yard tractor operation in general. Fuel economy improvements are partially offset by the relatively low thermal efficiency of the small generator motor compared to the larger diesel engines used to power the existing fleet.

4.3 Emissions Estimates

Using CARB's Offroad 2007 methodology, TIAX calculated estimates of the emissions from the PHETT™ and diesel terminal tractor based on the measured load factor reported in section 4.1. A complete description of the methodology is available in the CARB Technical Mailout MSC# 99-32. Emissions factors were calculated for three cases:

1. The baseline diesel terminal tractor as measured in this study
2. The PHETT™ as measured in this study
3. A yard tractor equipped with a 2009 diesel engine, using the CARB-approved load factor

Activity data are assumed to be the same in all three cases. This allows emissions comparisons to be made solely using the calculated emissions factors. Based on the CARB methodology, both the PHETT™ and the tested diesel terminal tractor are expected to produce significantly fewer NOx, PM and CO emissions compared to the CARB 2009 diesel baseline. The PHETT™ is also expected to produce the lowest PM emissions. NOx emissions from the PHETT™ may be somewhat higher than the tested diesel terminal tractor due to the diesel tractor's very low load factor and the higher emissions factors for small Tier 4i engines on a grams/bhp-hr basis. Also note that emissions from the baseline diesel tractor are estimated using Tier 3 off-road emissions factors given in the OFFROAD model, however, the baseline diesel tractor is equipped with an on-road certified engine and should have certified emissions factors lower than the Tier 3 standard. Table 5 summarizes the results of the emissions analysis and Figure 6 presents the results graphically.

Note that the CARB OFFROAD model does not generally include equipment with load factors as low as the load factor measured in the tested diesel yard tractor. Based on findings in the CRC E55/59 [10]work conducted by West Virginia University, the PHETT™ may emit significantly fewer emissions than the tested diesel yard tractor when accounting for the high levels of idle, creep, and transient operation indicated in the data.

Table 5. Comparison of estimated emissions rate for yard hostlers with different engine technologies

Engine	NOx Emissions	PM Emissions	CO Emissions	NOx Increase	PM Increase	CO Increase
	g/hr	g/hr	g/hr	above PHETT	above PHETT	above PHETT
PHETT™ (Tier 4i)	105.84	4.75	88.56	0.0%	0.0%	0.0%
Tested 2009 Diesel (Tier 3)	87.36	5.04	87.36	-17.5%	6.1%	-1.4%
CARB 2009 Diesel (Tier 3)	187.59	10.82	187.59	77.2%	127.7%	111.8%

[10] Clark, N.N., Gautam, M. et al, "Heavy-Duty Vehicle Chassis Dynamometer Testing for Emissions Inventory, Air Quality Modeling, Source Apportionment and Air Toxics Emissions Inventory" , Coordinating Research Council Report E55/59, August 2007.

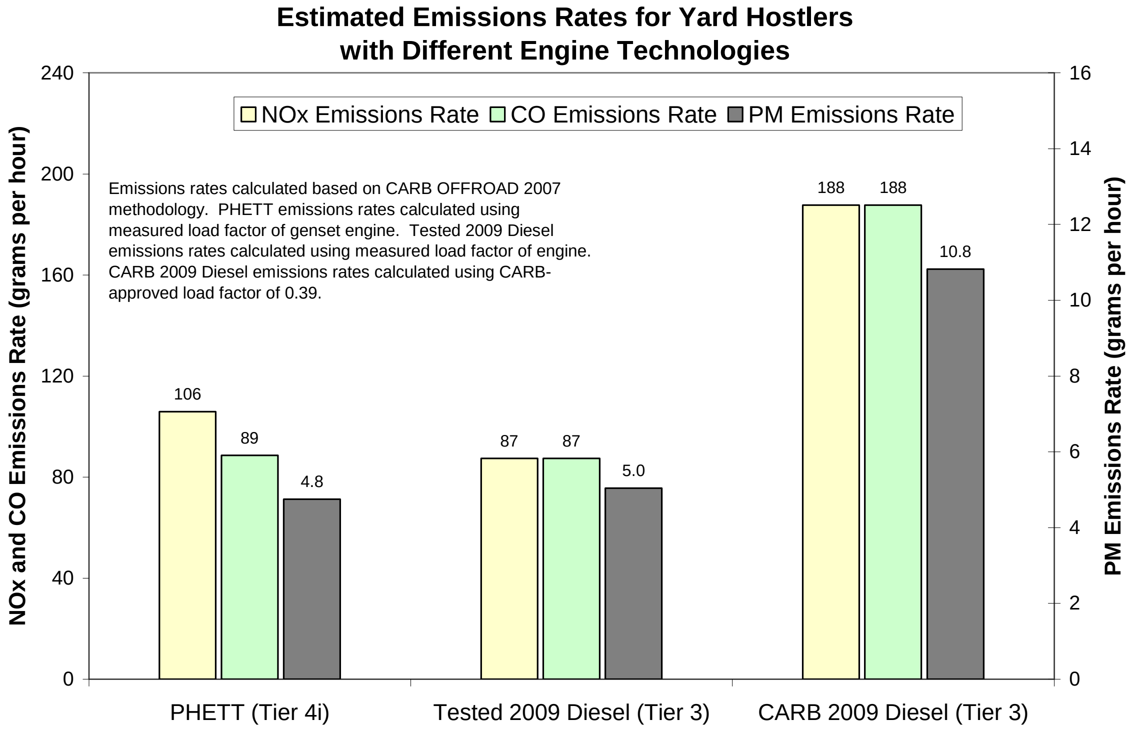

Figure 6. Comparison of estimated emissions rate for yard hostlers with different engine technologies

4.4 Operator Survey Results and Comments

YTI staff administered a performance survey to PHETT™ operators and the end of each shift. This survey asked operators to rank the PHETT™ as "Better Than", "Same As", or "Worse Than" a standard diesel terminal tractor. A copy of the survey is provided in Appendix B – Survey Form. Table 6 aggregates the results of the individual surveys. A total of 14 surveys were collected, with respondents answering all or some of the questions. Overall, the operators ranked the PHETT™ as better than a typical diesel terminal tractor. Pulling power and steering were noted as strong points. There were few complaints. However, of the complaints received the most common were low top speeds (approximately 20 mph) and narrow stairs for cab entry/exit.

Table 6. Operator Survey results

#	Performance Area	Respondents rating Performance Area as Better Than	Same As	Worse Than
1	Power: The ability to accelerate and move out effectively and safely.	4	10	0
2	Power Supply: Sufficient power to complete a shift without recharging.	8	3	0
3	Handling Characteristics: Smooth shifting on acceleration.	9	5	0
4	Turning radius: Ease of parking, negotiating tight places, and steering effort.	5	9	0
5	In-Cab Visibility: No blind spots, rear view.	4	7	1
6	Ride Comfort: Vibration and shocks, seat ergonomics.	9	5	0
7	In Cab Ergonomics: Controls gauges, switches conveniently placed, working smoothly.	7	6	0
8	Braking: Stops smoothly and evenly.	10	3	0
9	Noise Level: In-cab engine noise.	10	4	0
10	Ventilation: In-cab air circulation and comfort.	9	4	1
11	Ease of entry and exit from cab.	4	9	1
12	Overall Rating	10	3	0

Appendix A – Emissions Factors

Tested 2009 Diesel

Engine Year		**2009**	From YTI test vehicle
Engine Power	HP	**240**	From YTI test vehicle
Load Factor		**0.14**	From data logging results
Tier		**3**	From YTI test vehicle
NOx Emissions Factor	g/bh-hr (Zero hour)	**2.6**	http://www.arb.ca.gov/msprog/ordiesel/documents/PM_NOx_Emis_Factors.pdf
PM Emissions Factor	g/bh-hr (Zero hour)	**0.15**	http://www.arb.ca.gov/msprog/ordiesel/documents/PM_NOx_Emis_Factors.pdf
CO Emissions Factor	g/bh-hr (Zero hour)	**2.6**	http://www.arb.ca.gov/msprog/ordiesel/documents/Off-Road_Diesel_Stds.xls

PHETT™

Engine Year		**2009**	From PHETT™ data sheet
Engine Power	HP	**40**	From PHETT™ data sheet
Load Factor		**0.54**	From data logging results
Tier		**4i**	From PHETT™ data sheet
NOx Emissions Factor	g/bh-hr (Zero hour)	**4.9**	http://www.arb.ca.gov/msprog/ordiesel/documents/PM_NOx_Emis_Factors.pdf
PM Emissions Factor	g/bh-hr (Zero hour)	**0.22**	http://www.arb.ca.gov/msprog/ordiesel/documents/PM_NOx_Emis_Factors.pdf
CO Emissions Factor	g/bh-hr (Zero hour)	**4.1**	http://www.arb.ca.gov/msprog/ordiesel/documents/Off-Road_Diesel_Stds.xls

CARB 2009 Diesel

Engine Year		**2009**	
Engine Power	HP	**185**	From POLB 2007 EI
Load Factor		**0.39**	From POLB 2007 EI
Tier		**3**	
NOx Emissions Factor	g/bh-hr (Zero hour)	**2.6**	http://www.arb.ca.gov/msprog/ordiesel/documents/PM_NOx_Emis_Factors.pdf
PM Emissions Factor	g/bh-hr (Zero hour)	**0.15**	http://www.arb.ca.gov/msprog/ordiesel/documents/PM_NOx_Emis_Factors.pdf
CO Emissions Factor	g/bh-hr (Zero hour)	**2.6**	http://www.arb.ca.gov/msprog/ordiesel/documents/Off-Road_Diesel_Stds.xls

Appendix B – Survey Form

YUSEN TERMINALS INC VEHICLE DEMONSTRATION SURVEY

Name:__________________ Date:_____________ Shift:_____ Vehicle ID _____________

Please rate the _______Vehicle as "Better Than" / "The Same As" / "Worse Than" a gas/diesel vehicle. (Please check the box that applies.)	Better Than	Same As	Worse Than	Any additional comments
1) Power: The ability to accelerate and move out effectively and safely.				
2) Power Supply: Sufficient power to complete a shift without recharging.				
3) Handling Characteristics: Smooth shifting on acceleration.				
4) Turning radius: Ease of parking, negotiating tight places, and steering effort.				
5) In-Cab Visibility: No blind spots, rear view.				
6) Ride Comfort: Vibration and shocks, seat ergonomics.				
7) In Cab Ergonomics: Controls gauges, switches conveniently placed, working smoothly.				
8) Braking: Stops smoothly and evenly.				
9) Noise Level: In-cab engine noise.				
10) Ventilation: In-cab air circulation and comfort.				
11) Ease of entry and exit from cab.				
Overall Rating:				

Additional Comments:____

____

____

____

Driver's Signature: _________________________