EVALUATION OF THE WINTER PERFORMANCE OF COMPRESSED NATURAL GAS REFUSE TRUCKS

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PREPARED FOR:

ECOTECHNOLOGY FOR VEHICLES PROGRAM

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TRANSPORT CANADA

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CONTENTS

1.0 Executive Summary 2

2.0 Introduction 3

3.0 Technical Evaluation Process 3

4.0 Groupe EBI Profile 4

5.0 Use of CNG Refuse Trucks at EBI 4

6.0 Vehicle Configuration 5

7.0 Cummins Westport Natural Gas Engine 6

8.0 Key CNG-Specific Issues Which Can Affect Fleet Performance 6

9.0 Operation of CNG Vehicles in Cold Weather 7

10.0 EBI Cold Weather Aids 8

11.0 CNG Refueling 9

12.0 EBI Fleet Cold Weather Operating Experience 12

13.0 EBI Vehicle Data Monitoring 12

14.0 Emterra CNG Refuse Trucks 21

15.0 Conclusions 25

APPENDIX I – Description of OttoView CVS42 Data Logger 26

APPENDIX II – Cold Weather Operation – Cummins Westport ISL G Natural Gas Engine – Dec 2012 27

APPENDIX III – Sample EBI Trip Report 31

APPENDIX IV – Data from EBI Unit 1140 33

APPENDIX V – Additional Data from Driver Logs 40

1.0 EXECUTIVE SUMMARY

As new transportation technologies enter the Canadian marketplace, it is important to ensure that they have the ability to perform well in a typical Canadian environment which includes exposure to cold weather in winter and, in some regions, exposure to arctic conditions. Refuse trucks operating on compressed natural gas (CNG) are showing increased penetration in Canada, so it was important to evaluate the winter performance of the current generation of factory-built CNG trucks to:

- Ensure that satisfactory operation can be achieved in Canadian conditions;
- Document any areas requiring attention;
- Document operational best practices; and
- Better understand any cold weather issues so that fleets considering CNG can benefit from this information.

This work was endorsed by the Deployment Roadmap Technical Advisory Group (TAG), a government/industry group formed to address technical barriers related to medium and heavy natural gas vehicle adoption as outlined in the *Natural Gas Use in the Canadian Transportation Sector – Deployment Roadmap*.

The primary fleet chosen for winter performance evaluation was a fleet of 18 CNG refuse trucks operated by Groupe EBI in greater Montreal. A secondary source of information was recent cold weather experiences involving 58 CNG refuse trucks operated by Emterra Environmental in Winnipeg.

The evaluation process encompassed a number of areas including vehicle configuration and cold weather aids, vehicle data monitoring, fuel station configurations, and anecdotal fleet experiences. In addition to direct data collection, information was gathered through contact with engine, vehicle, and station equipment suppliers, literature search, and through a site visit.

EBI COLD WEATHER EXPERIENCE

EBI operates a fleet of Peterbilt trucks with a cab over design with the radiator located within the engine compartment and the air intake system protected behind the cab and close to the exhaust. The only cold weather aids added to the vehicles were two electric coolant heaters to assist warm up and an electric oil pan heater to reduce oil viscosity and improve cranking speed for starting in cold weather. Both types of heaters were plugged in overnight during the time fill refueling process. EBI had no prior information on detailed cold weather operating requirements for natural gas trucks, but recognized the need for coolant and oil heating based on their experience operating a diesel fleet in cold weather conditions in the Montreal area.

The design configuration of the Peterbilt trucks used by EBI was not inherently susceptible to cold weather issues and performed satisfactorily with minimal cold weather aids. This design provided adequate protection for cold weather operation in ambient winter temperatures down to – 16 C. The percent utilization of the fleet has been high with minimal downtime over two years of operation, ten hours daily runtime per truck, and an estimated 40,000 km annual mileage per truck. There have been very few reports of cold weather issues from the fleet over two years of operation. Vehicle starting and operation in cold weather is satisfactory as demonstrated by the vehicle data monitoring and from the daily driver trip reports.

All of the data obtained from data loggers installed in the two vehicles shows that CNG-equipped vehicles can operate effectively with no adverse effects or problems related to low ambient air temperatures provided proper winterization and design characteristics are present.

By far the most common issues which affect satisfactory performance of CNG vehicles in cold climates are fuel quality and contaminants. Moisture level, heavy hydrocarbons, and sulphur content in the fuel can create problems. Similarly, contamination from compressor oil carry over can also be an issue. The most common problem that is encountered is with water content in the fuel. The colder the ambient temperature becomes, the drier the natural gas has to be. It is therefore critical to ensure that a dryer is included in the CNG refueling station and that the dryer is properly maintained. The dryer needs to perform to the level required based on the ambient temperature, and the dew point, or frost point, of the fuel must always be below either the ambient temperature or the coldest temperature in the fuel system to which the fuel will be exposed. If this is achieved, there should be minimal issues with operating natural gas vehicles even in extreme arctic conditions.

In the case of the EBI vehicles, there have been minor incidences of water freezing in the fuel filters in two vehicles in the fleet, but this has not affected overall fleet operations.

As occurs with diesel engines, as the operating climate becomes colder, an increasing number of winter aids, vehicle modifications, vehicle preparation, operating practices, and maintenance procedures are typically required to ensure satisfactory vehicle operation. It can be concluded that if the vehicle winter aids are used that are appropriate for the vehicle at its designed ambient operating temperatures and if the natural gas fuel is adequately dry and meets requirements related to heavy hydrocarbons and compressor oil carry over, then normal operations will be experienced by natural gas vehicles in cold climates.

2.0 INTRODUCTION

The purpose of this report is to document the results of a project to evaluate the winter performance of a fleet of 18 compressed natural gas (CNG) refuse trucks operated by Groupe EBI in the Lanaudiere in the greater Montreal region of Quebec.

This work was endorsed by the *Deployment Roadmap* Technical Advisory Group (TAG), a government/industry group formed to address technical barriers related to medium and heavy natural gas vehicle adoption as outlined in the *Natural Gas Use in the Canadian Transportation Sector – Deployment Roadmap*, as it can help to determine and to document the satisfactory performance of current generation, factory-built CNG vehicles in Canadian cold weather conditions. While the primary focus of the project is the EBI fleet, a secondary source of information was recent cold weather experiences involving the 58 CNG refuse truck fleet operated by Emterra Environmental in Winnipeg.

This work documents and reports on observed technical and operational issues affecting the performance of the trucks in service operation as well as identifying resulting corrective actions. This information could assist with the future development of a guideline both for the natural gas vehicle industry and for fleets operating in cold weather environments as it highlights what is needed to ensure that satisfactory performance in Canadian cold weather conditions is assured and is the norm for natural gas fleet operators.

3.0 TECHNICAL EVALUATION PROCESS

The evaluation process encompassed a number of areas for monitoring and assessment. Information was gathered through contact with vehicle and station equipment suppliers, via direct data collection, by literature search, and through an EBI site visit that took place on March 14, 2013 which also involved a technician from Cummins Eastern Canada who had a working relationship with the fleet. Over the course of the project, there were four main areas of investigation and review:

VEHICLE CONFIGURATION

The layout of engine/vehicle systems was documented together with any cold weather aids such as block heaters, oil pan heaters, battery warmers, any supplemental filter heating systems, regulator heating with engine coolant, any radiator screens installed, and operational design. The use of any shrouds to assist with heating of intake air was also reviewed.

VEHICLE DATA MONITORING

OttoView data loggers (see description in Appendix 1) were installed by Cummins Eastern Canada on two vehicles. The data loggers are capable of monitoring various engine parameters on a continuous basis. The data loggers collected information which was then uploaded to Red River College for review and analysis. The information was stored and accessed via a memory card plugged into the data logger which allowed for data transfer to a computer on a periodic basis.

The original intent with the project was to collect data from February 11th to March 25th. Unfortunately, due to delays related to the data logger technology and its use, data collection occurred from March 18th to March 28th.

	Parameter	Units of Measurement	Frequency of Data Collection
1	Date & Time	-	Every second
2	Speed	Km/h	Every second
3	OttoView Power Supply	DC volt	Every second
4	Trip Duration	Hour/minute/second	Every second
5	Trip Distance	Km	Every second
6	Accelerator Pedal Position 1	Percentage of actuation	Every second
7	Engine Percent Load At Current Speed	Percentage	Every second
8	Actual Engine - Percent Torque	Percentage	Every second
9	Engine Speed	RPM	Every second
10	Engine Coolant Temperature 1	Degree Celsius	Every second
11	Barometric Pressure	KPa	Every second
12	Engine Intake Manifold Temperature	Degree Celsius	Every second
13	Outside Ambient Air Temperature	Degree Celsius	Every second

Figure 1 - Parameters Monitored by Data Loggers

This data monitoring provided a good overview of the operating environment and its effects upon the engine. In addition, daily ambient temperature and humidity were logged from Weather Underground data on the internet, as well as being noted in daily log sheets completed by EBI.

FUEL STATION CONFIGURATION

The basic CNG refueling station configuration was also documented. EBI has a private station with time fill and fast fill capabilities. Station details are included. The Fleet Manager was interviewed in order to gain information about the station's performance in cold weather and, in particular, the performance and maintenance of the dryers used to limit ingress of water into the fuel, the amount of oil carry over, and the ability of the station to fill all vehicles overnight in the time fill operation.

FLEET DATA

Interviews with EBI and Cummins Eastern Canada personnel provided anecdotal information on the overall performance of the fleet during cold weather operation including down time, operational effectiveness, and maintenance. The daily trip report was completed by the vehicle operators and it included hours of operation, fuel consumed, ambient temperatures, and any issues with operating the two trucks with the data loggers.

4.0 GROUPE EBI PROFILE

Groupe EBI is a privately-held, Quebec-based company with a fifty plus year history that started with a focus on excavation and snow removal as the primary business. The company began to move towards the environmental and refuse sector in 1970 with waste pickup services being provided at that time. The company further diversified its operations by obtaining a permit to operate a sewage treatment facility in 1978 and in 1982 a subsequent permit to treat septic field waste.

EBI ventured into the recycling industry in 1990 starting with the pickup of recyclable materials and with the composting of organic materials. EBI continued to develop systems of waste management by building sorting facilities in 1998 and by incorporating biogas recovery systems in 1999. These biogas recovery systems were improved and expanded from an initial system built in 2002 by bringing online a biogas treatment facility at the Environmental Industrial Park in the Gestion Environmental Econord Facility.

EBI continues to grow and expand its diverse portfolio of waste management activities involving household waste, hazardous materials, recycling depots, document shredding, sorting centers, landfill sites, and sewage treatment. EBI works with partners that include municipal governments, small businesses, light and heavy industries, and other corporate partners such as Hydro Quebec.

5.0 USE OF CNG REFUSE TRUCKS AT EBI

EBI ordered its first CNG refuse truck in 2010. At the time, the truck was one of the first CNG refuse trucks in Canada with a factory-built original equipment-manufactured (OEM) truck chassis with a fourth generation Cummins Westport 8.9 litre ISL G spark-ignited engine. Montreal-based Gaz Metro Transport Solutions provided mobile CNG refueling services.

EBI now has 18 CNG refuse trucks in service and plans to expand the fleet to 50 units during 2013. The fleet has been in regular service for about two years, providing satisfactory operation with minimal downtime. The vehicles are in use for about 10 hours before returning to base at the end of the day. The CNG trucks are used in the same way as diesel trucks would be with no changes to the refuse collection services provided or to the daily driving routes. Each truck travels an estimated 40,000 km per year which is typical for a refuse fleet operation.

Before new refuse trucks are delivered to EBI, the Peterbilt chassis shown on the left below, is delivered to the Labrie facility located near Montreal where the refuse body and CNG fuel storage system are installed as part of the final stage of manufacturing.

Figure 2 - Incomplete & Complete EBI Refuse Trucks

The completed vehicle is refueled at Labrie and then driven to EBI without any further refueling requirement given that Labrie is less than 200 km from EBI. From that point on, the vehicles are then refueled at the dedicated refuelling facility of EBI. The refueling history is therefore entirely known.

6.0 VEHICLE CONFIGURATION

The 17 recently acquired trucks that EBI has ordered incorporate Labrie "AUTOMIZER^{tm}" side-loader bodies with two axles and a total cubic capacity of 22 yds2 or 17 M3. As previously noted, these bodies are installed on the Peterbilt chassis and have the CNG fuel storage tanks located behind the cab. The chassis is a cab over design with the cooling system located under the cab in a traditional design. The Peterbilt chassis were manufactured in Denton, TX and then shipped via flatbed truck to Labrie in St-Nicolas, QC, near Quebec City. Once the Labrie bodies and CNG fuel storage system were installed, the trucks were refueled initially at Labrie's private CNG refueling station and then driven to EBI's location northeast of Montreal.

The CNG fuel storage system consists of five Dynetek Type 3 carbon fibre-wrapped aluminum fuel storage tanks with a storage capacity of 82 diesel gallon equivalent (DGE) located in an enclosure behind the cab as shown in the picture below. The tank enclosure adds an estimated 20" to the truck length and is mounted on the frame rails. This CNG tank package adds approximately 800 kg of weight which includes the tanks, instrumentation, and the back of cab enclosure. The CNG tanks are designed to be able to store natural gas at 3,600 psi. Private fleets with their own CNG refueling stations can fill to 3,600 psi in Canada. Vehicles that access public stations are currently limited to 3,000 psi pressure in Canada, although there is a proposal to change the current code (CSA B108-99) to allow 3,600 psi refueling at all CNG refuelling stations in Canada. In the U.S., all CNG refueling stations fill to 3,600 psi.

Figure 3 - EBI CNG Refuse Truck

The CNG fuel system includes a primary fuel shut off valve that is located upstream of the natural gas regulator. The function of the regulator is to regulate the fuel pressure from the higher tank pressures ranging from 3,000 to 3,600 psi to the pressure required by the engine at 70 to 150 psi. The regulator is heated with engine coolant to prevent freeze up in cold weather and is shown below labelled "Fuel Heater."

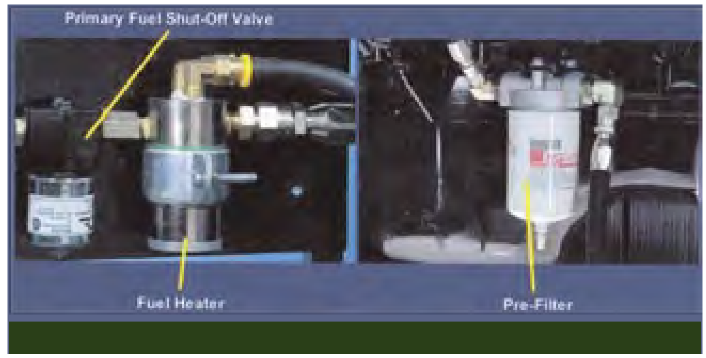


Figure 4 - Fuel Shut-Off Valve, Heater & Secondary Filter

The CNG fuel system also includes a fuel filter which is shown below that is equipped with a drain to drain off water and oil from the fuel system. There is a daily drain check requirement of the secondary filter and Cummins specifies that no more than about 1 oz of oil should be drained and collected for recycling each day as a service procedure. If there is more than this the fuel provider should be contacted.

Figure 5 – Fuel Filter Drain

The low pressure fuel is then supplied to the fuel management system of the engine. The air intake system is located behind the cab, but forward of the fuel storage containers. It is a conventional design without any auxiliary heating systems. There is no ducting routed from the engine compartment to the air cleaner inlet, but there is good protection from the elements as the air intake system is located behind the cab and close to the exhaust system.

7.0 CUMMINS WESTPORT NATURAL GAS ENGINE

The Cummins Westport ISL G engine is integrated by all truck manufacturers who offer natural gas chassis suitable for refuse applications. This 8.9 litre spark-ignited, 320 HP 1000 lb.ft torque at 1,300 rpm stoichiometric engine uses a three-way catalyst and does not require the use of a diesel particulate filter to reduce particulate matter (PM) emissions or a selective catalytic reduction (SCR) system to reduce NOx emissions.

Figure 6 - Cummins Westport ISL G Engine

Figure 7 - Cummins Westport Three-Way Catalyst

The technology also uses cooled exhaust gas recirculation (EGR) which results in 30% better torque at idle and 5% better fuel economy compared with previous generation lean burn CNG technology. Cooled EGR replaces the additional air in lean burn technology, reduces combustion temperatures similar to lean burn engines, and offers better efficiency and power density compared with lean burn and conventional stoichiometric engines.

The ISL G engine has "diesel like" torque throughout the operating speed range.

8.0 KEY CNG-SPECIFIC ISSUES WHICH CAN AFFECT FLEET PERFORMANCE

By far the most common issues which can affect satisfactory performance of CNG vehicles are fuel quality and contaminants. Ideally the fuel should correspond to the fuel specification detailed in *SAE J1616 – Recommended Practice for Compressed Natural Gas Vehicle Fuel. Cummins Service Bulletin 3379001 – "Fuels for Cummins Engines"* contains a fuel specification (CES 14624) for natural gas engines which includes minimum methane numbers for on-highway vehicles. From time to time, contaminants are found in the natural gas fuel supply which to a greater or lesser extent can affect the performance of the CNG vehicle. These are detailed below together with their effects.

- Moisture
  - Ice build-up in the fuel
  - Can clog fuel filter and/or foul engine sensors

- Heavy Hydrocarbons
  - Sensor and injector issues
  - Can clog fuel filter and/or foul engine sensors

- Compressor Oil Carryover
  - Causes solenoid valve to stick and function intermittently
  - Can clog fuel filter and/or foul sensors

- High Sulphur Content
  - May cause component corrosion
  - Burst disks susceptible to damage

In addition to contaminants in the fuel supply, it has also been observed that water and oil contaminants can build up in the fuel storage cylinders over time. Fleets should contact their local truck dealer if further information is needed regarding CNG fuel cylinder issues.

Another variable may be introduced when new CNG vehicles are being delivered to the fleet. If driven from the manufacturer's plant, fuel contamination of the CNG cylinders may occur depending on the number of refueling stops on the way and the different types of equipment used at these stations. As the refueling history for the EBI trucks is completely known, the potential risk of fuel contamination associated with a range of different refueling stations and different equipment is minimal. The daily drain procedure of the secondary filter is also a critical procedures as of when the CNG trucks go into service.

9.0 OPERATION OF CNG VEHICLES IN COLD WEATHER

When a truck is destined for operation in a cold weather environment, its specifications and modifications will vary depending on whether the temperature where it will be used is considered normal winter (-20 C) or arctic conditions (-32 C to -54 C). Most specifications and modifications required to adjust for these different levels of cold weather will apply whether the truck is a diesel truck or a natural gas truck, and are listed in the engine owners' manual.

The main difference with a CNG truck is that special attention may be required for the broader system including the refueling station so as to plan to avoid: (a) excessive moisture in the fuel; or (b) compressor oil carry over. In the latter case, depending on the viscosity of the compressor oil used, gelling of the oil may occur in the fuel filter causing restriction of flow and resulting in poor engine performance. Auxiliary heating of the fuel filter will be required to remedy that issue in extreme cold weather or a change in the viscosity of the compressor oil may be required during arctic conditions. If a lighter viscosity compressor oil is used, however, increased solubility of natural gas in the oil occurs, further reducing the viscosity and increasing potential for compressor cylinder wear. There is therefore a trade-off in the acceptability of lower viscosity compressor oils.

Satisfactory performance of heavy duty diesel or natural gas vehicles in cold weather depends on planning for the temperature range to which they will be exposed. As the operating climate becomes colder, an increasing number of winter aids, vehicle modifications, vehicle preparation, operating practices, and maintenance procedures will be required. In addition to reasonable starting practices, the vehicle must be prepared so that a dependable warm up of the engine will occur to a level that is acceptable for both vehicle performance and durability. Warm up to a coolant temperature of about 80 C should normally take about 15 minutes before drive away occurs. With a natural gas truck, adequate warm coolant supply to the fuel system regulator will improve performance.

Typical modifications and operating practices which may be required for cold weather operation include:

ELECTRICAL SYSTEMS

Battery efficiency decreases at low temperatures, and if the required cranking speed is to be maintained to start the engine, then battery warmers must be employed or increased capacity of the batteries must be added including the use of 24 volt systems if necessary.

AIR INTAKE SYSTEMS

If the vehicle is to be operated in ambient temperatures below freezing, then the air intake should be located within the engine compartment so that warm engine air is drawn in for the combustion process. If the air intake system and air cleaner are located outside of the engine compartment, then warm air from the engine should be ducted into the air cleaner or a heat exchanger should be designed to transfer exhaust heat to the intake air system.

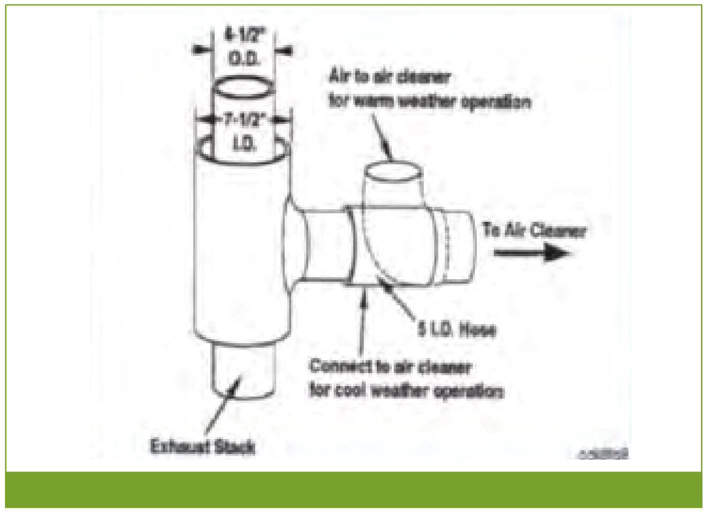


Figure 8 - Intake Air Heating System

COOLING SYSTEMS

Air flow across the engine can extend warm up time and, in very cold weather, prevent the engine from reaching minimum operating temperatures. This can be corrected by adding electrical coolant heaters to maintain coolant temperatures overnight and to aid in bringing the coolant to the minimum operating temperature required for start up. For colder temperatures, radiator shutters or "winter fronts" as they are also known, should be installed. A typical winter front is shown below.

Figure 9 - Typical Winter Front

In addition, a temperature-controlled fan drive can be used to reduce air flow across the engine. These devices operate by disconnecting or partially disconnecting the fan from its drive.

LUBRICATING OILS

The viscosity of the engine lubricating oil is very important as the oil viscosity will increase with colder temperatures which reduces cranking speed and increases load on the battery to start the vehicle. Use of a low viscosity oil is recommended for winter operations which will increase cranking speed for easier starting and allow the free flow of oil through the engine. Cummins recommends 10W40 oils for winter conditions, and 0W30 oil for extreme arctic temperatures, which meet the Cummins oil specification CES 20074 required for natural gas engines.

If the viscosity of the oil is higher than Cummins recommendations, heating the oil with an oil pan electric heater will reduce viscosity and pour point, and improve engine starting and lubrication

EQUIPMENT MODIFICATIONS AS AMBIENT TEMPERATURE DECREASES

At normal winter temperatures of 0 C down to -20 C, coolant heaters and oil pan heaters will normally be required. At the lower end of the temperature range, winter fronts will help maintain engine operating temperatures and ducting warm air from the engine compartment into the air intake system may be required. Having the air intake system designed so that it is within the engine compartment will ensure optimal winter performance.

When the ambient temperature reaches arctic conditions of -32 C to – 54 C, then considerable modifications using various cold weather aids will likely be required to assist with starting and to maintain satisfactory engine operating temperatures. Trucks with a cab over design with the cooling system located under the cab in a traditional design readily lend themselves to vehicle modifications to retain engine heat within the engine compartment. In addition to the aids described above for temperatures down to – 20 C, winter fronts should be designed to fit well and prevent cold air leakage into the engine compartment, side curtains may be added, and an insulated oil pan cover may also be required to maintain satisfactory engine oil temperatures. A 24 volt cranking system may be required and a battery warmer should be added. An off/on type fan will also reduce the amount of cold air flow to the engine.

Where possible, the heated fuel regulator and fuel filter should be located within the engine compartment where engine heat can be used to prevent freezing of filter and/or regulator with compressor oil or moisture. A fuel regulator with adequate coolant flow should be employed and auxiliary heating of the fuel filter may be required.

If the natural gas vehicle is properly winterized for its intended ambient temperature operation, there should be no operational problems in extreme cold climates including operation in arctic conditions.

Further detailed information on winterizing vehicles for cold weather can be found in operation and maintenance manuals and in the *Cummins Service Bulletin No 4332709 "Operation of Automotive Natural Gas Engines in Cold Weather"* which is available at no cost from local Cummins distributors. Appendix II contains information from Cummins Westport on cold weather operation of the Cummins Westport ISL G natural gas engine.

10.0 EBI COLD WEATHER AIDS

EBI plugs in all of their CNG trucks to an electric supply system for power for winter aids each night in the winter. There are two block heaters and one oil pan heater on each truck. EBI had no prior information on detailed cold weather operating requirements, but recognized the need for coolant and oil heating based on their experience operating a diesel fleet in cold weather conditions in the Montreal area. The oil grade EBI uses for winter operations for the natural gas trucks is 5W40, which is the standard natural gas engine oil meeting CES 20074 specifications.

Being a conventional cab over design, with the radiator located under the cab, the engine compartment is enclosed allowing heat build-up from the engine. Data logger information has shown that coolant temperatures of 80 C can be maintained in an ambient temperature of - 16 C during the stop and go duty cycle of the refuse trucks. The starting aids deemed necessary were therefore coolant and oil pan heaters to assist starting.

Figure 10 - Conventional Radiator Design

As seen in the picture on the previous page, there are no radiator winter fronts on the vehicles, but the radiator is well protected within the engine compartment based on the design of the vehicle.

An auxiliary intake air heating system design can be incorporated if required to improve air intake temperatures in arctic conditions. No such intake air heating system was used by EBI.

The EBI intake air system shown below is conventional without special winter aids.

Figure 11 - EBI Conventional Air Intake System

There is no ducting routed from the engine compartment to the air cleaner inlet, but there is good protection from the elements behind the cab and close to the exhaust system.

This vehicle design affords adequate protection for cold weather operation in the service ambient temperatures experienced of 0 C to – 20 C.

11.0 CNG REFUELING

CNG REFUELING STATION

The refueling needs of the EBI fleet are met with the use of a "Sulzer" natural gas compressor that has been installed and maintained by Syst Mes GNC Inc. of Laval, Que. There are two model C50 2-11 GPX Sulzer units on site with one of the units put into service six months ago to replace an original trial unit with a second unit of the same size and design. These compressors meet the needs of both the time fill overnight refueling system as well as that of the fast fill dispenser also located on site. These two dispensing systems allow for the units to time fill, but if fuel demands are higher than expected throughout the normal operational hours, fast fill capability is available. Both systems use the industry standard NGV 3.1 compliant nozzles for vehicle refueling and were designed to meet the CSA B108 standard for CNG refueling stations.

Figure 12 - Sulzer Compressor Station

The Sulzer compressor station has a system capacity of 172 standard cubic feet per minute (SCFM) @ 200C and has a 25 pounds per square inch gauge (psig) limit on the inlet side of the system. The 25 psig limit on the intake is considered to be slightly above expected available pressures during the winter months due to higher demand for natural gas for winter heating from the local gas distribution system. Some system designers have stated that inlet pressures within the winter months may be closer to 20 psig in this local area. Local gas distribution companies can advise regarding typical system pressures at different times of the year.

Critical to the refueling station is the local supply of pipeline-quality natural gas and the installation and use of a properly sized natural gas dryer. Information on the gas supply moisture content can be obtained from the local gas utility and should be verified before specifying a dryer unit or designing a compressor station for use in a CNG vehicle application. Pipeline quality gas typically contains up to 7#MMSCE meaning that 7 pounds of water can be present in 1 million cubic feet of natural gas. This volume of moisture may be adequate for household appliances and furnaces, but requires the installation of a dryer of suitable capacity to ensure a clean, dry supply of fuel is available for use in the vehicle fuel and filtration system.

It is recommended that CNG used in vehicles adhere to the criteria in *ISO 15403 – Natural Gas for Use as a Compressed Fuel for Vehicles* in order to ensure the proper threshold limits and composition of the natural gas. Items of concern within this standard relate to water content, sulphur compounds, particulate matter, higher hydrocarbons, carbon dioxide (CO_2), free oxygen, glycol/methanol, oil content, and corrosive components.

Figure 13 - PSB Natural Gas Dryer

The dryer selected for the station is a PSB model NG-SV-5.0-1.5 unit. This is a “suction side” dryer that is more economical than installing a high pressure discharge dryer. Some design companies prefer the high pressure discharge units as they are seen as a system that limits moisture within the system versus the suction side systems which require replaceable desiccant.

Depending on the refueling station requirements, there are a range of different dryers that are available for installation from various suppliers. It is worth noting that the dryer systems at both EBI and Emterra are both supplied by PSB and are both suction side single vessel units. Care must be taken to specify the proper dryer for local operating conditions.

Typical flow through the dryer system is a closed loop system with a heat exchange system built into the unit to remove moisture generated through compression of the gas. It was not mentioned throughout the interview with the Fleet Manager whether normal desiccant was used in the dryer or whether an alternative type of “super” desiccant is used.

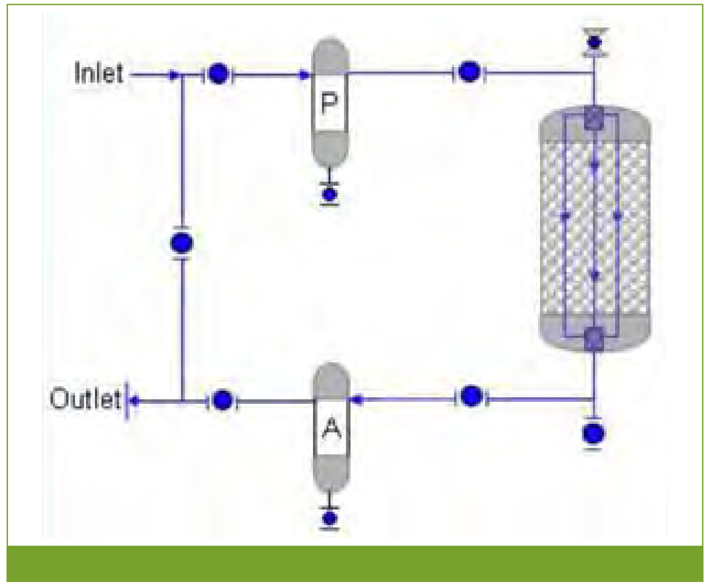


Figure 14 - Gas Dryer Schematic

Easy view monitoring along with all the necessary safety compliance systems are incorporated into the EBI refueling station. The station has performed well since it was installed. All scheduled maintenance is performed by qualified and certified technicians.

Accessibility to the compressor station is accomplished via one of five different access points allowing fast service access to the units as shown on the next page.

All safety compliance signage is present and refueling training is provided in compliance with Régie du Batiment standards in Quebec with only trained and authorized personnel allowed to participate in refueling on the site. Compliance in regards to ANSI NGV 1, NGV 2, NGV 3.1, NGV 4.1, NGV 4.2, and NGV 4.6 are all followed as applicable to the vehicles, facility and refueling practices. Initial refueling station training was provided by the system designer and installer Syst Mes GNC Inc. after commissioning the station.

A fast fill refueling pump is located on a separate small island for periodic fast fill of CNG service vehicles.

Figure 15 - View of Station Gauges

Figure 16 - Equipment Inside Station Enclosure

Figure 17 - Fast Fill Dispenser

TRUCK REFUELING

The picture on the following page shows a truck parked at the time fill refueling post during refueling. The hose is connected to the truck via a conventional ANSI NGV 3.1 compliant nozzle. The refueling nozzle is designed to mate with the refuelling receptacle located on the vehicle and complies with the industry accepted standard ANSI NGV 3.1.

Once the fueling hose is connected to the receptacle and the system is turned on, the gas will start to flow into the vehicle. During refueling, a completely sealed system is formed and there is no risk of gas leakage. There is also no risk of fumes or spills.

The picture below shows the fuel gauges which are located below the fuel tank enclosure. One gauge shows the high pressure in the fuel storage tanks, and the other shows the regulated low pressure downstream of the regulator. The fuel filter is located behind the fill point in a convenient location to allow oil draining, but is outside of the engine compartment.

As the EBI trucks are used for 10 hour shifts per day, the trucks leave the yard with full tanks of fuel at approximately 3,600 psi. Over the course of the day as fuel is used, the pressure drops so that by the end of the shift, approximately 1,000 – 1,500 psi is left in the tanks as shown on the fuel gauge. This provides an adequate fuel margin for completing a shift before plugging into the time fill refueling system.

Figure 18 - EBI Truck & Time Fill Post

Figure 19 - Fuel Gauges Below EBI Truck Tank Enclosure

12.0 EBI FLEET COLD WEATHER OPERATING EXPERIENCE

The design of the CNG trucks used by EBI provides adequate protection for cold weather operation in their intended service in winter ambient temperatures down to – 20 C. There have been minimal reports of cold weather issues from the fleet over two years of operation. Vehicle starting and operation in cold weather is satisfactory as seen from the vehicle data monitoring results and from the daily trip reports shown in Appendix III.

The percent utilization of the fleet is very high with minimal down time. There have been reports of water freezing in the fuel filters, but this has occurred in only two vehicles in two different locations with the vehicles being refueled from two separate refueling stations. This suggests that there may be water contamination from the fuel or other source occurring in the fuel tanks of these particular vehicles. Other than this, there are no significant issues to report with operation of this fleet in cold weather.

13.0 EBI VEHICLE DATA MONITORING

The data collection process involved the use of two vehicles within the EBI fleet being equipped with data loggers to collect information to analyse operation of CNG equipped vehicles in a cold weather environment. The data loggers are J1939 compatible and gather in excess of 80 subject lines of data. For this project a selection of 13 main areas of data collection were targeted with daily manual driving logs adding supporting information related to operational aspects of operation. The report focused on the following parameters:

	Parameter	Units of Measurement	Frequency of Data Collection
1	Date & Time	-	Every second
2	Speed	Km/h	Every second
3	OttoView Power Supply	DC volt	Every second
4	Trip Duration	Hour/minute/second	Every second
5	Trip Distance	Km	Every second
6	Accelerator Pedal Position 1	Percentage of actuation	Every second
7	Engine Percent Load At Current Speed	Percentage	Every second
8	Actual Engine - Percent Torque	Percentage	Every second
9	Engine Speed	RPM	Every second
10	Engine Coolant Temperature 1	Degree Celsius	Every second
11	Barometric Pressure	KPa	Every second
12	Engine Intake Manifold Temperature	Degree Celsius	Every second
13	Outside Ambient Air Temperature	Degree Celsius	Every second

Figure 20 - Parameters Monitored by Data Loggers

The data is arranged into a series of four spreadsheet and graphical representations to transmit the data into a usable form. The reason for this approach is to represent the findings in the most transparent manner possible. The data shows that in a cold weather environment where the ambient temperature ranged from +4 C to -16 C, with an average temperature of -60C over the monitoring period, the CNG equipped vehicles can operate effectively with no adverse impacts or problems related to the ambient air temperature given that proper winterization and design characteristics are present.

The following table shows the average weather statistics for the operating area for Feb 25, 2013 – Mar 25, 2013.

Max Temp:	6.8°C
Max Temp.Date:	Mar.11,2013
Min temp:	-12.9 °C
Min Temp.Date:	Mar.18,2013

Local temperatures recorded on the EBI driver logs showed temperatures of -160C at the start of one shift and an overall average temperature of -80C for the week of March 18 – 22nd. During this same week, temperatures in EBI's operating area were comparable to those of Winnipeg. As this week included the coldest temperature value, it was selected for use in the tables and graphs.

During the reporting period, the use of block heaters and oil pan heaters were used more than 75% of the time. This resulted in start-up oil pressure rates in the normal range of 70 – 80 psi and the normal operating range being achieved within a 15 minute warm-up period. One of the two units left inside for service was the only exception to these values and it had a 35 psi reading at start-up after being serviced and left inside overnight.

The following graphs highlight some of the operating characteristics of the units. The first chart highlights four specific aspects of the engine operation taken every second but condensed into an hour by hour basis to allow for data to be more effectively reported.

Within this data chart, the relationship of speed, throttle position, and actual torque applied to maintain load compared to actual engine coolant temperature demonstrate the ability for the engine to continue to operate at acceptable levels. Recognizing that the trucks are in refuse collection service, the mileage may seem lower than expected. The actual amount of high idle running time is a contributing factor to the engine's ability to maintain temperature of the coolant.

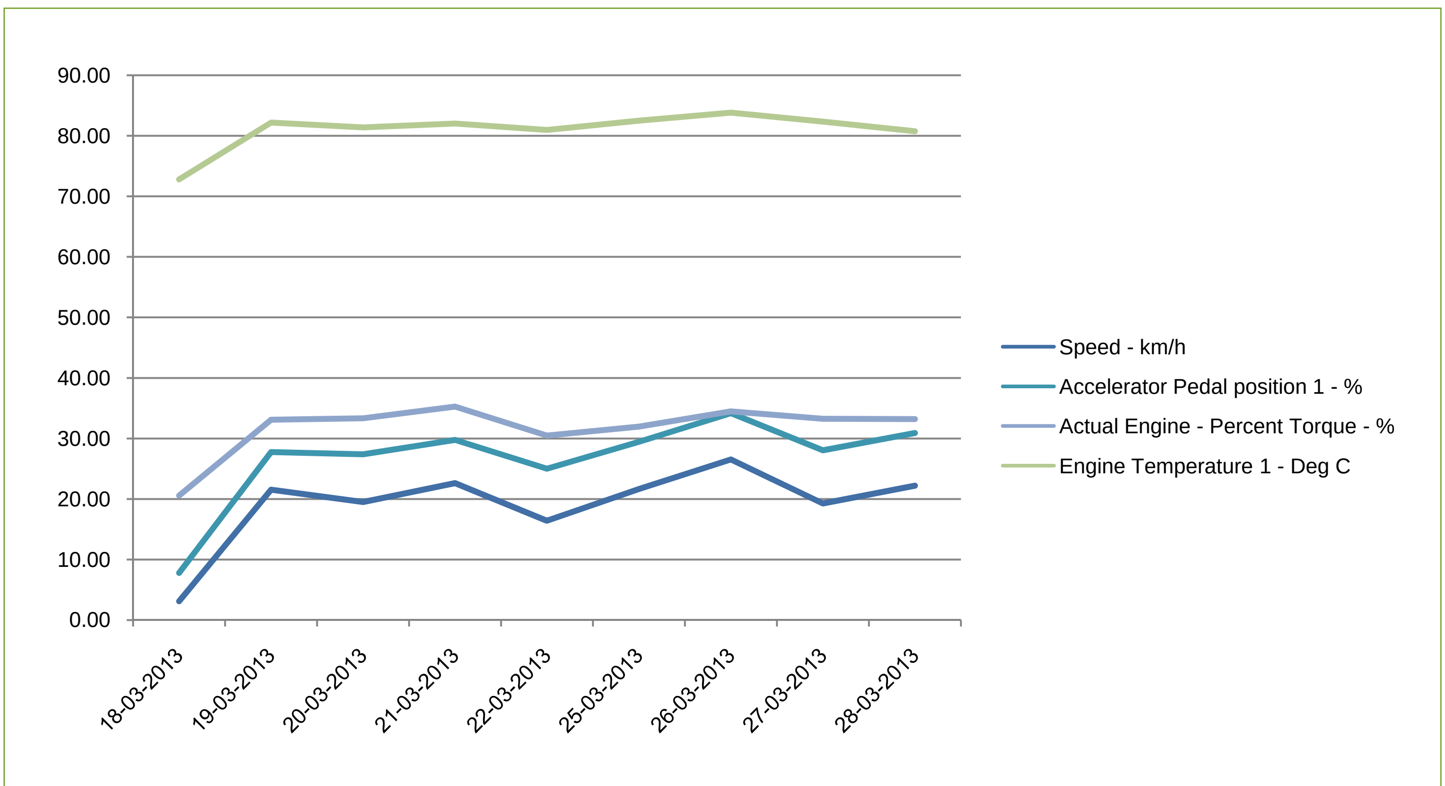
Note that the March 18th data included data logger set up, which explains why the vehicle utilization and mileage was low.

Nevertheless, adequate engine temperatures were maintained even at ambient temperatures of -16C .

Table 1 - Unit 1875

Date	Speed	Accelerator Pedal Position 1	Actual Engine - Percent Torque	Engine Temperature 1
			PGN 61444/SPN 513	PGN 65262/SPN 110
Average for:	**km/h**	**Percent**	**Percent**	**C**
March 18, 2013	3.10	7.79	20.57	72.79
March 19, 2013	21.51	27.77	33.10	82.21
March 20, 2013	19.48	27.38	33.32	81.42
March 21, 2013	22.62	29.78	35.26	82.05
March 22, 2013	16.40	25.00	30.48	80.97
March 25, 2013	21.64	29.45	31.96	82.51
March 26, 2013	26.53	34.19	34.47	83.84
March 27, 2013	19.25	28.06	33.26	82.35
March 28, 2013	19.19	26.70	31.74	80.99

Graph 1 - Unit 1875

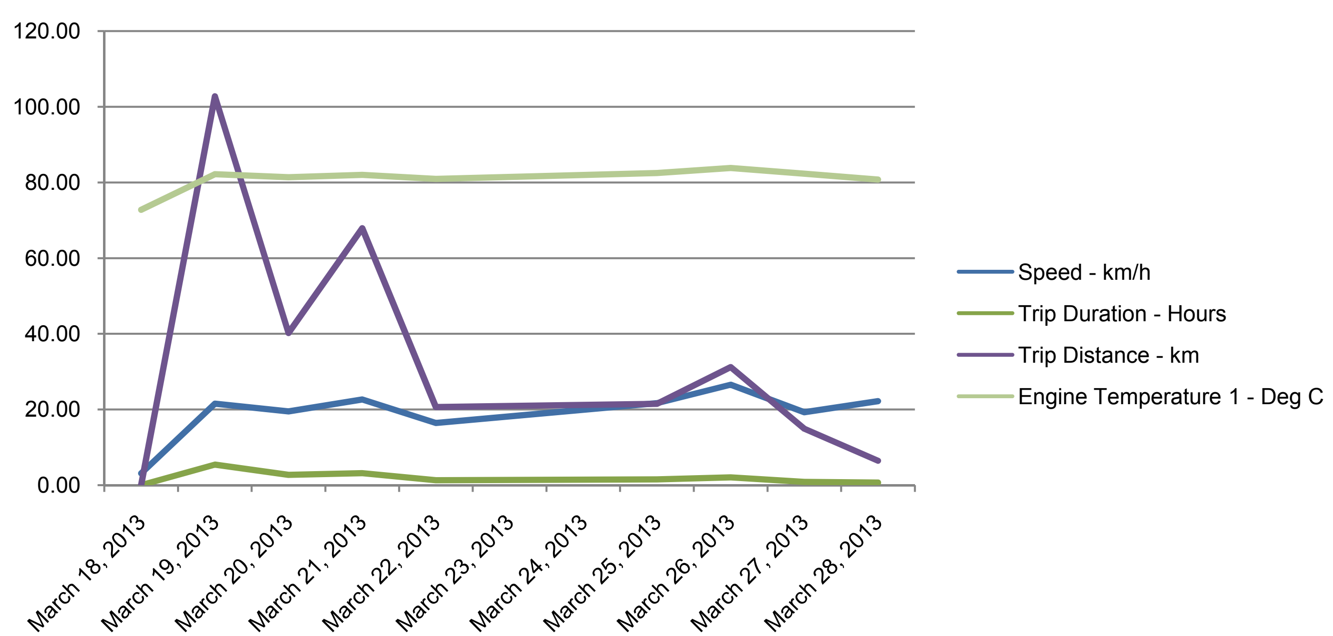


The second set of parameters collected are representative of the speed, distance traveled, duration of trip in hours, and how these relate to engine coolant temperature and the ability to maintain temperature. The ability to hold temperature and reduce the cold running characteristics of the engine is reflected in these tables and charts.

Table 2 - Unit 1875

Date	Speed	Trip Duration	Trip Distance	Engine Temperature 1
				PGN 65262/SPN 110
Average for:	km/h	Hours	km	C
March 18, 2013	3.10	0.02	0.06	72.79
March 19, 2013	21.51	5.44	102.78	82.21
March 20, 2013	19.48	2.71	40.23	81.42
March 21, 2013	22.62	3.15	67.91	82.05
March 22, 2013	16.40	1.28	20.64	80.97
March 25, 2013	21.64	1.53	21.51	82.51
March 26, 2013	26.53	2.08	31.22	83.84
March 27, 2013	19.25	0.88	14.95	82.35
March 28, 2013	19.19	1.97	33.97	80.99

Graph 2 - Unit 1875

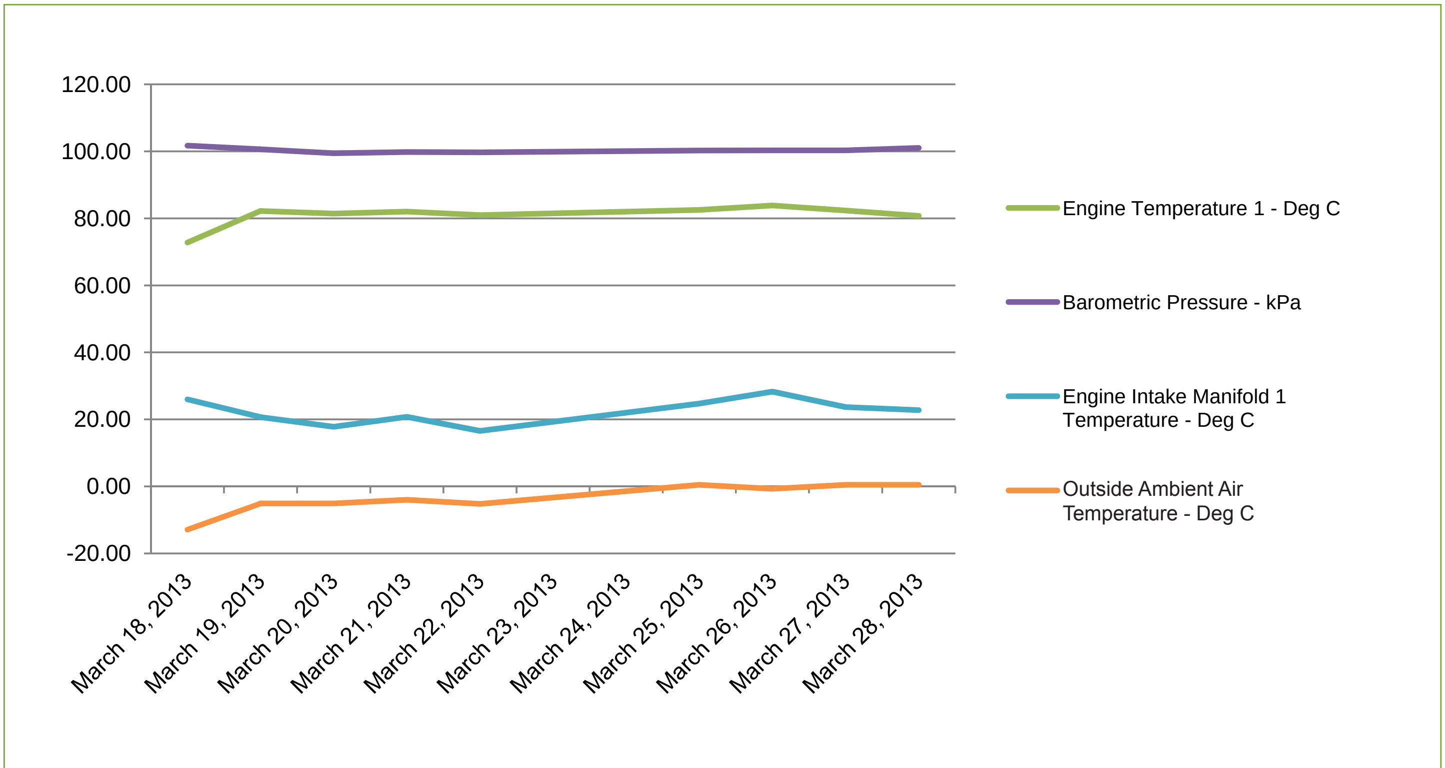


In the data from the third group of parameters the correlation of engine temperature, barometric pressure, and intake manifold temperature are compared to the outside ambient air temperature. Once again the engine was able to maintain coolant temperatures and operational efficiencies throughout the operation of the vehicle in normal service duties.

Table 3 - Unit 1875

Date	Engine Temperature 1	Barometric Pressure	Engine Intake Manifold 1 Temperature	Outside Ambient Air Temperature
	PGN 65262/SPN 110	PGN 65269/SPN 108	PGN 65270/SPN 105	PGN 65276/SPN 169
Average for:	C	kPa	C	C
March 18, 2013	72.79	101.70	25.97	-12.9
March 19, 2013	82.21	100.61	20.68	-5.1
March 20, 2013	81.42	99.43	17.78	-5.1
March 21, 2013	82.05	99.79	20.75	-4.0
March 22, 2013	80.97	99.69	16.55	-5.2
March 25, 2013	82.51	100.27	24.71	0.5
March 26, 2013	83.84	100.31	28.30	-0.7
March 27, 2013	82.35	100.30	23.70	0.5
March 28, 2013	80.77	101.05	22.75	0.5

Graph 3 - Unit 1875



With the widest selection of data incorporated into the table and graph below, the next two figures again highlight the thermal effectiveness of the CNG engine in this specific vehicle configuration. The engine consistently operates within specified limits for coolant temperature operating levels and exhibited no reliability issues during the timeframe of data collection.

Table 4 - Unit 1875

Date	Speed	Accelerator Pedal Position 1	Engine Percent Load at Current Speed	Actual Engine - Percent Torque	Engline Speed	Engine Temperature 1	Engine Intake Manifold 1 Temperature	Outside Ambient Air Temperature
			PGN 61443/ SPN 92	PGN 61444/ SPN 513	PGN61444/ SPN 190	PGN 65262/ SPN 110	PGN 65270/ SPN 105	PGN 65276/ SPN 169
Average for:	**km/h**	**percent**	**percent**	**Percent**	**rpm x10**	**C**	**C**	**C**
March 18, 2013	3.10	7.79	29.42	20.57	88.59	72.79	25.97	-12.9
March 19, 2013	21.51	27.77	40.58	33.10	115.90	82.21	20.68	-5.1
March 20, 2013	19.48	27.38	39.81	33.32	114.20	81.42	17.78	-5.1
March 21, 2013	22.62	29.78	42.11	35.26	118.42	82.05	20.75	-4.0
March 22, 2013	16.40	25.00	38.85	30.48	110.19	80.97	16.55	-5.2
March 25, 2013	21.64	29.45	39.5	31.96	118.61	82.51	24.71	0.5
March 26, 2013	26.53	34.19	41.16	34.47	124.45	83.84	28.30	-0.7
March 27, 2013	19.25	28.06	39.89	33.26	117.71	82.35	23.70	0.5
March 28, 2013	22.18	30.90	41.32	33.21	116.47	80.77	22.75	0.5

The final graph gives a very clear picture of the stability of the CNG engines' operating abilities and more importantly its consistency when comparing all levels of parameters that were measured and recorded.

Graph 4 - Unit 1875

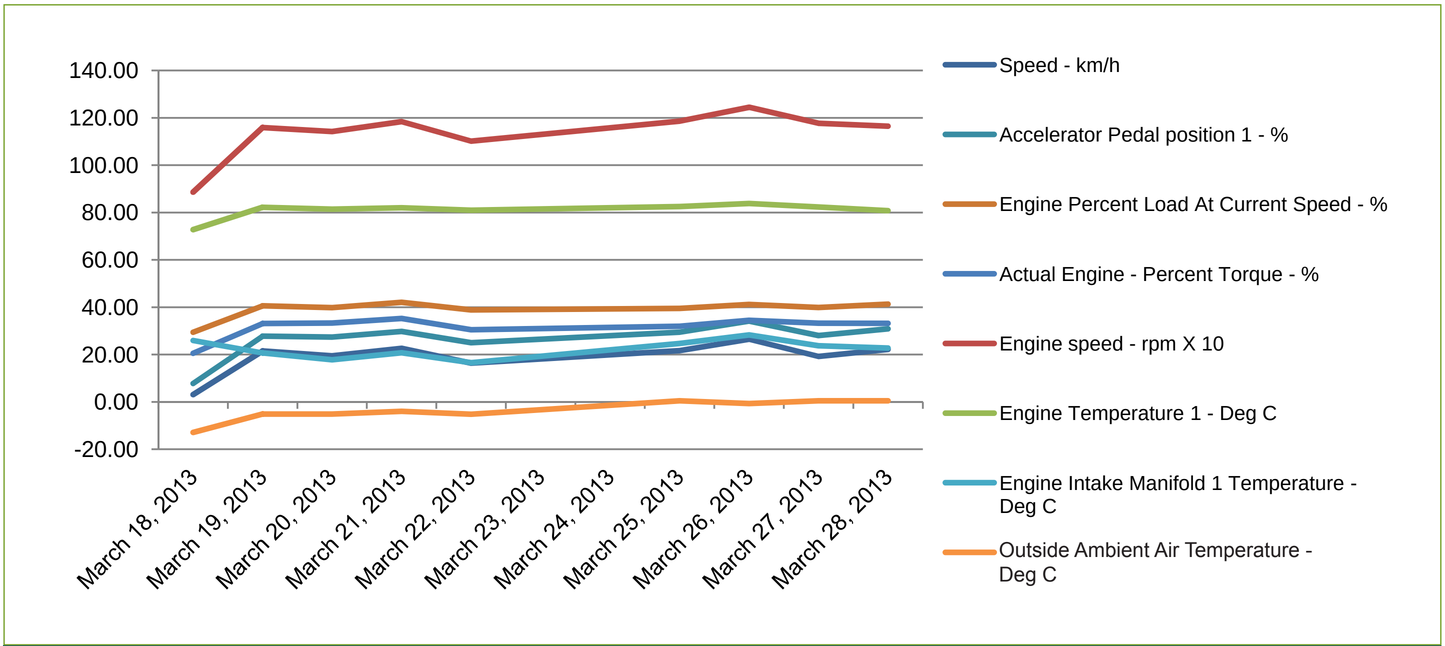


Table 5 - Overall Data for Unit 1875

Date	Speed	OttoView power supply	Trip Duration	Trip Duration	Trip Distance	Accelerator Pedal Position 1	Engine Percent Load at Current Speed	Actual Engine - Percent Torque	Engline Speed	Engine Temp. 1	Barometric Pressure	Engine Intake Manifold 1 Temp.	Outside Ambient Air Temp.
							PGN 61443/ SPN 92	PGN 61444/ SPN 513	PGN61444/ SPN 190	PGN 65262/ SPN 110	PGN 65269/ SPN 108	PGN 65270/ SPN 105	PGN 65276/ SPN 169
Average for:	**km/h**	**DC Volts**	**HH:MM:SS**	**Hours**	**km**	**percent**	**percent**	**Percent**	**rpm x10**	**C**	**kPa**	**C**	**C**
March 18, 2013	3.10	13.65	0:00:59	0.02	0.06	7.79	29.42	20.57	88.59	72.79	101.70	25.97	-12.9
March 19, 2013	21.51	13.66	5:26:14	5.44	102.78	27.77	40.58	33.10	115.90	82.21	100.61	20.68	-5.1
March 20, 2013	19.48	13.76	2:42:39	2.71	40.23	27.38	39.81	33.32	114.20	81.42	99.43	17.78	-5.1
March 21, 2013	22.62	13.86	3:09:01	3.15	67.91	29.78	42.11	35.26	118.42	82.05	99.79	20.75	-4.0
March 22, 2013	16.40	13.86	1:17:06	1.28	20.64	25.00	38.85	30.48	110.19	80.97	99.69	16.55	-5.2
March 25, 2013	21.64	13.93	1:32:03	1.53	21.51	29.45	39.5	31.96	118.61	82.51	100.27	24.71	0.5
March 26, 2013	26.53	13.92	2:04:35	2.08	31.22	34.19	41.16	34.47	124.45	83.84	100.31	28.30	-0.7
March 27, 2013	19.25	13.93	0:52:37	0.88	14.95	28.06	39.89	33.26	117.71	82.35	100.30	23.70	0.5
March 28, 2013	22.18	13.90	0:40:23	0.67	6.44	30.90	41.32	33.21	116.47	80.77	101.05	22.75	0.5
Overall Average	**19.19**	**13.83**	**1:58:24**	**1.97**	**33.97**	**26.70**	**39.18**	**31.74**	**113.84**	**80.99**	**100.35**	**22.35**	**-3.50**

Graph 5 - Overall Data for Unit 1875

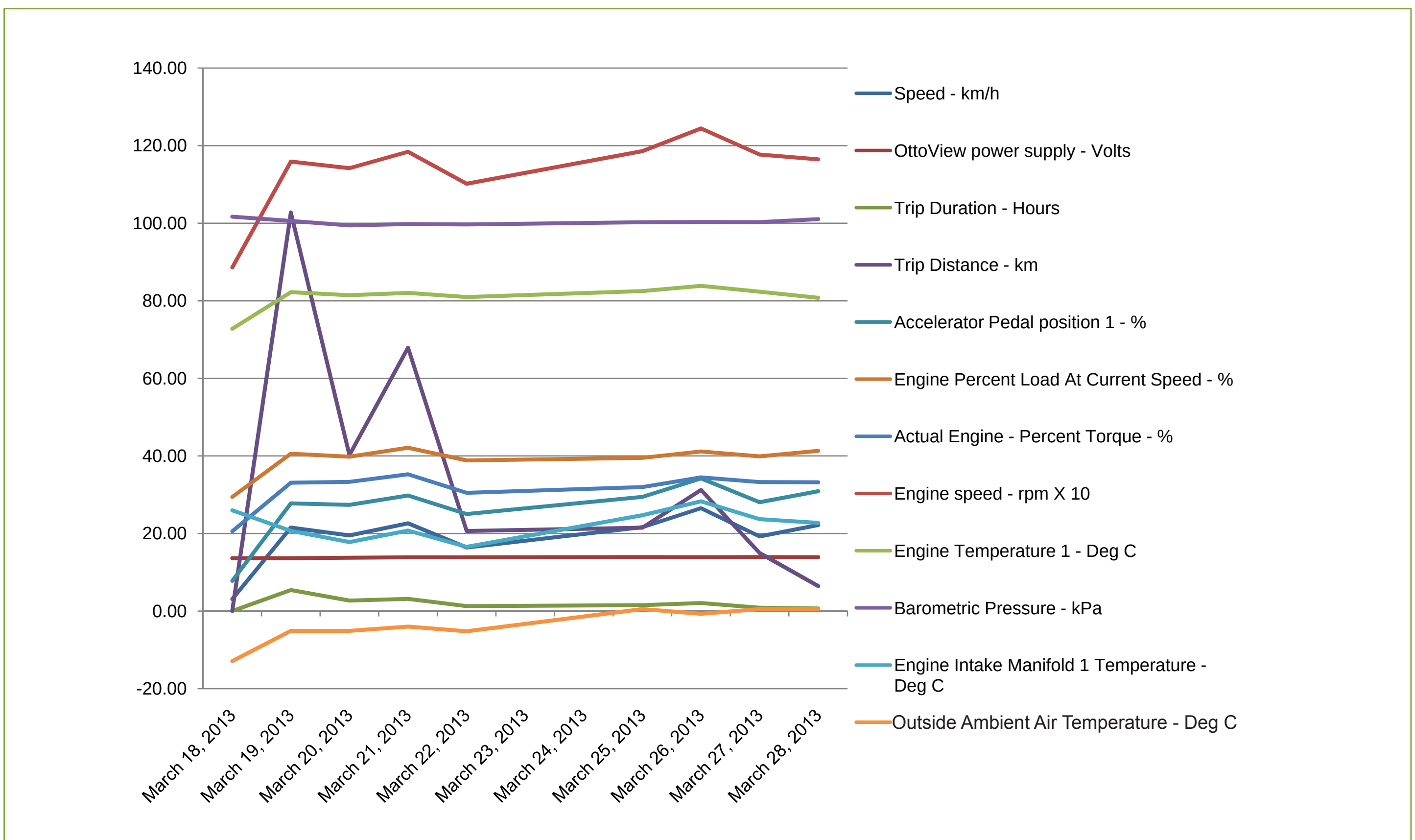


Table 6 - Overall Averages for Unit 1875

Date	Total Duration	Total Idle Time	Total Distance
	HH:MM:SS	HH:MM:SS	km
March 12, 2013	0:07:53	0:04:26	0.40
March 13, 2013	19:35:03	7:16:44	444.4
March 18, 2013	11:00:48	5:21:43	239.1
March 19, 2013	6:33:18	3:07:34	109.5
March 20, 2013	1:43:37	0:27:00	52.2
March 21, 2013	10:13:46	4:48:11	216.7
March 22, 2013	6:09:07	2:33:51	154.9
March 25, 2013	9:07:44	4:26:11	204.4
March 26, 2013	9:53:42	4:33:55	224.2
March 27, 2013	8:03:42	3:23:15	159.7
March 28, 2013	6:03:49	2:58:19	137.7
Total	**88:32:29**	**39:01:09**	**1943.20**

Table 7 - Overall Averages for Unit 1875

Date	Speed	OttoView power supply	Trip Duration	Trip Duration	Trip Distance	Accelerator Pedal Position 1	Engine Percent Load at Current Speed	Actual Engine - Percent Torque	Engline Speed	Engine Temp. 1	Barometric Pressure	Engine Intake Manifold 1 Temp.	Outside Ambient Air Temp.
							PGN 61443/ SPN 92	PGN 61444/ SPN 513	PGN61444/ SPN 190	PGN 65262/ SPN 110	PGN 65269/ SPN 108	PGN 65270/ SPN 105	PGN 65276/ SPN 169
Average for:	**km/h**	**DC Volts**	**HH:MM:SS**	**Hours**	**km**	**percent**	**percent**	**Percent**	**rpm x10**	**C**	**kPa**	**C**	**C**
March 18, 2013	3.10	13.65	0:00:59	0.02	0.06	7.79	29.42	20.57	88.59	72.79	101.70	25.97	-12.9
March 19, 2013	21.51	13.66	5:26:14	5.44	102.78	27.77	40.58	33.10	115.90	82.21	100.61	20.68	-5.1
March 20, 2013	19.48	13.76	2:42:39	2.71	40.23	27.38	39.81	33.32	114.20	81.42	99.43	17.78	-5.1
March 21, 2013	22.62	13.86	3:09:01	3.15	67.91	29.78	42.11	35.26	118.42	82.05	99.79	20.75	-4.0
March 22, 2013	16.40	13.86	1:17:06	1.28	20.64	25.00	38.85	30.48	110.19	80.97	99.69	16.55	-5.2
March 25, 2013	21.64	13.93	1:32:03	1.53	21.51	29.45	39.5	31.96	118.61	82.51	100.27	24.71	0.5
March 26, 2013	26.53	13.92	2:04:35	2.08	31.22	34.19	41.16	34.47	124.45	83.84	100.31	28.30	-0.7
March 27, 2013	19.25	13.93	0:52:37	0.88	14.95	28.06	39.89	33.26	117.71	82.35	100.30	23.70	0.5
March 28, 2013	22.18	13.90	0:40:23	0.67	6.44	30.90	41.32	33.21	116.47	80.77	101.05	22.75	0.5
Overall Average	**19.19**	**13.83**	**1:58:24**	**1.97**	**33.97**	**26.70**	**39.18**	**31.74**	**113.84**	**80.99**	**100.35**	**22.35**	**-3.50**

The preceding data was from unit number 1875 with a second unit which is numbered 1140 also being involved in the data collection. This second unit has recorded data placed in Appendix IV of this report so as not to confuse the reader with two very similar data records.

14.0 EMTERRA CNG REFUSE TRUCKS

EMTERRA FLEET

The Emterra Group began refuse collection in Winnipeg on October 1st 2012 with a fleet of 58 CNG Crane Carrier Company (CCC) trucks that use a combination of rear-loading and side-loading Heil bodies. This is at present the largest fleet of current generation CNG trucks in the world operating in an arctic environment.

Winnipeg is exposed to severe winter weather during the months of December through to March, with arctic conditions on certain days and record low temperatures.

Figure 21 - Emterra CNG Refuse Fleet

2012 Average Temperature – Winnipeg

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average high	-12.7	-8.5	-1.1	10.3	19.2	23.3	25.8	25	18.6	10.8	-0.9	-9.7
Average low	-22.8	-18.7	-11	-2.4	4.8	10.7	13.3	11.9	6	-0.3	-9.6	-19.1
Average	**-17.8**	**-13.6**	**-6.1**	**4**	**12**	**17**	**19.5**	**18.5**	**12.3**	**5.3**	**-5.3**	**-14.4**

2012 Average Precipitation – Winnipeg

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly rainfall (mm)	0	3	7	22	58	90	71	75	52	31	6	2
	Annual average: 415											
Monthly snowfall (mm)	23	14	16	10	1	0	0	0	0	5	21	20
	Annual average: 110											
Monthly precipitation (mm)	**20**	**15**	**21**	**32**	**59**	**90**	**71**	**75**	**52**	**36**	**25**	**18**

EMTERRA VEHICLE CONFIGURATIONS

Emterra's trucks are equipped with the Cummins Westport 8.9L, ISL G engine. The CNG engines are installed into a CCC Low Entry Tilt model LET2 chassis. The chassis is fitted out with either a Heil Durapak rear loading collection body or the Heil Rapid Rail automated side loading body.

The bodies provide the platform for the top mount CNG multi tank storage system which adds height to the vehicle, but does not require the use of a longer frame as with back of cab CNG tank systems.

Figure 22 - Emterra Low Entry Refuse Truck

Figure 23 - Fuel Filter on Emterra Truck

The fuel filter is located in a convenient location for draining compressor oil, but is relatively open to the ambient weather. A secondary filter is located under the exhaust system.

Figure 24 - Secondary Filter on Emterra Truck

Figure 25 - Behind Cab Radiator Cooling System

This particular chassis also incorporates a behind the cab radiator cooling system that is constructed with a 1200 sq.in. surface area with a triple core design. A hydraulically-driven fan assembly provides supplementary cooling effect if necessary.

The Emterra vehicles have a standard dry air filtration system with a ram air intake plenum that extends above the rear left hand side of the cab.

Figure 26 - Air Intake Plenum

EMTERRA REFUELING STATION

Truck refueling is accomplished via a bumper mount refueling connection that is compliant with the ANSI NGV 3.1 standards. The refueling station used to refuel the trucks is a time fill system that also has the capabilities to rapid fill if necessary.

Figure 27 - Fill Post with Pressure Gauge

Figure 28 - Time Fill Post & Truck

The refueling needs of the fleet are met via a Clean Energy CNG refueling station. The station utilizes a multi-stage compressor that has the maximum capability to operate at 1,000 SCFM. The maximum inlet pressure of this system is 25 psig, but normal operating conditions at this station are at a constant 20 psig. The compressor station is also equipped with a high side suction dryer to ensure that the fuel supply is dried for use in CNG-equipped vehicles.

Figure 29 - Compressor Station Enclosure

Figure 30 - Equipment Inside Enclosure

COLD WEATHER EXPERIENCE IN ARCTIC CONDITIONS

The fleet initially performed according to expectations. However, with the advent of colder weather in January and February where the ambient temperatures reached – 25 C to – 35 C and included some days with arctic conditions of -32 C or lower, a number of cold weather-related issues arose which resulted in many of the trucks being unable to perform according to their intended duty cycle.

The radiator cooling system is located behind the cab in the Emterra trucks, and so it is not within the confines of the engine compartment where it would be exposed to heat build-up in the compartment from the engine operation. It appears that the arctic temperatures experienced did not allow the engine coolant to reach the required operating temperatures with this vehicle design in the absence of winter aids. Issues such as ice build-up in the air intake were related to the engine operating below its designed temperature of about 80 C, and an inability to maintain the inlet air temperature above 0 C.

It is important to recognize that these cold weather operational issues were not related to the vehicles being designed to operate on natural gas. They were related to the vehicle's design and the need for appropriate winter aids to be added to allow it to operate satisfactorily in extreme cold weather environments. This would be true for a gasoline engine, a diesel engine, or a natural gas engine. Some vehicle designs, of course, lend themselves to easier application of winter aids and should be considered for use in extreme arctic environments.

The only natural gas issue related to the cold weather experience was the incidence of frozen fuel filters. It was not clear if this was a result of gelling of compressor oil in the extreme cold or from ingress of moisture creating ice in the filters. Locating the fuel filters within the engine compartment would reduce the likelihood of this recurring or providing auxiliary heating to the filters. It is possible that fuel filter contamination could be a result of moisture collected while refueling the vehicles at stations other than Emterra's CNG station in transport from the truck manufacturing plant in Alabama to Winnipeg at the time of delivery of the vehicles.

There is a need to recognize that water is a potential contaminant in CNG automotive fuel and should not be present in any amount that will interfere with vehicle operation. CNG fuel needs to be very dry and, the colder the ambient temperature becomes, the drier the gas has to be. It becomes critical that the dew point (or frost point) of the fuel needs to be below the lowest ambient temperature in which the vehicles will operate. The dew point of the fuel may be satisfactory at -20 C for example, with the relative humidity below 100%, but when the temperature reaches -30 C and below, the dew point of the fuel may be reached at a relative humidity of 100% causing condensation which will freeze in fuel filters.

It should also be recognized that the dew point of a gas increases as its pressure increases. Therefore although the dew point may be low when the gas is supplied to the compressor, it will be significantly higher when the gas leaves the compressor and enters the vehicle. The performance of the dryer is therefore critical to minimize water contamination in order to achieve satisfactory operation of natural gas vehicles in extreme cold weather.

It is also possible to install a precision dew point monitor at the dryer control panel with a digital dew point indication in degrees C or F. The moisture sensor is installed at the dryer outlet to continuously verify the dew point. Two hygrometer set points can be factory adjusted; the first to signal deteriorating dew point performance and the second to indicate when dryer regeneration is required.

If such a dew point monitor is installed, and the dew point of the gas controlled, then freezing of fuel filters and other components should never be encountered. This type of equipment installation should be considered critical for use on a fuel station when vehicles are exposed to arctic weather conditions.

15.0 CONCLUSIONS

- In order to achieve successful operation of any vehicle in a cold weather environment, and especially in winter and arctic weather conditions, the vehicles must be winterized per the engine manufacturer's recommendations with appropriate winter aids As the operating climate becomes colder, an increasing number of winter aids, vehicle modifications, vehicle preparation, operating practices and maintenance procedures will be required. These modifications are required independent of the fuel used to power the vehicle.

- Groupe EBI's fleet of CNG refuse trucks has operated successfully with minimal winter aids of coolant and oil pan heaters at temperatures down to -20C. There have been very few reports of cold weather issues from the fleet over two years of operation. The percent utilization of the fleet is high with minimal down time. Vehicle operational data collected from data loggers installed on two of the trucks indicate that the engine consistently operates within specified limits for coolant temperature operating levels and exhibited no reliability issues during the timeframe of data collection.

- By far the most common issues which can affect satisfactory performance of CNG vehicles are fuel quality and contaminants. Moisture level, heavy hydrocarbons, and sulphur content in the fuel can create problems. Similarly, contamination from compressor oil carry over can also be an issue. Water content causing freezing of fuel filters and regulators is the most common complaint from fleets operating CNG vehicles in cold climates. The lower the ambient temperature, the drier the natural gas has to be. The performance of the dryer at the compressor station is therefore critical to achieving satisfactory operation of natural gas vehicles in extreme cold weather.

- The fleet of Emterra CNG refuse trucks operating in Winnipeg had its first winter experience in 2012-2013 and experienced numerous operational issues most of which were related to the base vehicle design being susceptible to arctic weather conditions and the need for extensive cold weather aids and vehicle modifications to allow the vehicles to reach normal engine operating temperatures. The incidence of frozen fuel filters and regulators related to the need to increase coolant flow to the regulator, and likely also to the dew point (or frost point) of the fuel reaching a critical condition equivalent to the ambient temperature, causing condensation which will freeze in fuel filters.

- It is possible to install dew point meters on the outlet of compressor stations which will detect when the dew point reaches a critical condition based on water content and ambient temperature, and signal a need for servicing the dryer at the station especially as the temperature falls to arctic conditions. Use of such a monitor would seem very beneficial for fueling CNG vehicles exposed to cold weather and especially in severe arctic conditions.

APPENDIX I

DESCRIPTION OF OTTOVIEW-CVS42 DATA LOGGER

The OttoView-CVS42 model is an autonomous data logging system for commercial vehicular applications such as the OttoFleet Management System (OFMS) as well as for research projects requiring detailed trip logs. The device collects, stores, and transmits vehicular and driving behaviour data, and also provides drivers with audible and visual feedback relating to their driving behaviour as well as numerous vehicle performance metrics such as fuel economy and CO2 emissions. The comprehensive nature of the data logging capability combined with driver-feedback is based upon years of research in OBDII and GPS-based product developments and research-based project deployments.

The device includes an integrated touch-screen display, an OBDII vehicle communications core, an internal GPS module and topology that supports the Otto-driving companion® driving behaviour functionality using municipal coverage map PSL information, and an integrated cellular radio for over-the-air trip report transmissions. The standard package contains the following items:

- One OttoView™-CVS42 device.
- One cable with SAEJ1962M plug and RJ45 8P8C connector.
- One SD Memory Card (2 GByte).
- Back plate dual-T mount (Arkon bracket compatible – www.arkon.com)
- CVS Application utility for device configuration and data management

The device will connect to 1996 and newer vehicle model years, as defined in a technical standard developed by the Society of Automotive Engineering (SAE) , using a standard OBDII SAEJ1962 cable. The device is mounted under the console-dash of the vehicle within 1m of the DLC.

The device is powered entirely through the vehicle's OBDII connector and will operate over a voltage range of +9VDC to +12 VDC. The device will turn-off (sleep mode) approximately 60 seconds after the vehicle is turned off, thereby not imposing any load on the vehicle's battery and electrical system. The device interrogates the ECM for data and does not modify/change any vehicle parameters.

OttoView-CV242

SOURCE:

http://www.persentech.com/index.php/our-products-and-services/ottoview-product-family/111-ottoview-cvs42

FOR FURTHER INFORMATION:

www.persentech.com

APPENDIX II
COLD WEATHER OPERATION

CUMMINS WESTPORT ISL G NATURAL GAS ENGINE – DECEMBER 2012

ISL G Maintenance Intervals - Refuse

Refuse Truck	Hours	Miles	Kilometers	Months
Check CAC cooler, piping and Air Cleaner	250	3,000	5,000	3
Oil & Filter*	500	6,000	10,000	6
Coolant Filter**	None[1]	None[1]	None[1]	None[1]
Spin-on Fuel Filter	1,000	12,000	20,000	12
Spark Plugs	1,500	18,000	30,000	18
Standard Coolant	2,000	24,000	40,000	24
Overhead Adjustment***	2,000	24,000	40,000	24
Air Cleaner/Element	Follow vehicle manufacturers published recommendations			

Initial
Overhead
Adjustment
@
1,000 hours
12,000 miles
12 months

- Distance intervals will increase or decrease based on average speeds.
- The default interval is the hours shown. Perform maintenance at hours, distance, or months indicated, whichever comes first
- Refer to the Owners Manual for complete details on Maintenance Intervals

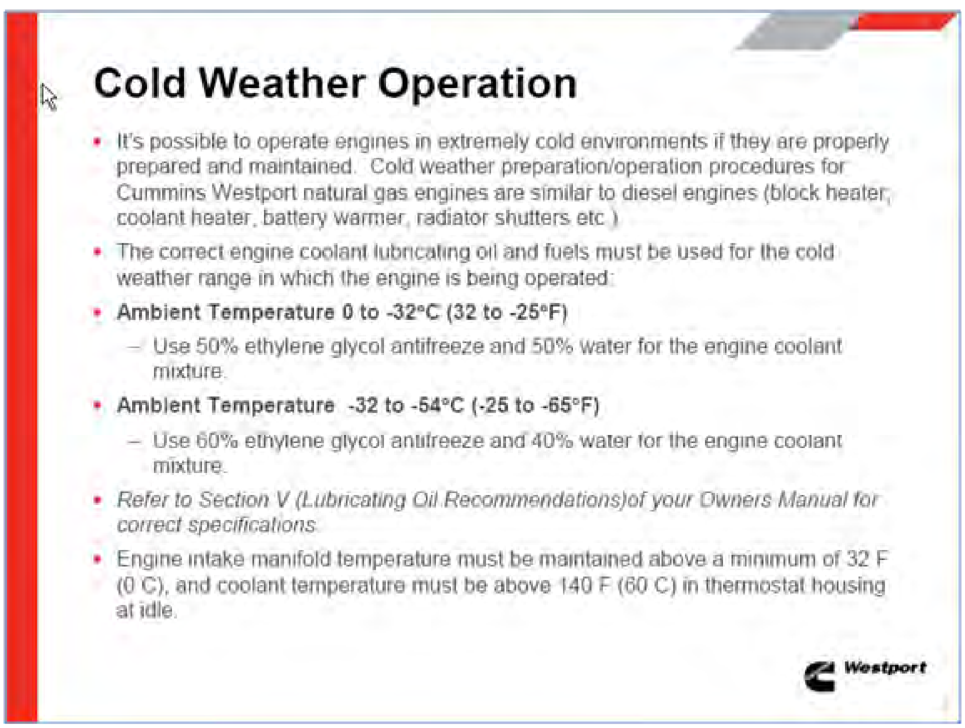
[1] If the engine is equipped with an optional coolant filter, the coolant filter will need to be replaced at the same intervals as the oil filter. Regardless of whether the engine is or is not equipped with a coolant filter, SCA/DCA additive levels must be checked according to the interval listed in the Owners Manual.

* Assuming normal duty cycle/based on 12 mph average speed
** Do not change if SCA above 3
*** Initial Overhead Adjustment at 1,000 hours.

Westport

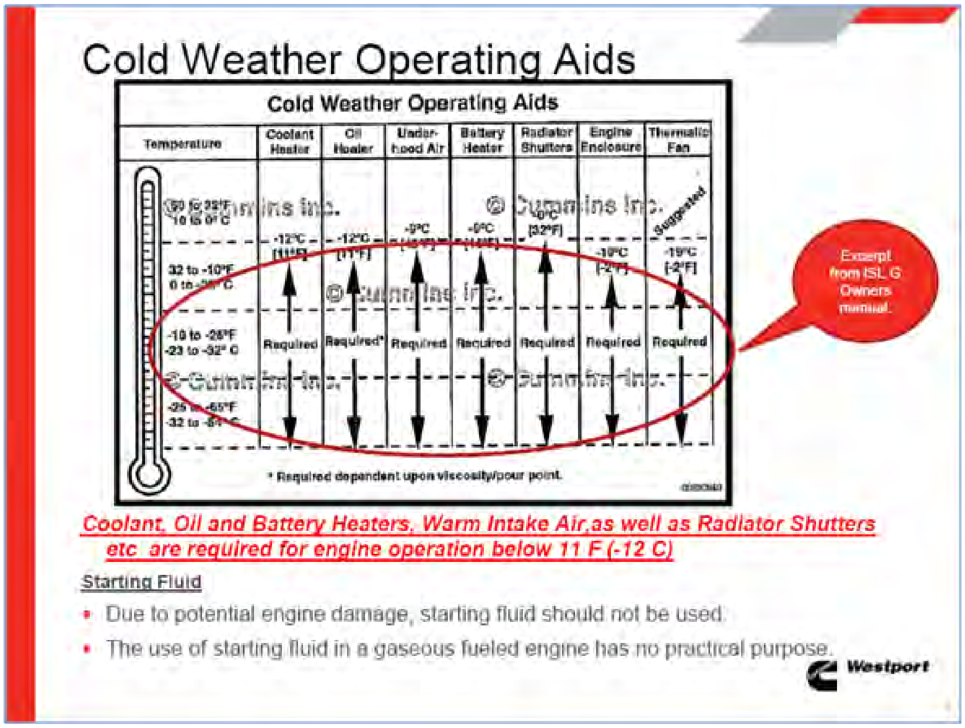
APPENDIX II (CONT'D)
COLD WEATHER OPERATION

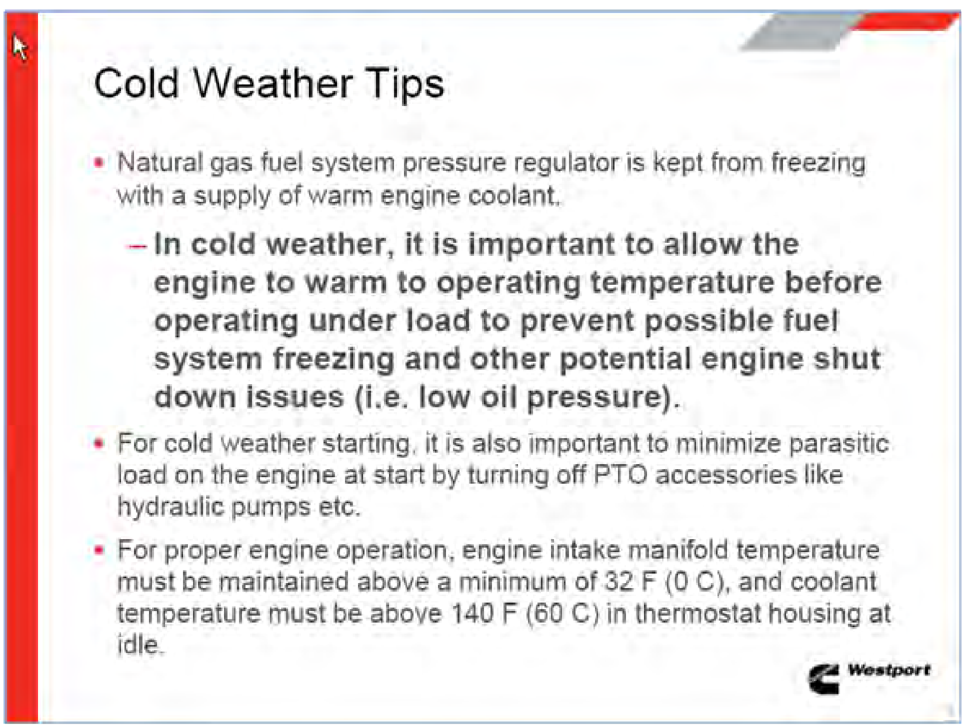
CUMMINS WESTPORT ISL G NATURAL GAS ENGINE



APPENDIX II (CONT'D)
COLD WEATHER OPERATION

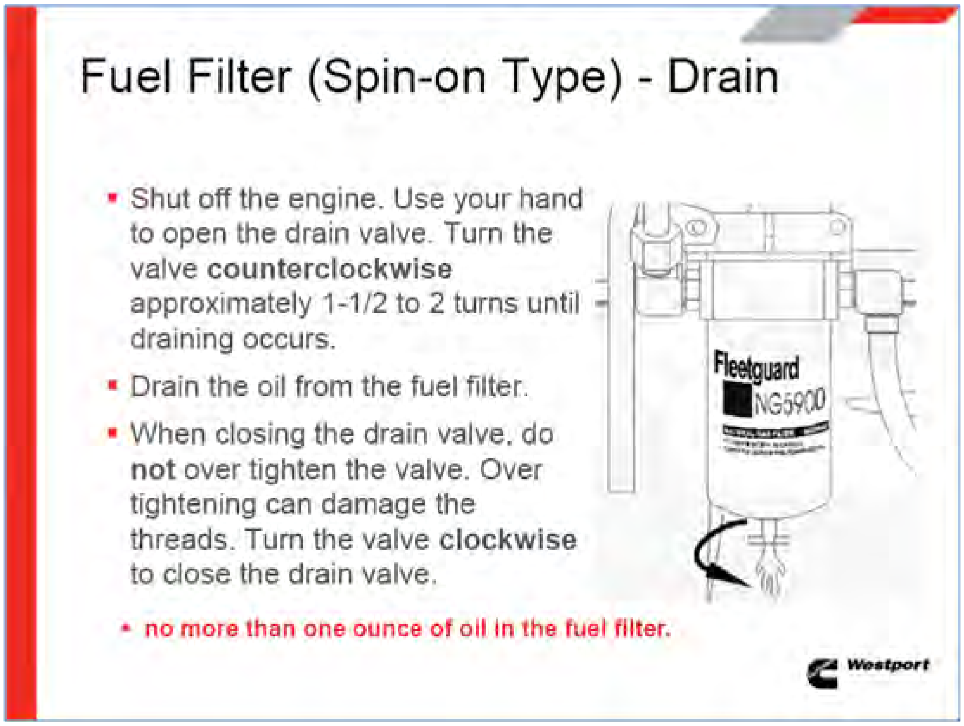
CUMMINS WESTPORT ISL G NATURAL GAS ENGINE

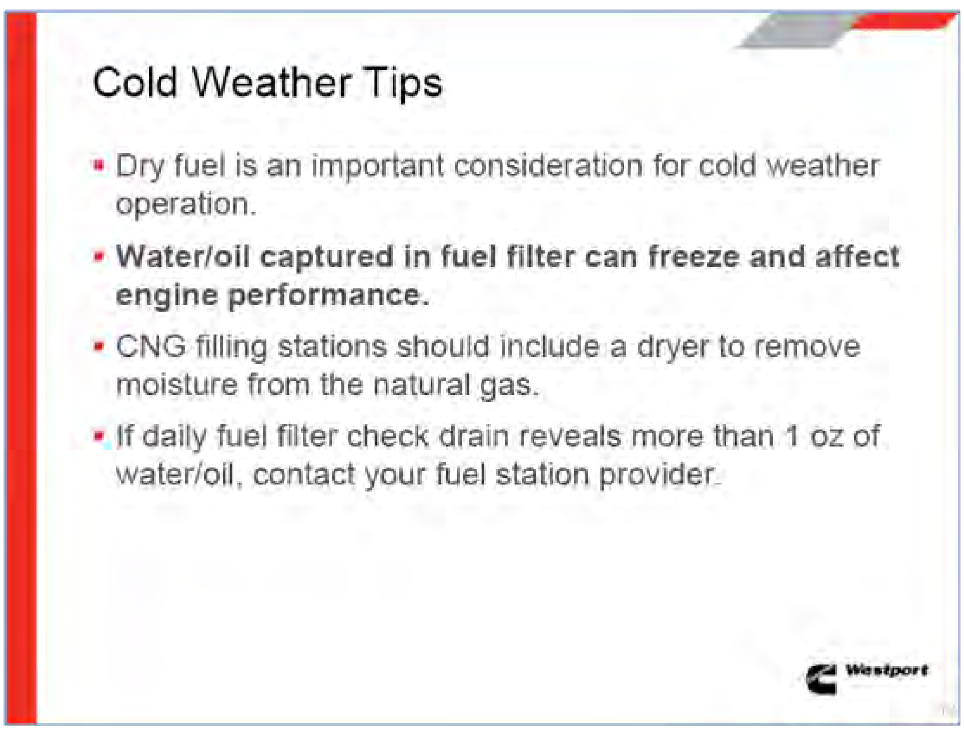




APPENDIX II (CONT'D)
COLD WEATHER OPERATION

CUMMINS WESTPORT ISL G NATURAL GAS ENGINE





APPENDIX III
SAMPLE EBI DAILY TRIP REPORT

03/01/2013 08:24 FAX 450 836 7913 Atelier mecanique EBI 0002/0005

1875

Projet EBI

Relevé quotidien

Nom: S. Brisebois | N° d'unité 1875 | Date : 27.02.2013

1. Enreg. les heures d'exploitation : Départ 6,30 Arrivée 7,50
2. Odomètre : Départ 12182 Arrivée 12361
3. Température de l'air ambiant : -2 C
4. Pression d'essence : Départ 3,400 Arrivée 1,400
5. État au départ : Branché ✓ Démarrage à froid ____
6. Niveau d'huile : Acceptable ✓ Bas ____ Quantité ajoutée ____ L
7. Niveau liquide de refroidissement : Acceptable ✓ Bas ____ Quantité ajoutée ____ L
8. Pression d'hile au démarrage : 70 psi/kPa
9. Indicateur de dépression du filtre à air : Acceptable ✓ Réparation nécessaire ____
10. Pannes moteur : Actif ✓ Inactif ____
11. Utilisation de garniture hivernale : Non ✓ Oui ____ fermé à ____ %
12. Durée de marche : 0 à 2 h ____ 2 à 4 h ____ 4 à 6 h ____ 8 à 10 h ✓
13. Pannes liées au moteur : ____
14. Pannes non liées au moteur : ____
15. Préoccupations/commentaires de l'utilisateur : ____

APPENDIX III (CONT'D)
SAMPLE EBI DAILY TRIP REPORT

ebi environnement

Évaluation de la qualité de la ronde de sécurité

1139 Conducteur : D. Savoie Date : 07-03-013 Heure : 5h35

Le conducteur a vérifié :

	Oui	Non
Frein de service	☑	☐
Frein de stationnement	☑	☐
Direction	☑	☐
Klaxon	☐	☑
Essuie-glaces (lave-glace)	☑	☐
Rétroviseurs	☑	☐
Matériel de secours	☑	☐
Niveau de l'extincteur	☑	☐
Éclairage et signalisation	☑	☐
Fuite des liquides	☑	☐
Fuite sous le véhicule	☑	☐
Valve hydraulique	☑	☐
Niveau d'huile servodirection	☑	☐
Visuel niveau de carburant	☑	☐
Bouton d'urgence pour pompe	☑	☐

	Oui	Non
Niveau d'huile (HUB de roue)	☑	☐
Niveau d'huile	☑	☐
Niveau d'antigel	☑	☐
Niveau d'huile hydraulique	☑	☐
Niveau d'huile transmission	☑	☐
Pneus	☑	☐
Roues	☑	☐
Suspension	☑	☐
Cadre châssis	☑	☐
Alarme de recul	☑	☐
Courroies (jeu, usure)	☑	☐
Appareils d'arrimage	☑	☐
Pelle et Balais	☑	☐
Constat amiable	☑	☐

Le document est complété correctement Oui ☑ Non ☐

Le conducteur connaît la procédure à suivre pour effectuer la ronde de sécurité : Oui ☑ Non ☐
(Se référer au document guide de vérification avant le départ et à la politique des filiales de EBI)

Formation requise : Oui ☐ Non ☑ Mesure disciplinaire requise : Oui ☐ Non ☑

Réévaluation prévue le : Le 1139 esT Propre

Remarques : FaiT de la Bonne Façon

[illegible]
Signature du chauffeur

[illegible]
Nom de la personne qui évalue la qualité de la ronde

07 Mars 2013
Date

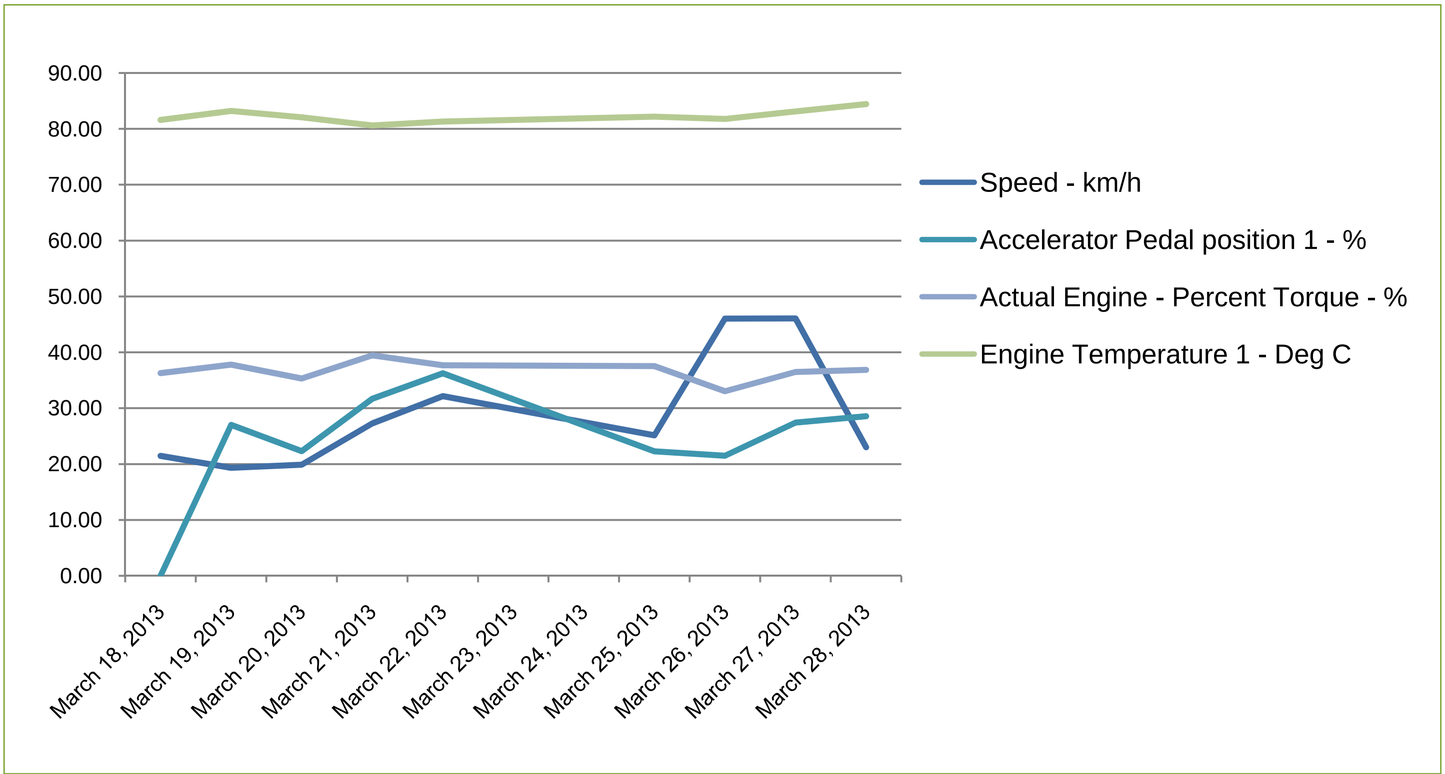
Créé par [illegible]

APPENDIX IV
DATA FROM EBI UNIT 1140

Table 1 - Unit 1140

Date	Speed	Accelerator Pedal Position 1	Actual Engine - Percent Torque	Engine Temperature 1
			PGN 61444/SPN 513	PGN 65262/SPN 110
Average for:	km/h	Percent	Percent	C
March 18, 2013	21.47	0.00	36.25	81.60
March 19, 2013	19.34	27.01	37.78	83.20
March 20, 2013	19.9	22.29	35.29	82.06
March 21, 2013	27.29	31.67	39.45	80.60
March 22, 2013	32.16	36.24	37.66	81.30
March 25, 2013	25.14	22.26	37.53	82.17
March 26, 2013	46.02	21.48	33.02	81.76
March 27, 2013	46.06	27.42	36.46	83.11
March 28, 2013	23.01	28.56	36.86	84.44

Graph 1 - Unit 1140

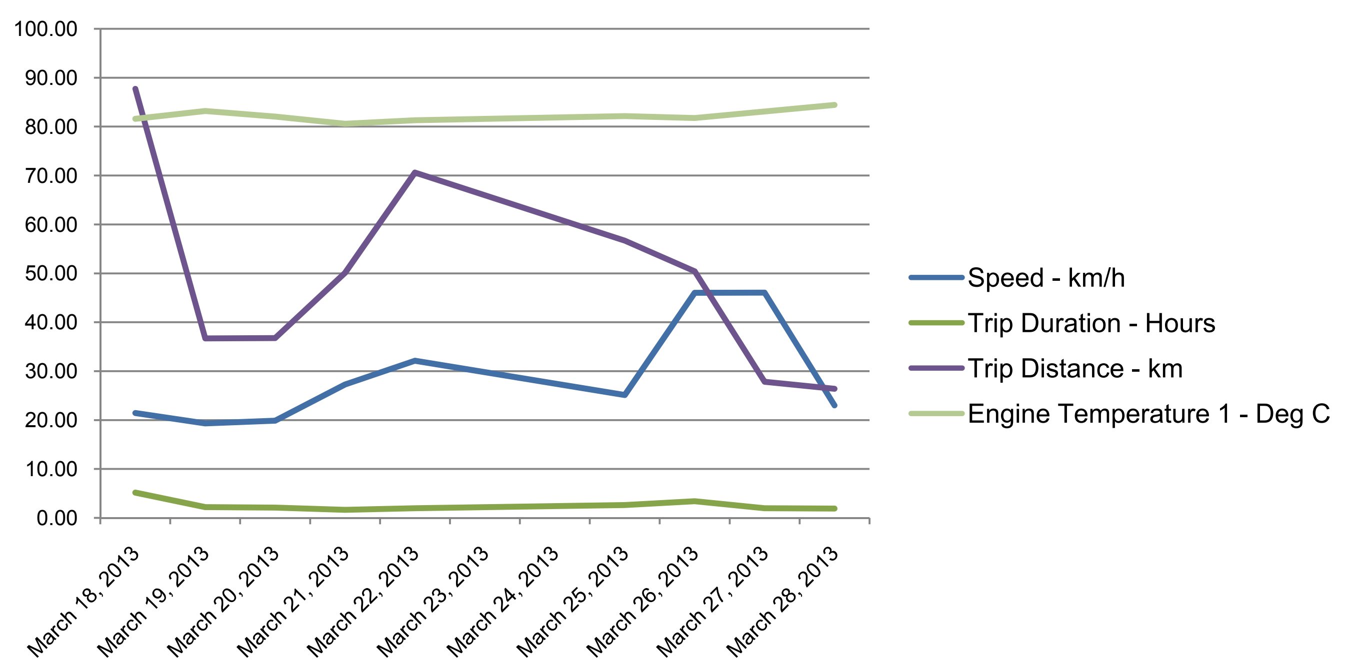


APPENDIX IV (CONT'D)
DATA FROM EBI UNIT 1140

Table 2 - Unit 1140

Date	Speed	Trip Duration	Trip Distance	Engine Temperature 1
				PGN 65262/SPN 110
Average for:	km/h	Hours	km	C
March 18, 2013	21.47	5.18	87.73	81.60
March 19, 2013	19.34	2.22	36.69	83.20
March 20, 2013	19.9	2.10	36.77	82.06
March 21, 2013	27.29	1.65	50.09	80.60
March 22, 2013	32.16	1.97	70.62	81.30
March 25, 2013	25.14	2.62	56.70	82.17
March 26, 2013	46.02	3.43	50.43	81.76
March 27, 2013	46.06	1.99	27.84	83.11
March 28, 2013	23.01	0.08	1.92	84.44

Graph 2 - Unit 1140

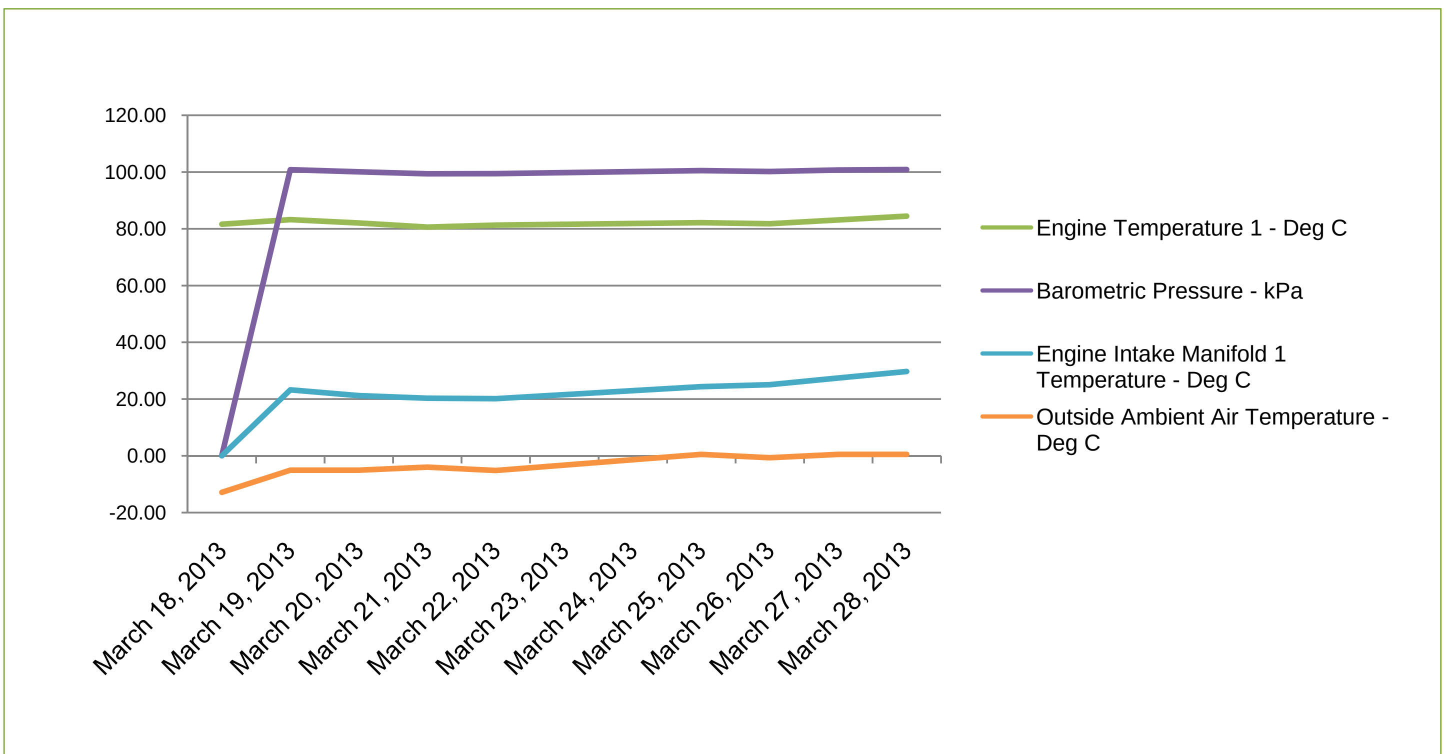


APPENDIX IV (CONT'D)
DATA FROM EBI UNIT 1140

Table 3 - Unit 1140

Date	Engine Temperature 1	Barometric Pressure	Engine Intake Manifold 1 Temperature	Outside Ambient Air Temperature
	PGN 65262/SPN 110	PGN 65269/SPN 108	PGN 65270/SPN 105	PGN 65276/SPN 169
Average for:	C	kPa	C	C
March 18, 2013	81.60	0.00	0.00	-12.9
March 19, 2013	83.20	100.86	23.25	-5.1
March 20, 2013	82.06	100.09	21.20	-5.1
March 21, 2013	80.60	99.43	20.30	-4.0
March 22, 2013	81.30	99.48	20.13	-5.2
March 25, 2013	82.17	100.55	24.38	0.5
March 26, 2013	81.76	100.22	25.05	-0.7
March 27, 2013	83.11	100.74	27.40	0.5
March 28, 2013	84.44	100.90	29.72	0.5

Graph 3 - Unit 1140

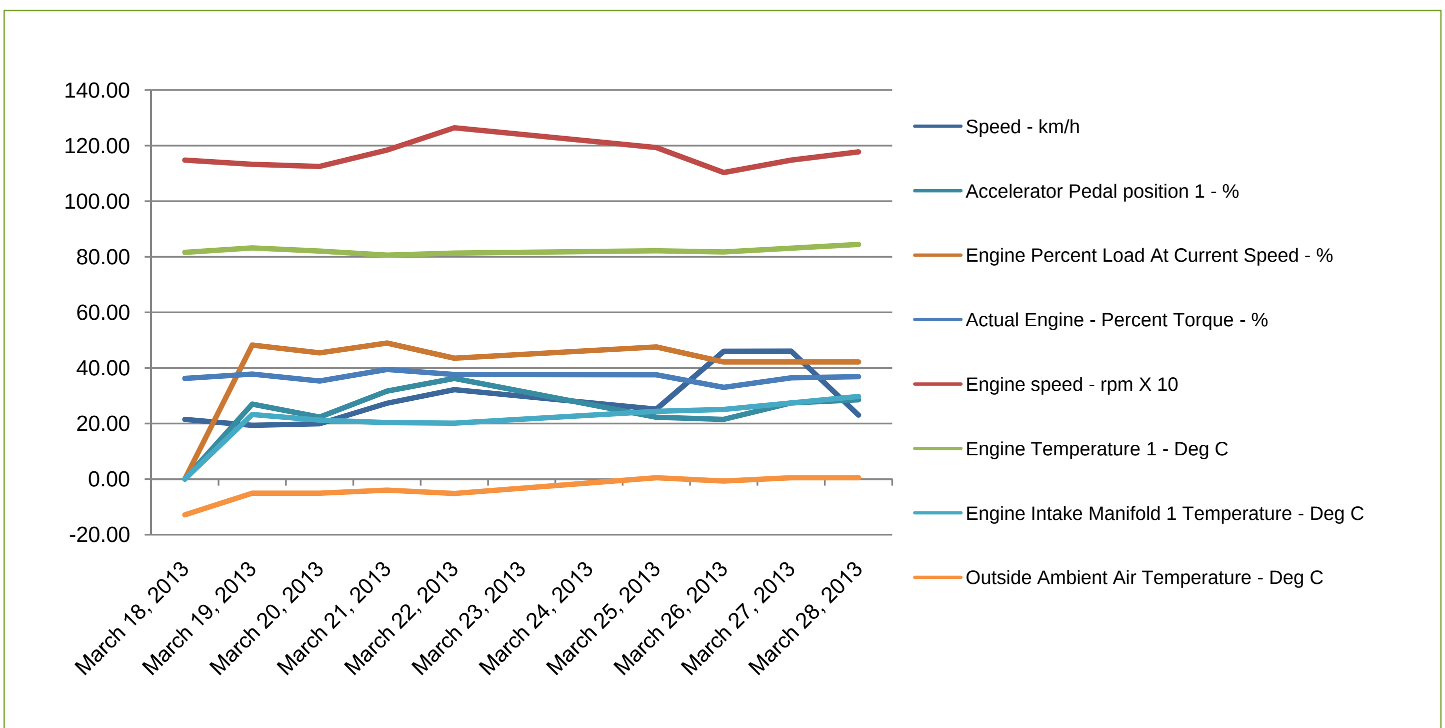


APPENDIX IV (CONT'D)
DATA FROM EBI UNIT 1140

Table 4 - Unit 1140

Date	Speed	Accelerator Pedal Position 1	Engine Percent Load at Current Speed	Actual Engine - Percent Torque	Engline Speed	Engine Temperature 1	Engine Intake Manifold 1 Temperature	Outside Ambient Air Temperature
			PGN 61443/ SPN 92	PGN 61444/ SPN 513	PGN61444/ SPN 190	PGN 65262/ SPN 110	PGN 65270/ SPN 105	PGN 65276/ SPN 169
Average for:	**km/h**	**percent**	**percent**	**Percent**	**rpm x10**	**C**	**C**	**C**
March 18, 2013	21.47	0.00	36.25	36.25	114.80	81.60	0.00	-12.9
March 19, 2013	19.34	27.01	37.78	37.78	113.29	83.20	23.25	-5.1
March 20, 2013	19.9	22.29	35.29	35.29	112.51	82.06	21.20	-5.1
March 21, 2013	27.29	31.67	39.45	39.45	118.36	80.60	20.30	-4.0
March 22, 2013	32.16	36.24	37.66	37.66	126.42	81.30	20.13	-5.2
March 25, 2013	25.14	22.26	37.53	37.53	119.31	82.17	24.38	0.5
March 26, 2013	46.02	21.48	33.02	33.02	110.33	81.76	25.05	-0.7
March 27, 2013	46.06	27.42	36.46	36.46	114.81	83.11	27.40	0.5
March 28, 2013	23.01	28.56	36.86	36.86	117.73	84.44	29.72	0.5

Graph 4 - Unit 1140

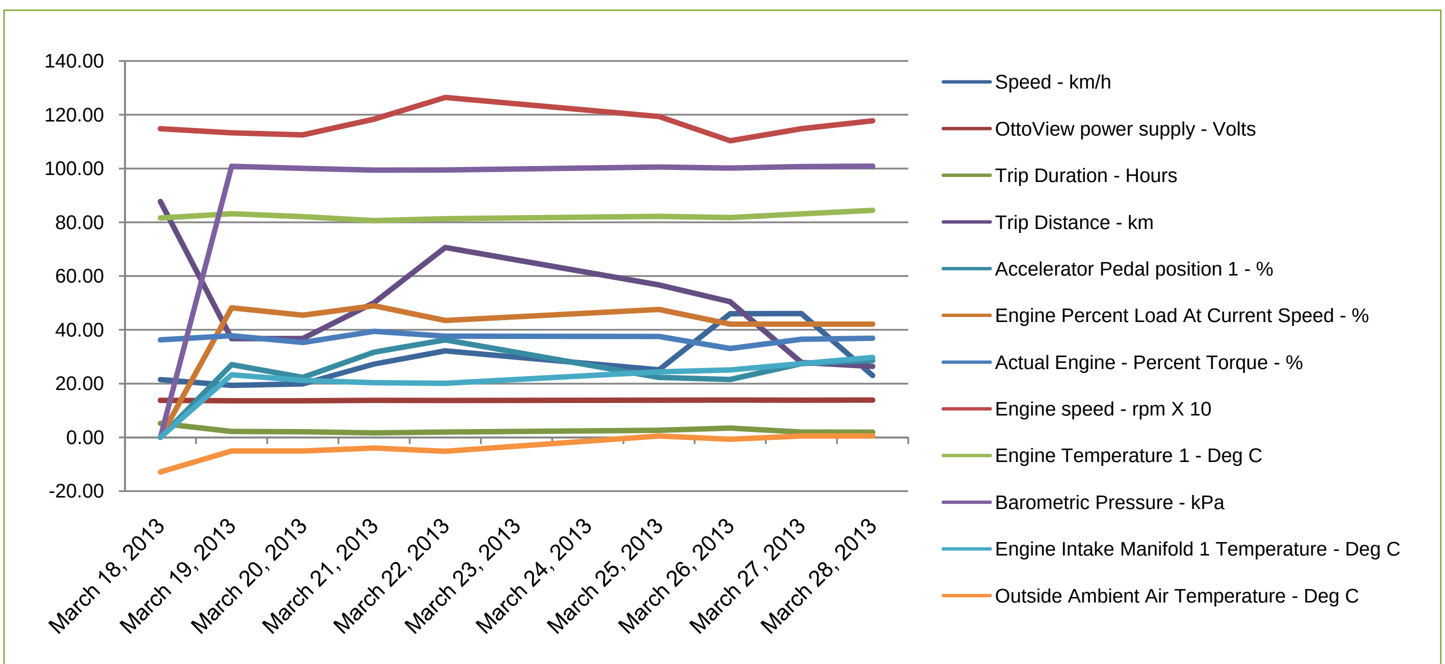


APPENDIX IV (CONT'D)
DATA FROM EBI UNIT 1140

Table 5 - Overall Data from Unit 1140

Date	Speed	OttoView power supply	Trip Duration	Trip Duration	Trip Distance	Accelerator Pedal Position 1	Engine Percent Load at Current Speed	Actual Engine - Percent Torque	Engline Speed	Engine Temp. 1	Barometric Pressure	Engine Intake Manifold 1 Temp.	Outside Ambient Air Temp.
							PGN 61443/ SPN 92	PGN 61444/ SPN 513	PGN61444/ SPN 190	PGN 65262/ SPN 110	PGN 65269/ SPN 108	PGN 65270/ SPN 105	PGN 65276/ SPN 169
Average for:	**km/h**	**DC Volts**	**HH:MM:SS**	**Hours**	**km**	**percent**	**percent**	**Percent**	**rpm x10**	**C**	**kPa**	**C**	**C**
March 18, 2013	21.47	13.76	5:10:35	5.18	87.73	0.00	36.25	36.25	114.80	81.60	0.00	0.00	-12.9
March 19, 2013	19.34	13.61	2:13:02	2.22	36.69	27.01	37.78	37.78	113.29	83.20	100.86	23.25	-5.1
March 20, 2013	19.9	13.62	2:05:54	2.10	36.77	22.29	35.29	35.29	112.51	82.06	100.09	21.20	-5.1
March 21, 2013	27.29	13.77	1:39:00	1.65	50.09	31.67	39.45	39.45	118.36	80.60	99.43	20.30	-4.0
March 22, 2013	32.16	13.70	1:58:23	1.97	70.62	36.24	37.66	37.66	126.42	81.30	99.48	20.13	-5.2
March 25, 2013	25.14	13.81	2:37:11	2.62	56.70	22.26	37.53	37.53	119.31	82.17	100.55	24.38	0.5
March 26, 2013	46.02	13.84	3:25:43	3.43	50.43	21.48	33.02	33.02	110.33	81.76	100.22	25.05	-0.7
March 27, 2013	46.06	13.79	1:59:35	1.99	27.84	27.42	36.46	36.46	114.81	83.11	100.74	27.40	0.5
March 28, 2013	23.01	13.86	1:54:58	1.92	26.39	28.56	36.86	36.86	117.73	84.44	100.90	29.72	0.5
Overall Average	**28.93**	**13.75**	**2:33:49**	**2.56**	**49.25**	**24.10**	**40.99**	**36.70**	**116.39**	**82.25**	**89.14**	**21.27**	**-3.50**

Graph 5 - Overall Data for Unit 1140



APPENDIX IV (CONT'D)
DATA FROM EBI UNIT 1140

Table 6 - Overall Averages for Unit 1140

Date	Total Duration	Total Idle Time	Total Distance
	HH:MM:SS	HH:MM:SS	km
March 12, 2013	19:13:38	6:36:24	448.50
March 13, 2013	0:24:12	0:24:12	0.00
March 18, 2013	10:21:10	4:54:19	225.60
March 19, 2013	8:56:01	3:49:08	177.50
March 20, 2013	8:02:57	3:43:26	166.20
March 21, 2013	6:52:48	2:24:43	191.50
March 22, 2013	6:42:50	1:37:46	221.00
March 25, 2013	5:30:51	2:30:55	141.70
March 26, 2013	10:01:29	5:03:59	215.90
March 27, 2013	10:00:02	4:13:31	212.60
March 28, 2013	7:20:07	3:17:59	155.60
Total	**93:26:05**	**38:36:22**	**2156.10**

APPENDIX IV (CONT'D)
DATA FROM EBI UNIT 1140

Table 7 - Overall Averages from Unit 1140

Date	Speed	OttoView power supply	Trip Duration	Trip Duration	Trip Distance	Accelerator Pedal Position 1	Engine Percent Load at Current Speed	Actual Engine - Percent Torque	Engline Speed	Engine Temp. 1	Barometric Pressure	Engine Intake Manifold 1 Temp.	Outside Ambient Air Temp.
							PGN 61443/ SPN 92	PGN 61444/ SPN 513	PGN61444/ SPN 190	PGN 65262/ SPN 110	PGN 65269/ SPN 108	PGN 65270/ SPN 105	PGN 65276/ SPN 169
Average for:	**km/h**	**DC Volts**	**HH:MM:SS**	**Hours**	**km**	**percent**	**percent**	**Percent**	**rpm x10**	**C**	**kPa**	**C**	**C**
March 18, 2013	21.47	13.76	5:10:35	5.18	87.73	0.00	36.25	36.25	114.80	81.60	0.00	0.00	-12.9
March 19, 2013	19.34	13.61	2:13:02	2.22	36.69	27.01	37.78	37.78	113.29	83.20	100.86	23.25	-5.1
March 20, 2013	19.9	13.62	2:05:54	2.10	36.77	22.29	35.29	35.29	112.51	82.06	100.09	21.20	-5.1
March 21, 2013	27.29	13.77	1:39:00	1.65	50.09	31.67	39.45	39.45	118.36	80.60	99.43	20.30	-4.0
March 22, 2013	32.16	13.70	1:58:23	1.97	70.62	36.24	37.66	37.66	126.42	81.30	99.48	20.13	-5.2
March 25, 2013	25.14	13.81	2:37:11	2.62	56.70	22.26	37.53	37.53	119.31	82.17	100.55	24.38	0.5
March 26, 2013	46.02	13.84	3:25:43	3.43	50.43	21.48	33.02	33.02	110.33	81.76	100.22	25.05	-0.7
March 27, 2013	46.06	13.79	1:59:35	1.99	27.84	27.42	36.46	36.46	114.81	83.11	100.74	27.40	0.5
March 28, 2013	23.01	13.86	1:54:58	1.92	26.39	28.56	36.86	36.86	117.73	84.44	100.90	29.72	0.5
Overall Average	**28.93**	**13.75**	**2:33:49**	**2.56**	**49.25**	**24.10**	**40.99**	**36.70**	**116.39**	**82.25**	**89.14**	**21.27**	**-3.50**

APPENDIX V
ADDITIONAL DATA FROM DRIVER LOGS

Daily driver logs provided some additional information which is included below.

UNIT 1140 OVER THE 15-DAY REPORTING PERIOD FROM FEB 27, 2013 – MAR 28, 2013 REPORTED THE FOLLOWING SUPPLEMENTARY INFORMATION:

- Two active engine faults reported during the period.
- The first fault occurred March 18th with a low temperature that day of -150C; this wasn't a shutdown fault and went inactive within 10 minutes of start-up.
- The second fault occurred March 22nd with a low temperature of -100C; this fault also went away within 10 minutes of vehicle start-up.
- Cause of both faults was not disclosed and the unit was plugged in and coolant level was reported as being acceptable. Operation of the vehicle wasn't impacted by the active fault reported.
- Unit 1140 only reported using the winter front on two occasions, February 27th and 28th at which time the temperature was -10C and -20C respectively.
- Average daily fuel pressure ranged from a maximum level at full of 3,475 psi to a low of 750 psi. At shift completion, the average fuel pressure was 1,938 psi.
- Average oil pressure reading upon cold start was 77.2 psi with the unit having been plugged in 14 of 15 reported days.

UNIT 1875 OVER THE 15-DAY REPORTING PERIOD FEB 27, 2013 – MAR 28, 2013 REPORTED THE FOLLOWING SUPPLEMENTARY INFORMATION:

- Three active engine faults were reported during the time period.
- The first two occurrences were Feb, 27th and 28th where the temperature ranged from -20C - +20C and again on March 22, 2013 when it was reported to be a low of -110C on the EBI property.
- The start-up oil pressure average reading was 77.7 psi with this unit having been plugged in every night at the end of the shift.
- Average daily fuel pressure usage from a maximum level at full of 3,500 psi to a low of 700 psi. At shift completion, the average fuel pressure was 2,185.7 psi.

APPENDIX V (CONT'D)
ADDITIONAL DATA FROM DRIVER LOGS

UNIT 1875

Daily Driver Logs				
Driver #1	All values are actual values observed by drivers			Unit 1875
Date	**Air Temp C**	**Oil PSI at Start-up**	**Hrs of Service**	**Fuel PSI Usage**
2/27/2013	-2	70	8-10 hrs	2000
2/28/2013	2	80	8-10 hrs	2300
3/6/2013	2	80	8-10 hrs	2500
3/7/2013	-2	70	8-10 hrs	2500
3/11/2013	2	77	8-10 hrs	2100
3/12/2013	4	76	8-10 hrs	2300
3/15/2013	-14	80	8-10 hrs	2000
3/18/2013	-16	80	8-10 hrs	2000
3/19/2013	-7	80	8-10 hrs	2400
3/20/2013	-6	80	8-10 hrs	1800
3/22/2013	-11	80	8-10 hrs	1800
3/26/2013	-2	80	8-10 hrs	2000
3/27/2013	-2	80	8-10 hrs	1900
3/28/2013	0	75	8-10 hrs	3000
Avg temp	**-3.714285714**			
Avg Oil PSI at Start-up		**77.71428571**		
Av Hrs of Service			**8-10 hrs**	
Average Fuel PSI Usage				**2185.714286**

APPENDIX V (CONT'D)
ADDITIONAL DATA FROM DRIVER LOGS

UNIT 1140

Daily Driver Logs				
Driver #2	All values are actual values observed by drivers			Unit 1140
Date	**Air Temp C**	**Oil PSI at Start-up**	**Hrs of Service**	**Fuel PSI Usage**
2/27/2013	-1	75	8-10 hrs	1950
2/28/2013	-2	75	8-10 hrs	2000
3/6/2013	0	75	8-10 hrs	2400
3/7/2013	-3	75	8-10 hrs	2350
3/11/2013	1	65	8-10 hrs	2050
3/12/2013	4	75	8-10 hrs	1400
3/15/2013	-12	90	8-10 hrs	2000
3/18/2013	-15	80	8-10 hrs	1950
3/19/2013	-3	75	8-10 hrs	2000
3/20/2013	-3	80	8-10 hrs	1600
3/22/2013	-10	80	8-10 hrs	1600
3/26/2013	-2	78	8-10 hrs	1800
3/27/2013	-1	78	8-10 hrs	2275
3/28/2013	0	n/a	8-10 hrs	3000
Avg temp	**-3.357142857**			
Avg Oil PSI at Start-up		**77**		
Av Hrs of Service			**8-10 hrs**	
Average Fuel PSI Usage				**2026.785714**