Demonstration of Diesel Fired Coolant Heaters in School Bus Applications

Final Report

Prepared for

The New York State
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Albany, NY

Joseph Tario
Senior Project Manager

and

The New York State
Department of Transportation

Mike Smith
Director
Office of Safety & Security Services
Passenger Carrier Safety Bureau

Prepared by

Brown Coach, Inc.
Amsterdam, NY

Stephen Brown
Vice President

Rensselaer Polytechnic Institute
Troy, NY

Stephen Rock
Research Scientist
&
Raymond Puffer
Program Director

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ABSTRACT

Engine block pre-heating can reduce fuel consumption, decrease pollution, extend engine life, and it is often necessary for reliably starting diesel engines in cold climates. This report describes the application and experience of installing 36 diesel fired coolant heaters in a demonstration school bus fleet. This demonstration was conducted at Brown Coach facilities in Amsterdam, New York and Scotia, New York. Benefits beyond those obtainable when using more traditional immersion electric block heating were experienced, including: Pre-heating to near full operating temperature without need for engine idling; Inter-run cabin auxiliary heating to facilitate anti-idling; and Supplemental heat during the drive cycle for better engine efficiency, reduced emissions, and increased passenger comfort.

Keywords: Diesel Fired Coolant Heater, Engine Block Pre-Heating, Idle Reduction, School Bus Transportation

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SUMMARY

The benefits of pre-heating internal combustion engines in cold climates are well documented and include: significantly reduced fuel consumption, decreased pollution, extended engine life, and reliable cold-start operation. While this can be done use electrically powered coolant immersion heaters, diesel fired coolant heaters offer an alternative with additional functionality including:

- Pre-heating to near full operating temperature without need for engine idling and reduced cold-start emissions;

- Inter-run cabin auxiliary heating to facilitate anti-idling;

- Supplemental heat during the drive cycle for better engine efficiency, reduced emissions, and increased passenger comfort.

This report describes results from a demonstration project on which three dozen diesel fired coolant heaters were installed in a school bus fleet and monitored for one heating season. Heaters were located behind the rear axle and exhausted at the rear of the bus such that interlocks were not necessary to prevent heater operation and possible exhaust infiltration of the passenger cabin during the drive cycle. Proheat X45 heaters manufactured by Teleflex were selected for this demonstration based on past experience with the heaters and their data logging capability. Each heater generates approximately 45,000 BTUs/hr, which unlike some lower-output alternatives, proved to be sufficient to provide supplemental heat during engine operation. Brown Coach had installation and maintenance experience with these heaters on the motor coaches fleet we operate, and consider the Proheat brand to be the state-of-the-art in commercially available diesel fired heating technology.

Improved technology has lead to highly efficient engines in school buses that lack reject heat sufficient to fully heat the bus cabin in cold ambient conditions. Properly configured, the fuel fired coolant heaters can be used to provide supplemental heat during the drive cycle that both increases passenger comfort while ensuring the engine maintains temperature for reduced emissions. As emissions regulations are further tightened, this later consideration will become of increasing importance across all bus operations.

1. INTRODUCTION

Cold diesel engines start poorly or fail to start reliably, and they produce considerable emissions until they warm up [Hoglund, 1998]. Pre-heating the engine to near operating temperature ensures the engine starts reliably, minimizes cold-start emissions, and facilitates compliance with anti-idling initiatives. New engines also suffer from being so efficient that, in bus applications where the cabin space is large relative to the engine used, there is insufficient reject heat available from the engine to adequately heat the cabin. This may lead to cooling the engine to a suboptimal operating temperature or result in passenger discomfort.

A particular finding of note comes from the joint New York Power Authority (NYPA), New York State Energy Research and Development Authority (NYSERDA) Hybrid Electric School Bus Demonstration Project. Brown Transportation, Inc., in partnership with Schenectady City Schools, is the operator in year one of the project. Two full size International Hybrid Electric school busses are used daily in the project. Because of the added efficiency of the hybrid drive train, the diesel engine runs under significantly reduced load. As a result, it produces much lower levels of reject heat and lower coolant temperatures in cold weather operation. The vehicles entered service in December of 2008 and experienced operator and passenger complaints due to lack of cabin heat. Proheat X45 diesel fired coolant heaters, similar to the ones used in this project, were installed in the busses and the heating complaints were eliminated.

Diesel fired coolant heaters (DFCH) installed and exhausted such that they can be operated in tandem with the drive cycle offer a unique solution to these problems. They can quickly pre-heat an engine and do this almost to operating temperature to minimize cold-start emissions from the engine. They can be used to provide auxiliary heat to the vehicle cabin when the engine should be turned off in compliance with anti-idling regulations. Diesel fired coolant heaters of appropriate size and capability can also be used to provide supplemental heat during engine operation both for passenger comfort and to limit the lower operating temperature of the engine. This may be of particular importance for school bus operations where the "duty-cycle" per se of the school bus is relative low. That is, it spends a fair portion of its time idling while passengers board and are discharged from the bus. This in particular makes demonstration in the school bus application of particular interest and utility. Facilitating transportation security in times of crisis, these heaters are independent of physical infrastructure. For example, if an ice storm knocks out the power for multiple days in the north country of NY State, buses can be preheated and remain operational.

The DFCH installation used in this demonstration project has coolant lines that are in series with the main cabin heater blower units. Coolant is drawn from the engine through the heater/blower assemblies, through the DFCH, where it is then returned to the engine block. In a preheat environment, minimal heat loss occurs at the heater cores due to the lack of forced airflow across the core. Warmed coolant is returned to the engine block until the coolant temperature reaches 180 degrees F. and the DFCH goes into a standby mode. This is contrasted with the installation of a smaller DFCH plumbed directly to the engine block. With the typical 15-17,000 Btu DFCH, the coolant plumbing is typically too small in diameter to be installed in series with the cabin heating loop. The smaller heater can effectively heat the engine for starting purposes, but the unheated coolant in the cabin heater loop causes a rapid drop in engine coolant temperature upon start up and leads to extended idle to reach sufficient defrost temperature or driving with limited visibility while trying to warm the vehicle to operating temperature. Where the smaller heater easily facilitates the cold weather starting of the engine, the added benefits of heating the coolant loop, providing supplemental heat, and the ability to provide some level of stand by cabin heating, dependent on battery state of charge and capacity, we believe make the larger heater a much more feasible, versatile, and cost effective investment.

Figure 1 shows the X45 diesel fired coolant heater and Proheat control module (PCM) deployed in the present demonstration project.

Figure 1 - Proheat X45 Bus & Coach Heater
(Source: Teleflex, Inc., used with permission.)

An earlier NYSERDA demonstration project conducted at Ravena Coeymans Selkirk schools made use of an Espar Hydronic Series heater, as shown in Figure 2, below, producing 15-17,000 BTU/hr. As was discussed previously, this size heater is limited to heating the engine only, not the entire coolant loop, due to the size of the coolant connections. The heater was positioned behind the battery box, immediately behind the left front wheel of the vehicle. As the exhaust was exhausted on the left front side of the vehicle rather than at the rear bumper, an ignition interlock with the engine was required by New York State Department of Transportation (NYSDOT) to prevent heater exhaust fumes from entering cabin during operation of the vehicle with passengers. As outlined above, the heater did an excellent job of warming the vehicle for reliable starting, but prolonged idle was necessary to defrost the windshield area for acceptable visibility.

It should be noted that this is not a limitation of the particular brand of heater, but merely caused by the heaters maximum rated capacity and installation location. It is our belief that representatives of Espar returned to RCS and installed a larger heater in a rear exhausted configuration with positive results.

Figure 2 - Espar Auxiliary Heater Installation

Figure 3 and Figure 4 below show a Webasto Scholastic Series Heater. This installation was seen on the project team's field trip to Ballston Spa Central Schools. This particular heater is a 45,000 BTU model that is similar in output to the Proheat X45 chosen for our project. It is installed in a battery box style enclosure, mounted behind the rear axle, and exhausted to the rear of the vehicle, so as to put no restrictions on its use.

Figure 3 - Webasto Scholastic Series Heater

Figure 4 - Webasto Scholastic Series Heater

2. INSTALLATION

Shown below are coolant flow diagrams for three different typical installations. The first is the DFCH in series with the coolant heater coils similar to the X45 installation in this project. Please note the potential for coolant flow through the heater to be disrupted when a passenger coolant valve is closed. The second shows a more sophisticated installation typical of a motor coach using a larger capacity 80,000 BTU heater in series with the passenger heating unit, but also utilizing a bypass loop to ensure that the heater never loses a coolant flow path when passenger heat valve is closed. In a motor coach, an automated system usually controls the passenger temperature control, and the control of the bypass valve. The last coolant flow diagram shows a typical X45 installation in an MCI coach. As the X45 heater is too small to be used in series with the coach passenger heating system, it is plumbed directly to the block. While in this arrangement, it does supply adequate preheat, and supplemental heat, it does experience the same issues with cold coolant in the passenger heater loop on preheat in cold ambient conditions.

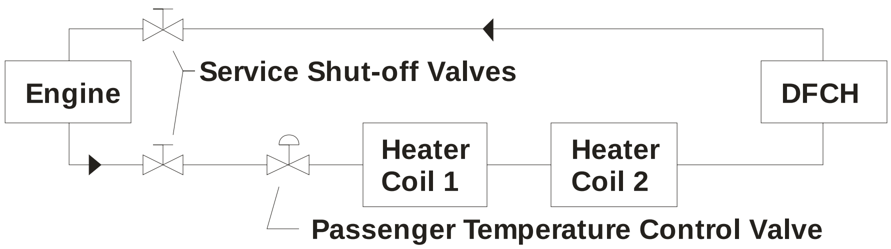

Figure 5 - DFCH in Series with Coolant Heater Coils

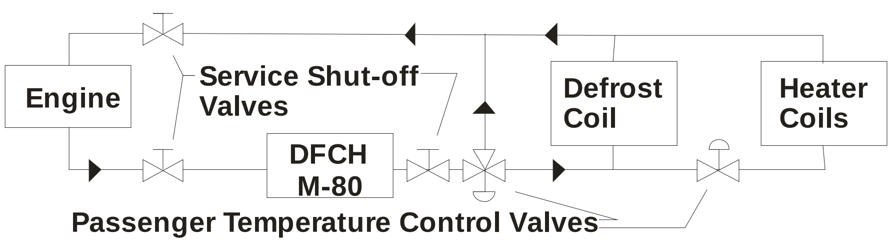

Figure 6 - DFCH in Series with Passenger Heating Loop with Bypass Valve to Maintain Coolant Flow

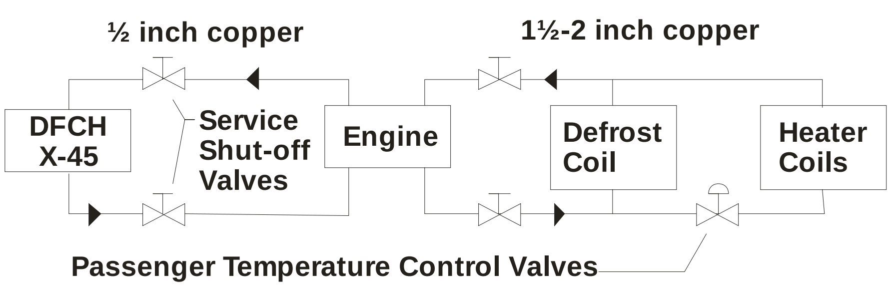

Figure 7 - DFCH Plumbed Directly to Engine Block

Shown in Figure 8 below, is a typical battery box style enclosure that has been installed in a late model IC conventional school bus body. While this box can be ordered as a factory installed option, this enclosure was installed by Brown Coach staff. Installation is located behind the left rear dual wheels of the vehicle and necessitates cutting a hole in the side paneling of the vehicle, modifying the lower rub rail assembly, and repainting that area of the vehicle similar to a sectional body damage repair. Please note that the proper lettering for the compartment door reading "DIESEL COOLANT HEATER" was not yet installed at the time of this photograph.

Figure 8 -Typical battery box style enclosure installed in a late model IC conventional school bus body

Shown in Figure 9 below, a Proheat X45 heater has been installed in the retrofitted compartment. Fuel coolant and electrical connections are clearly visible. Also shown is the option air intake piping (blue tubing on the left side of the heater) that was installed to provide a cleaner source of intake air for the heater. The Proheat Control Module, or PCM, is clearly visible in the center of the picture and has an LED display of any fault codes which greatly simplifies the troubleshooting process in the event of a malfunction. The PCM is also the source of the downloadable history of heater operation that was instrumental in the data gathering on this project.

Figure 9 - Proheat X45 heater has been installed in the retrofitted compartment

Exhaust from the X45 was directed to the rear of the vehicle to ensure there were no issues with exhaust fumes entering the passenger cabin while occupied. This is shown below in Figure 10 and Figure 11.

Figure 10 - Exhaust from X45 Parallels Vehicle Exhaust to Exit at Rear Bumper

Figure 11 - Exhaust from X45 Battery Box to Rear of Vehicle

It should be noted that the upward slope in the X45 exhaust pipe presents the potential for water collection at the elbow. A close-up photograph of this elbow is provided in Figure 12, below.

Figure 12 - Exhaust Elbow Under DFCH Box

It is recommended by NYS DOT that a 1/8" diameter hole be drilled in the low point of this exhaust pipe to serve as a drain hole.

Shown below in Figure 13 are the Proheat operating controls installed in the driver's compartment of the vehicle. At the center of the picture is the Proheat PK 0001Timer. It is customizable for 12 or 24 volt applications, as a single day or seven day timer, single or multiple start times a day, and duration of run time for the heater.

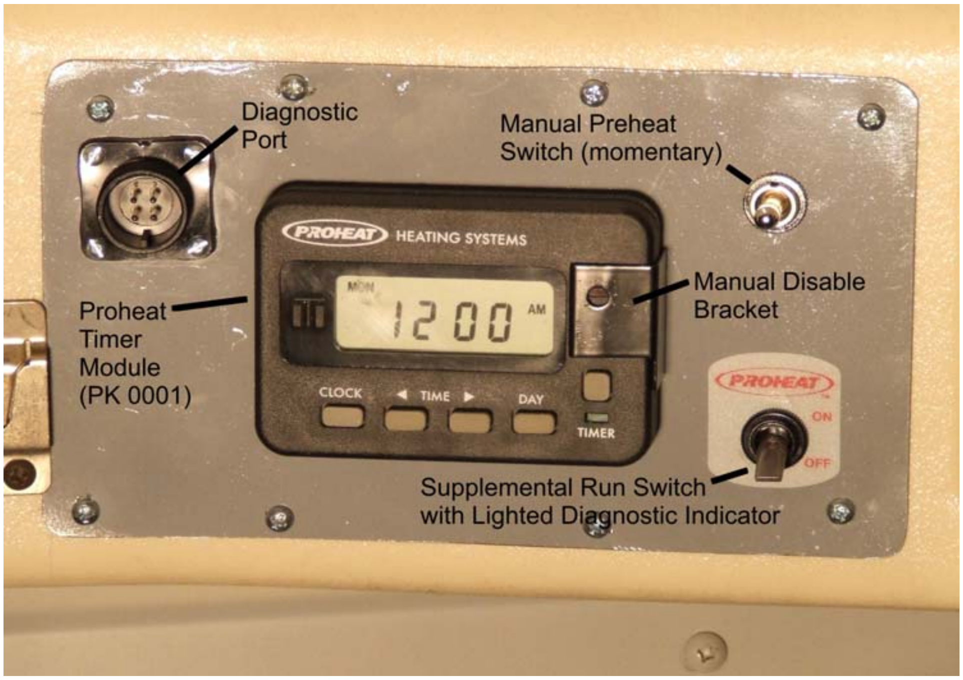

Figure 13 - Proheat Timer and Controls

The timer is very user friendly and is simple to set, and operate. The timer has one operational issue. If the "manual" button on the timer is used to turn the heater on, the heater will run indefinitely. The fix for this shortcoming of the timer is to install a manual button disable bracket over the manual button on the timer and utilize the software in the PCM to control manual operation of the heater. The momentary on-off-on toggle switch shown to the upper right of the timer is used for this purpose. Briefly toggling the switch to the up position applies a voltage signal to the proper auxiliary heater input on the heater to enable a timed 90 minute manual preheat operation. Briefly holding the switch in the down position cancels out the manual operation and the heater shuts off. The button in the lower right hand corner of the timer is used in conjunction with the lower row of buttons on the timer to set the timer controlled operations. The "Proheat" toggle switch in the bottom right of the panel is enabled when the vehicle ignition is on, and allows for supplemental heating operation of the Proheat unit when the vehicle is in operation. Leaving the switch in the "up" position has no unattended effects when the vehicle is shut down. The connector in the upper left of the panel is the diagnostic connector for interfacing with the download history in the Proheat PCM. Alternately, the download cable can be connected directly to the Proheat PCM at the center switch input connection. The experience of the project team was that a reliable data download connection could not be made in the cab, and required the direct connection to the unit. This has not been diagnosed as of producing this report, but it is believed that the digital signal degrades or interference is picked up over the long cable run to the front of the vehicle.

3. DRIVER REACTIONS TO DFCH

SURVEY RESULTS

A survey was developed to formally gauge driver reaction to the installation of diesel fired coolant heaters. A copy of this survey is included for reference in Appendix C. The results were overwhelmingly positive and are summarized in Appendix D. Drivers were asked to report their bus number and answer six questions related to their experience with the diesel fired coolant heaters. Twenty seven responses were obtained, all from drivers who characterized the frequency with which they operated buses equipped with DFCH units as 'most always'. Among these, all 27 felt that the bus cabin heated more quickly in the morning before leaving the garage when they operated DFCH-equipped units. Likewise, all 27 responded that the units defrosted quicker. When asked how much quicker, answers ranged between 3 and 15 minutes with an average of responses at 6.5 minutes quicker defrost.

Drivers were also asked if they were able to idle the vehicle less because the DFCH would help to keep the cabin warm. All but one driver who was unsure responded that they were able to idle less in DFCH-equipped vehicles. They were again asked for an estimate of how much less they were able to idle, and results ranged from 10 to 20 minutes with an average of responses at 13.5 minutes of idle reduction. Drivers were also asked if they were able to run the heater fans with the engine off to maintain cabin temperature. However, here the responses were much more varied. 25.9% of drivers indicated they never did this. 63% of drivers indicated they made use of this 'occasionally'. Only 2 drivers, or 7.4%, indicated they did this 'often, and only one driver responded 'always'. This could result from a lack of understanding of the potential to manage cabin temperature by running the various heater fans with the ignition in the accessory position with power supplied by the batteries. However, this limited use could instead result from concern that this practice could drain batteries below the state of charge necessary to successfully start the engine – something that is more challenging on the very days when auxiliary cabin heating would be most beneficial. This survey result suggests additional driver education may be useful, and it leads us to consider whether installation of additional battery capacity may be warranted to facilitate this anti-idling behavior.

Environmental and economic analysis based on survey results will be presented in section 4, below.

QUOTES FROM DRIVERS

Three drivers provided feedback in the open-ended 'Comments:' section at the end of the survey. They were all positive, as follows:

- "Great to have should be put in all buses"

- "Pro Heat is the best"

- "It's really good. I have no complaints. I like it."

Note that while surveys did not request driver names, each survey did request a bus number and may therefore not have offered complete anonymity. However, the drivers are typically quite candid about dislikes and complaints, so this is unlikely to have materially affected survey results.

4. DATA COLLECTION & ANALYSIS

DATA SOURCES

Data used in conduct of this demonstration project was obtained from four sources: the X45 Proheat control module (PCM), the bus engine computer through a diagnostic interface to a laptop, an independent portable temperature logger, and from surveys returned by many of the drivers of DFCH-equipped vehicles.

DFCH X45 PCM

The Teleflex Proheat X45 diesel fired coolant heater (DFCH) offered an industry-leading data logging capability at project inception that was particularly well suited for the type of information needed. This was intended as the primary source for the data required by this demonstration project based on experience with a 24V model installed in motor coach applications at Brown Coach, Inc.

The Proheat Control Module (PCM) retains performance data on each X45 and this data can be obtained by connecting a laptop with an RS-232 serial port and downloading the data. The unit maintains a record of total hours of operation, flame hours, total cycles, and duty cycle. It also maintains an event history for the most recent 500 events. Figure 14 shows an example screen from the Proheat Datalink software (version 6.00d) provided with the heaters. Note that the total cycles and duty cycle are also maintained by the PCM. The serial number of each heater was set to correspond to the bus number to simplify data gathering and analysis.

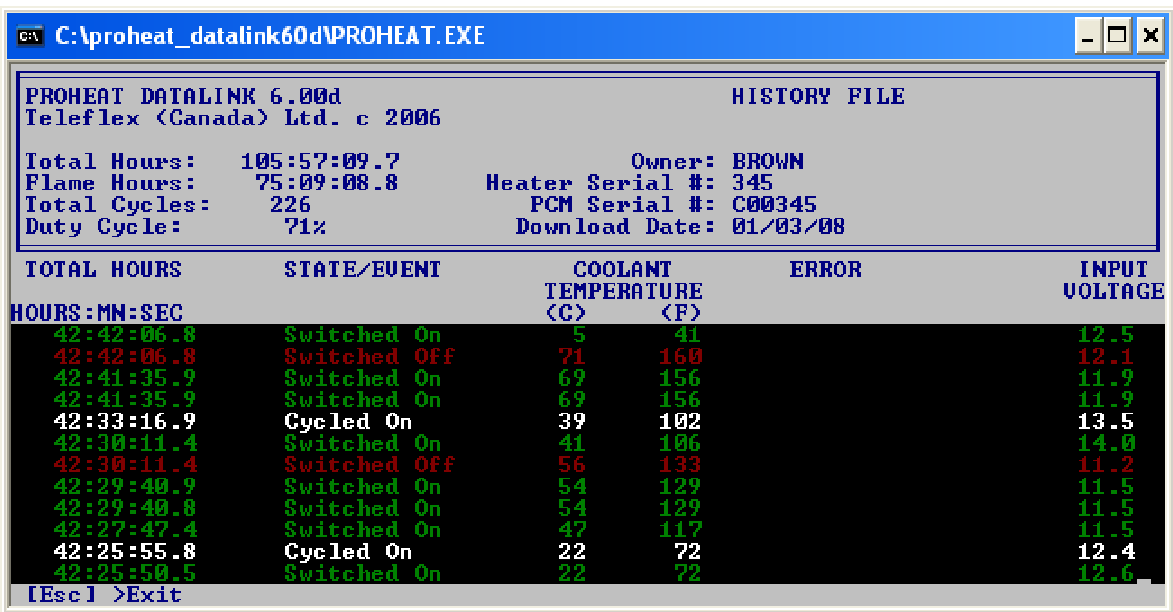

Figure 14 - Proheat Datalink Example Screen

Note that events are logged based on operating time, as shown in the example; however, closer examination of the raw file generated by the PCM revealed a time-stamp that appeared to correspond to clock time. This is illustrated in Figure 15. The last column in the data file denotes clock time, and times are represented by floating point values in the raw .HIS data file. Teleflex confirmed the presence of power hours being logged in the file. They also advised that there is a diagnostic mode on the Datalink software accessible by pressing the <Alt>-S key combination. While this value is then accessible in the Datalink software, this software does not offer a convenient means for automatically processing resulting data from a large number of vehicles. This was best done externally, but it requires understanding of the .HIS file format. Requests to obtain a complete definition of the raw data file were unsuccessful. To facilitate automatic compilation of statistics across the fleet of test vehicles, efforts were made to understand the format of the data file, and results are provided in Appendix F. This includes formulas for converting from this floating point time to clock time, and this applies both to total hours as shown in Figure 14 as well as to the power hours that appear in the last column of the raw data file.

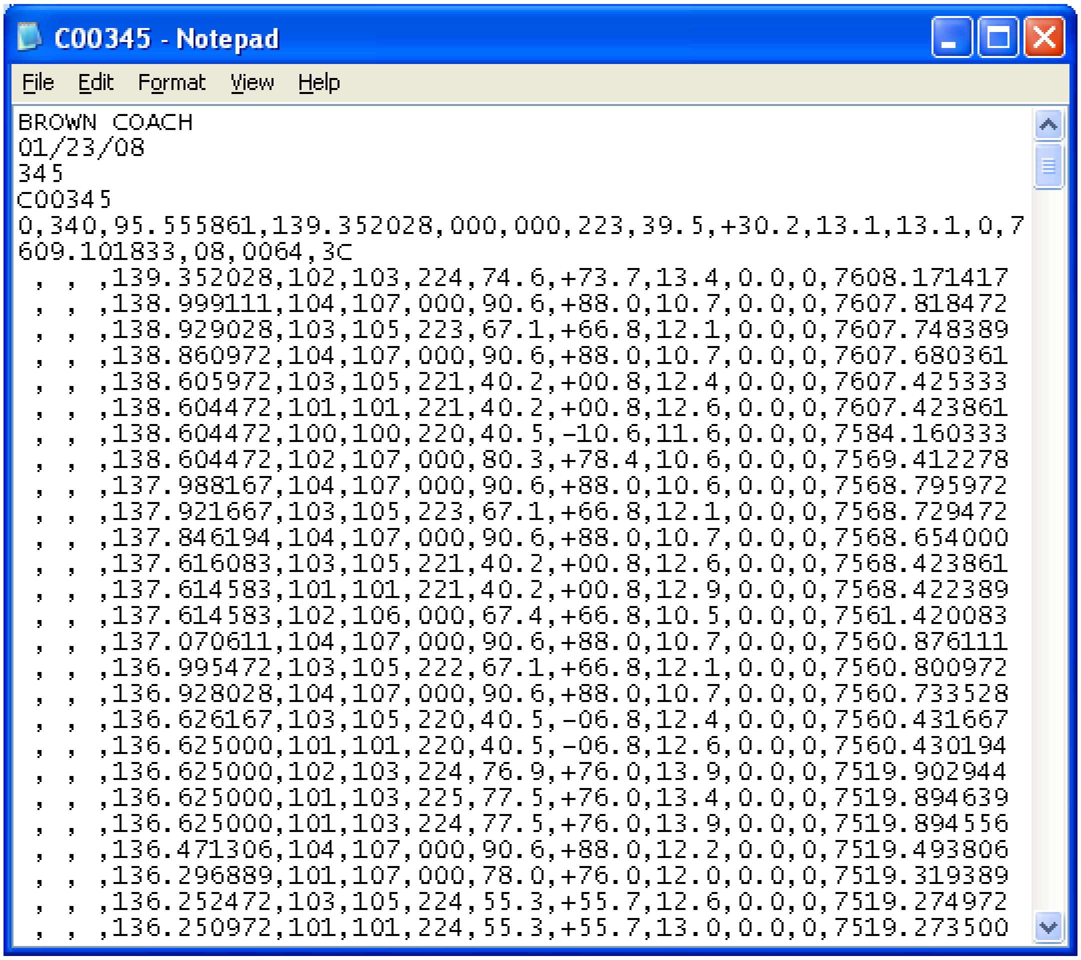

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Figure 15 - PCM Raw Data File Example

Understanding the comma separated value raw data file supports automated analysis of the data files and compilation of summary information across all vehicles in the study. Appendix G contains developmental code that was used in part to prepare the analysis that follows.

Note that since the PCM does not maintain or record date information in the file, it is necessary to rely on knowledge of the download date, which is recorded from the laptop at each download, along with power hours, to infer actual dates throughout the data file. Note that the dates provided in the analysis data summary of Appendix E were obtained in this way. It is also interesting to note that, unlike on prior installations done on motor coaches, the battery voltage being logged does not provide insight on engine state. On motor coaches tested in advance of this project, there was a readily detectable charging system voltage difference when the engine was running and when it was turned off. This was unfortunately not the case in the 12V system of the school buses tested, so detailed analysis based on engine state was not possible.

Summing the operating and flame hours of the fleet reported in Appendix E reveals that 8625.9 total operating hours were accumulated over all 36 test vehicles in the fleet, and of that time 4020.2 flame hours were logged. A cumulative total of 35246 total heating cycles were logged, and the units operated at a composite duty cycle of 46.6%. Further analysis that examines cycle on, cycle off, and error events, as well as noting associated times, is described in the benefits discussion that follows.

Bus Engine Interface

Using the J1939 interface, it was possible to access the vehicle computer during an actual drive cycle and record a variety of engine and vehicle parameters on the software supplied by the engine manufacturer. The hardware used is shown in Figure 16.

Figure 16 - J1939 Vehicle Data Bus Interface and Laptop

A test route was devised that would highlight a variety of driving conditions, and the same driver repeated testing on four successive days. The first test served to baseline the vehicle and drive cycle performance without any use of the DFCH (Figure 17). Then tests were conducted with only preheat (Figure 18), only supplemental heat (Figure 19), and with both preheat and supplemental heat (Figure 20). Results are shown below.

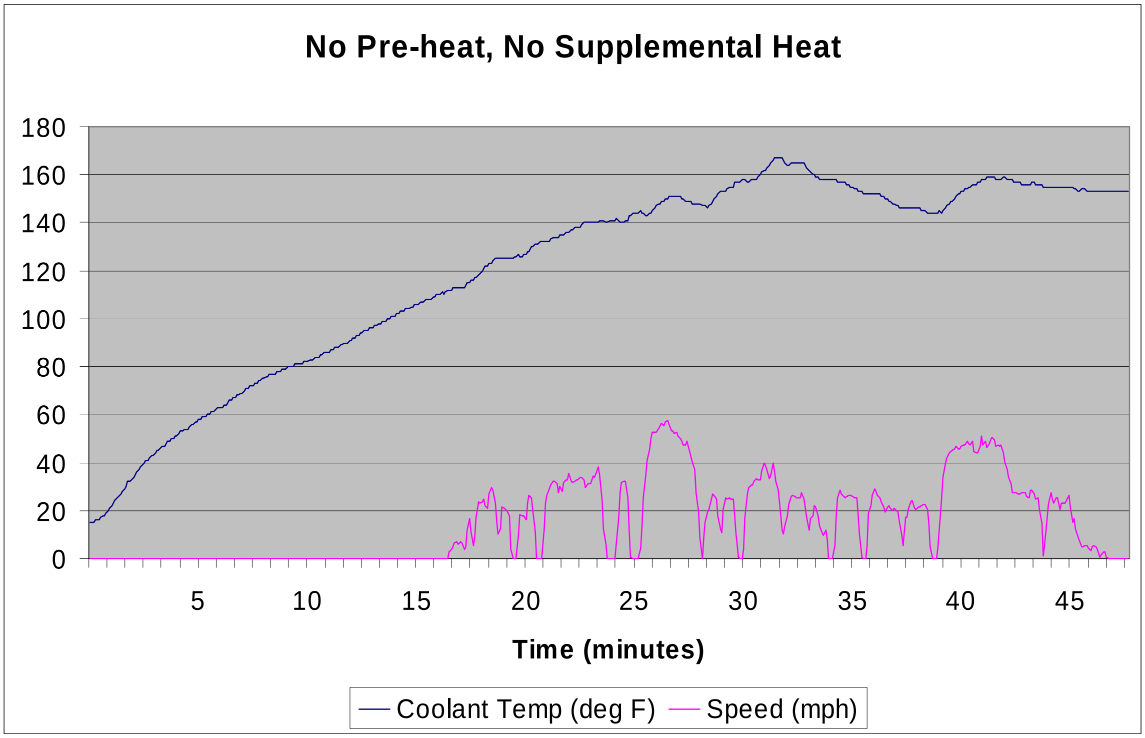

Figure 17 - Test Drive Cycle - No Preheat, No Supplemental Heat

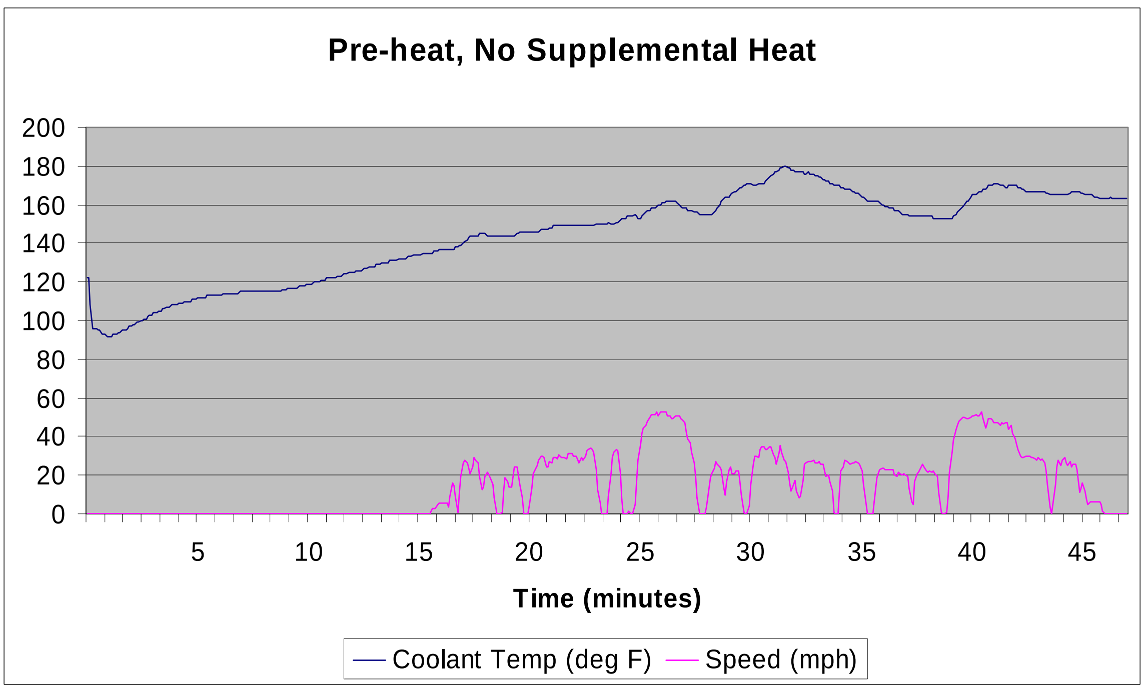

Figure 18 - Test Drive Cycle - With Pre-heat, No Supplemental Heat

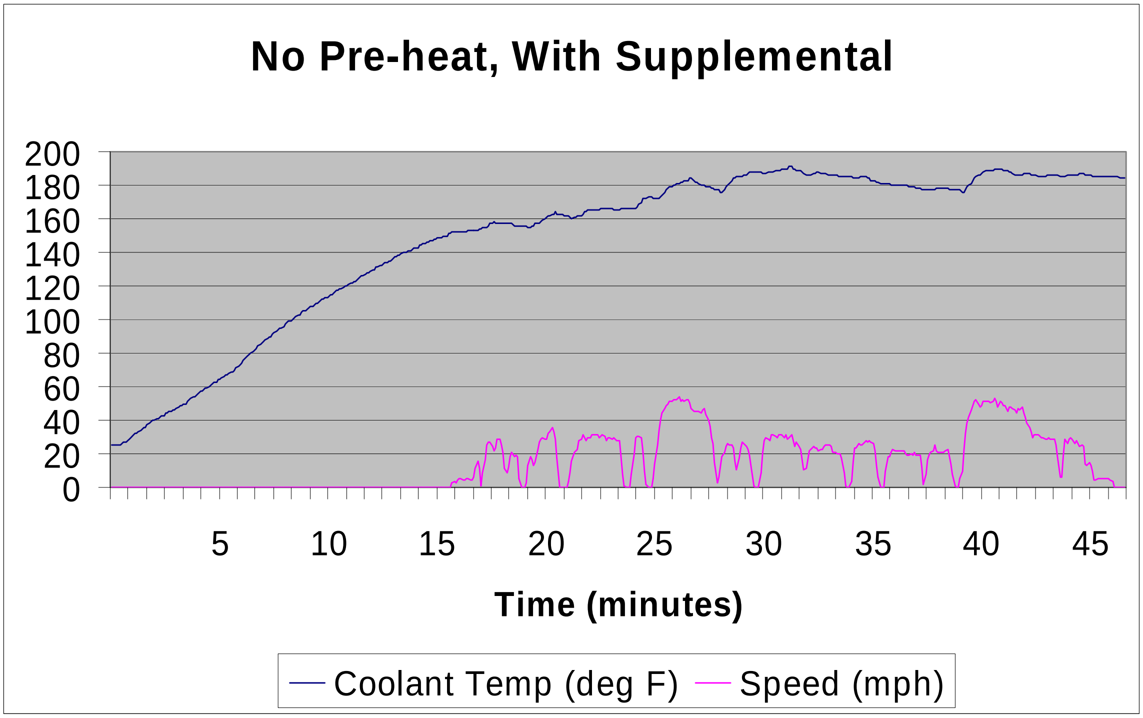

Figure 19 - Test Drive Cycle - No Pre-heat, With Supplemental Heat

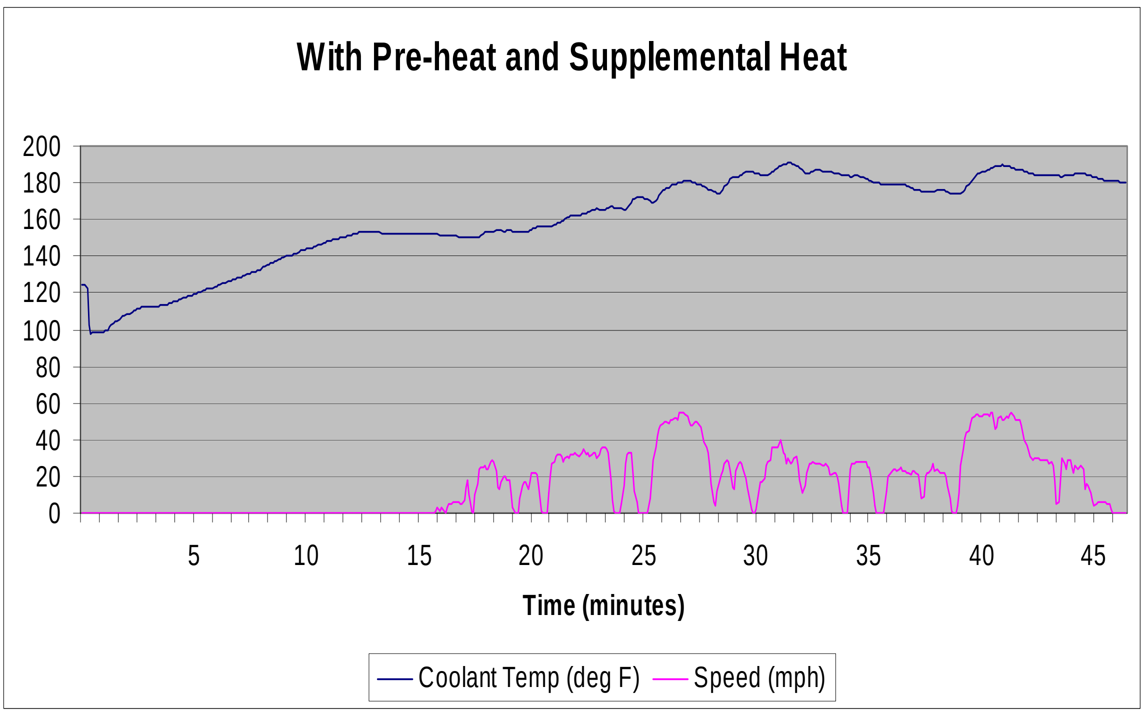

Figure 20 - Test Drive Cycle - With Pre-heat, With Supplemental Heat

It is interesting to note how well the speeds and timing of the four drive cycles match. It is also interesting to note the temperature drop that occurs at engine start (approximately time = 0). Preheating for 90 minutes does not raise the engine block to full operating temperature, but it certainly provides a head start when contrasted with the non-pre-heat cases.

Portable USB Temperature Logger

A portable USB temperature logger was also used in this study to record vehicle temperatures near the front windshield to support understanding of the effect that pre-heating may have on defrost performance. Figure 21 shows the device that was used. Since the formation of windshield frost and the ability to defrost the windshield depend heavily on environmental conditions, temperature measurement offered the most quantitative means for evaluation. Results are described below.

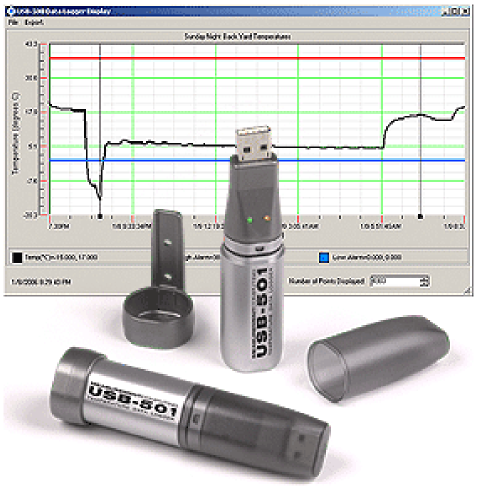

Figure 21 - USB-501 Portable Temperature Logger

Driver Surveys

A summary of driver survey results were presented in section 3, above. Appendix C provides a copy of the survey distributed to drivers of the test vehicles, and the spreadsheet provided in Appendix D provides details of their responses.

BENEFITS

This demonstration project sought to evaluate three primary benefits associated with Diesel Fired Coolant Heaters: Preheating without engine idling and realizing associated cold start emissions, Providing for inter-run cabin auxiliary heating to facilitate anti-idling, and Providing supplemental heat during the drive cycle to provide increased engine efficiency, reduced emissions, and better passenger comfort.

Preheating without Engine Idling

Using a heater such as the Proheat X45 that is sufficiently large to pre-heat the entire coolant loop instead of just the engine block, it is possible to provide more rapid defrost so that buses can be safely operated immediately after completing the pre-trip inspection without wasting additional fuel and causing additional pollution while waiting for the engine (usually on high idle) to generate enough heat to serve this cause.

By starting a DFCH 60 minutes before departure (Proheat timer modules heat for 90 minutes after their programmed start time) the coolant loop in the engine is already warmed to approximately 100deg F above ambient based on the results shown in Figure 23. This allows the engine to turn over more easily and provides some cabin heat immediately.

A test was devised to assess the defrost benefits gained from DFCH units by measuring the temperature near the front windshield in a bus with and without the DFCH heater activated for preheating. On the first day of this test, the data logger of Figure 21 was activated at 4:00am and hung from the front mirror. The preheat unit was programmed to start at 5:00am and the bus was started at 5:50am. At that time, the defroster fan was turned on high speed, the bus was set to high idle, and the preheat unit was turned on manually to effect the best-case defrost behavior. At 6:00am the bus was shut down.

On the next day of this test, the preheat unit was not used. The temperature logger was again deployed at 4:00am, and at 5:45am the bus was started, the defroster fan was turned on high speed, and the bus was set to high idle. Again, after 10 minutes, the bus was shut down.

Figure 22 shows the contrast between heating at the front windshield with and without preheating. Note that time zero corresponds to when each engine was started, and it is clear that by using the DFCH preheating, an increase of 15 degrees was observed at the windshield even before the defrost fans were engaged.

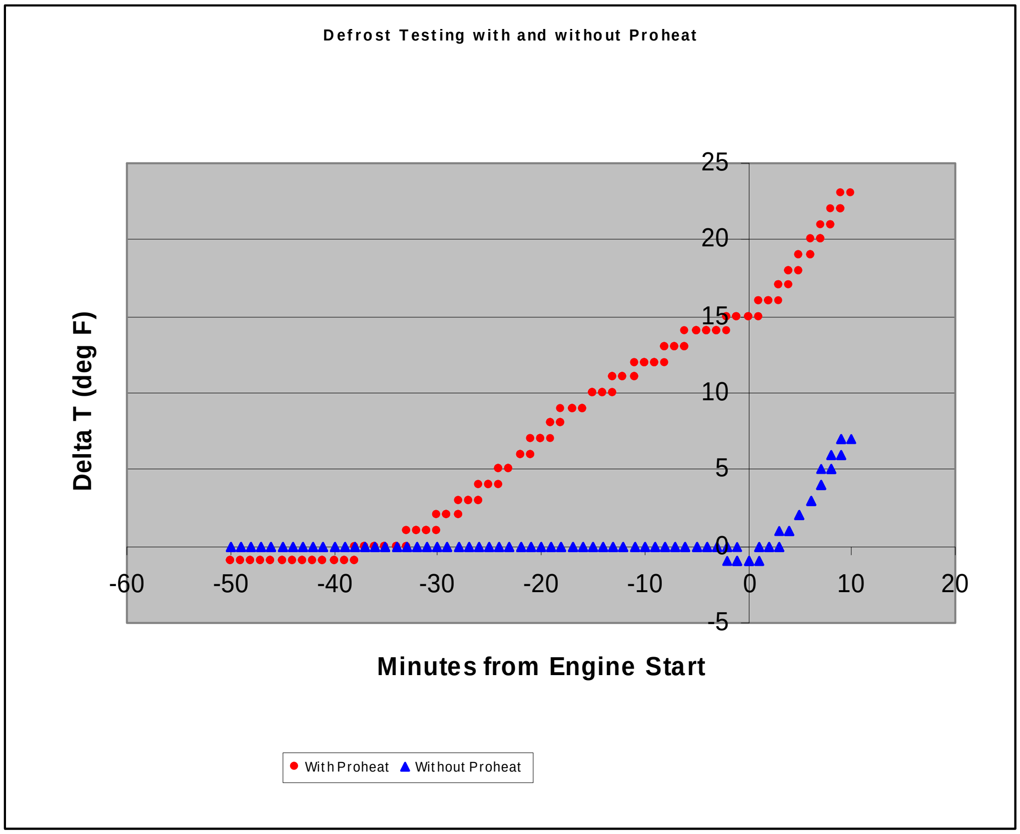

Figure 22 - Defrost Testing With & Without Preheat

This can represent a considerable decrease in relative humidity. For example, suppose the ambient temperature was 10deg F, and the dew point inside the vehicle was also 10deg F (i.e. 100% RH). By increasing the temperature 15deg F to 25deg F, the RH would decrease to 52.3%. Additionally, in this example, the air temperature near the windshield would be above freezing even before the engine was started.

In the survey described in section 3, drivers estimated saving on average 6.5 minutes per day from improved defrost performance with DFCH equipped vehicles. This would generally only be an issue in the morning on first use of the bus.

Inter-run Cabin Auxiliary Heating

The DFCH can easily maintain engine operating temperature in between runs or during short durations of inactivity. Using the DFCH to help maintain interior cabin temperature by running the heater blower fans with the vehicle in an ignition-on and engine-off scenario has not been widely implemented though it was possible given the hardware configuration in the test buses in this study. This is mainly due to the potential for a no-start condition in the field at the pick-up or lay-over point caused by depleting the chassis batteries below where the vehicle will reliably start. School buses generally do not have deep cycle ‘house batteries’ as are common with RV's that allow maintenance of passenger convenience items to be operated with the engine off.

Vehicle batteries were not sized and designed to provide long term use of accessories such as blower motors in situations where the engine is not running. This would either require additional batteries or a separate bank of batteries to further promote inter-run auxiliary heating. It is also likely that, in the case of simply adding chassis battery capacity, some sort of driver indicator signaling an acceptable state of charge in the battery would be required so drivers would be comfortable operating blower fans without the engine on. Note that in the driver survey results of Appendix D, very few drivers indicated that they considered running the heater fans with the engine off. This may suggest an opportunity for further training.

We are confident that the X45 (45kBTU) heater has sufficient capacity to maintain acceptable inter-run cabin temperatures in most climates in NYS. The Proheat X45 has demonstrated the ability to provide inter-run cabin auxiliary heating in the class 8 truck market suitable for overnight occupancy of the sleeper, and an 80kBTU DFCH has been reported to heat a motor coach interior to a very comfortable temperature.

Supplemental Heat During Drive Cycle

The Proheat X45 successfully provided supplemental heat during both the drive cycle itself and during warm-up of the engine in situations when pre-heat function had not been engaged. This is clearly illustrated when the engine temperature graphs shown in Figures 17-20 are normalized for ambient air temperature (i.e. reported as delta T) and overlaid on the same time scale as shown in Figure 23.

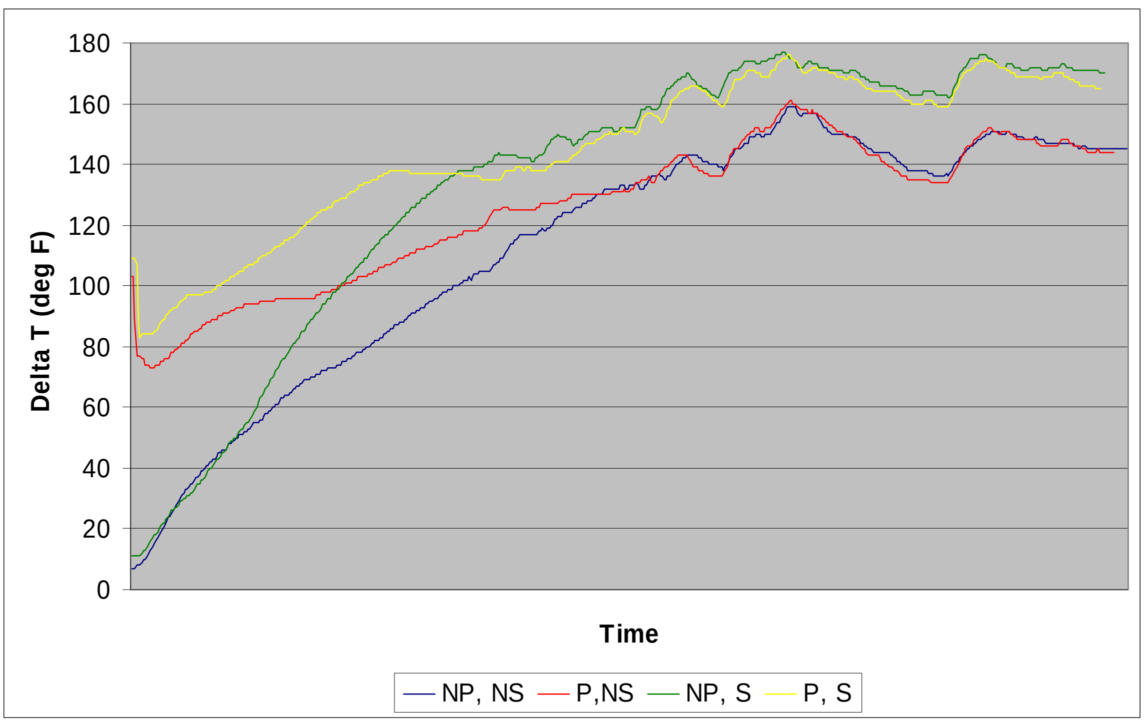

Figure 23 - Test Drive Cycle Heating Contrast

The use of preheating (P) offers a clear advantage to getting the engine up to temperature when contrasted with the no-preheating (NP) case. The use of supplemental heating (S) results in a very consistent increase in engine operating temperature of approximately 20deg F, once operating temperature is reached, when contrasted with the no-supplemental heating (NS) test case. This 20deg F differential seems to not vary significantly with the drive cycle nor the load placed on the engine and clearly demonstrates supplemental heating. The project team agreed that it would not be meaningful to compare emissions differences between runs with and without supplemental heat unless the vehicle could by dynamometer tested under controlled conditions. This was beyond the scope of the current effort.

Analysis of individual heater performance data illustrates that rather short firing of the DFCH is sufficient to provide this supplemental heat. While this will certainly vary based on several factors including weather and vehicle drive cycle, it is instructive to consider a histogram of the length of time each heating event is active. Figure 24 shows such a histogram for the data file C00181.

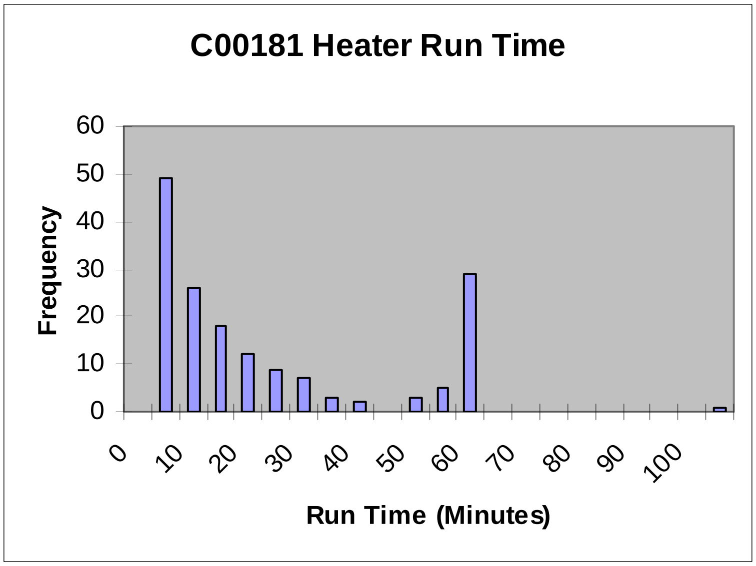

Figure 24 - Example Histogram of Heater Cycle Run Time

The majority of heating cycles fall in the 5 minute bin, indicating these are firings to provide supplemental heat. Likewise, most of the heating intervals up to 40 minutes in length are thought to correspond to supplemental heating activity. The high populations of 60 minute heating, as well as the adjacent heating lengths of 50 and 55 minutes, are thought to correspond to preheating instead of supplemental heating.

ANALYSIS OF ERROR CODES

The Proheat X45 records errors generated during operation using one of thirteen codes shown in Table 1.

Error Code	Meaning
1	Start
2	Flame Out
3	Coolant Flow
4	Coolant Overheat
5	Voltage (high/low)
6	Flame Sensor
7	Temperature Sensor
8	Fuel Pump
9	Compressor
10	Ignition Coil
11	Coolant Pump
12	Blower Combustion
13	Sleeper Fan

Table 1 - Proheat X45 Error Codes

VBA (Visual Basic for Applications) code was developed to scan the .HIS diagnostics log files for error codes, generate a summary sheet for the error codes identified in each data set, and also generate error totals summarizing the errors across all datasets in the fleet. This code is shown in Appendix G and was used to generate the results in Table 2. This code is embedded in the "Data Analysis.xls" spreadsheet included with the CD that accompanies this report. Please note that it will be necessary to enable macros in order to access this code.

Error Code	Meaning	Count	% Total Errors
1	Start	144	7.9%
2	Flame Out	377	20.6%
3	Coolant Flow	354	19.3%
4	Coolant Overheat	875	47.8%
5	Voltage (high/low)	51	2.8%
6	Flame Sensor	2	0.1%
7	Temperature Sensor	0	0.0%
8	Fuel Pump	0	0.0%
9	Compressor	14	0.8%
10	Ignition Coil	0	0.0%
11	Coolant Pump	2	0.1%
12	Blower Combustion	13	0.7%
13	Sleeper Fan	0	0.0%
Total Errors		1832	100.0%

Table 2 - Fleet Error Code Summary

The fleet error code summary reveals what at first may appear to be a large number of errors; however, it is important to note that errors are generally concentrated in certain log files and many appear to be related to initial start-up of the units. For example, data set C12360 shows 211 errors (all of code 4), for only 13 starts. This overheat code is indicative of a system safety device that keeps the heater from functioning if there is no coolant in the heat exchanger. The overheat switch is a manual reset device. The impact switch that prevents operation of the heater after a crash or rollover is wired in series with the overheat switch, and is the most likely cause of this fault. The impact switch can be tripped by tapping it, and is the easiest way to disable the heater operation, once the valves are closed for warmer weather operation. Again, a reoccurring fault will occur if repeated heater starts are attempted with this condition.

Error code 3 pertains to coolant flow and is caused by a rapid ramp up in coolant temperature. This condition is caused by a closed coolant valve, or a partially closed coolant valve. The coolant valve is used to control temperature in the cabin. If the supplemental run switch is on, or the timer is set, a reoccurring error code 3 will occur when the coolant valve is in the closed position. Software programming detects the rapid rise in temp and shuts the burner down. This is not detrimental to the heater, but it could accumulate considerable errors in the log file if not detected early.

Voltage errors primarily originate from low battery voltage, and are more of a vehicle charging system issue, than a Proheat issue. It is very interesting to note that component faults are virtually non-existent.

The compressor faults and combustion blower faults are reoccurring faults concentrated in a single unit (bus 350) with sporadic errors found in heaters for buses 154 (data set 12154), 357 (data set 10357), 360 (data sets 00360 and 10360), and 367 (data set 12367).

It is noteworthy that over 67% of all error codes reported across the fleet relate to coolant flow or coolant overheat, and both of these are generally caused external to the heater. In contrast to some heaters with high error counts, others data sets such as C12362 and C12364 show, respectively, a total of 3 diagnostic error codes over 150 starts and zero errors over a total of 165 starts.

The fleet had a total of 35246 heater cycles logged over a two heating season test period. If all heater errors are counted, this results in a 5.2% error rate; however, when coolant related errors are removed from consideration, only 603 diagnostic fault codes were logged for an error rate of 1.7%.

Our field experience while supporting these units has been generally problem free and suggests that most of these diagnostic fault codes do not lead to any actionable service requirements for the units.

IMPACTS: ECONOMIC & ENVIRONMENTAL

The cost to install a single DFCH at retail is estimated to be $3500 for a simple enclosure to around $5000 for a higher end battery box installation, as outlined in Appendix I. Although results of driver surveys suggest only 13.5 minutes of idle reduction per day, on average, operational experience and feedback from our mechanics suggest idle reduction of at least one hour is typical as the mechanics arrive before drivers to ensure all vehicles are ready for service on the coldest of days. Fuel savings are estimated based on 1 hour of avoided idling per day, to as much as 4 hours per day of idling based on particular fleet's operation cycle. Preheating typically occurs for a 4 month duration beginning in late November. If a bus on high idle consumes 1 gal/hr, and a Proheat DFCH consumes 0.32 gal/hr during burner operation, then the savings per bus for the heating season can be calculated as follows: 1h/day x 4mo. x 20days/mo. x (1gph – 0.32gph) x $3/gal.

Avoided Idle (hours)	Fuel Saved per Vehicle (US gal.)	Fuel Saved in 36 Bus Test Fleet (US gal.)	NYS Fuel Savings Potential ~45,000 Buses (US gal.)	CO2 Avoided per Vehicle (lbs.)	CO2 Avoided in Test Fleet (lbs.)	NYS CO2 Savings Potential (Tons)
1 Hour	54	1,958	2,448,000	1217	43829	27393
2 Hours	109	3,917	4,896,000	2435	87658	54786
3 Hours	163	5,875	7,344,000	3652	131487	82179
4 Hours	218	7,834	9,792,000	4870	175316	109572

Table 3 illustrates the fuel savings that would be experienced under different operating scenarios and also computes the carbon dioxide avoided based on each gallon of diesel burned releasing forming 22.3 pounds of CO2 [EIA, 2010].

Avoided Idle (hours)	Fuel Saved per Vehicle (US gal.)	Fuel Saved in 36 Bus Test Fleet (US gal.)	NYS Fuel Savings Potential ~45,000 Buses (US gal.)	CO2 Avoided per Vehicle (lbs.)	CO2 Avoided in Test Fleet (lbs.)	NYS CO2 Savings Potential (Tons)
1 Hour	54	1,958	2,448,000	1217	43829	27393
2 Hours	109	3,917	4,896,000	2435	87658	54786
3 Hours	163	5,875	7,344,000	3652	131487	82179
4 Hours	218	7,834	9,792,000	4870	175316	109572

Table 3 - Fuel and CO2 Savings

These savings are converted to fuel costs alone at various fuel prices in Table 4.

Avoided Idle (hours)	Fuel Saved per Vehicle (US gal.)	Cost $3.00 /gal	Cost $4.00 /gal	Cost $5.00 /gal
1 Hour	54	$163.20	$217.60	$272.00
2 Hours	109	$326.40	$435.20	$544.00
3 Hours	163	$489.60	$652.80	$816.00
4 Hours	218	$652.80	$870.40	$1,088.00

Table 4 - Fuel Cost Savings

As the length of avoided idling increases or fuel costs trend higher, the savings realized clearly grow. This is illustrated in

Simple Payback	Payback Period at $3,500 Installed Cost (years)			Payback Period at $5,000 Installed Cost (years)		
Avoided Idle (hours)	at Fuel Cost of $3.00 /gal	at Fuel Cost of $4.00 /gal	at Fuel Cost of $5.00 /gal	at Fuel Cost of $3.00 /gal	at Fuel Cost of $4.00 /gal	at Fuel Cost of $5.00 /gal
1 Hour	21.4	16.1	12.9	30.6	23.0	18.4
2 Hours	10.7	8.0	6.4	15.3	11.5	9.2
3 Hours	7.1	5.4	4.3	10.2	7.7	6.1
4 Hours	5.4	4.0	3.2	7.7	5.7	4.6

Table 5 by observing simple payback at two installed costs ($3,500 and $5,000, respectively) and for several fuel costs scenarios.

Simple Payback	Payback Period at $3,500 Installed Cost (years)			Payback Period at $5,000 Installed Cost (years)		
Avoided Idle (hours)	at Fuel Cost of $3.00 /gal	at Fuel Cost of $4.00 /gal	at Fuel Cost of $5.00 /gal	at Fuel Cost of $3.00 /gal	at Fuel Cost of $4.00 /gal	at Fuel Cost of $5.00 /gal
1 Hour	21.4	16.1	12.9	30.6	23.0	18.4
2 Hours	10.7	8.0	6.4	15.3	11.5	9.2
3 Hours	7.1	5.4	4.3	10.2	7.7	6.1
4 Hours	5.4	4.0	3.2	7.7	5.7	4.6

Table 5 - Simple Payback Exclusive of Maintenance Costs

Table 6 includes cost savings realized from less frequent oil change maintenance and reduced engine rebuild events, as well as adding the costs of maintaining the diesel fired coolant heater, and follows the worksheet produced by Argonne National Lab titled "How Much Could You Save by Idling Less?" [Argonne, 2010].

Payback Accounting for Maintenance	Payback Period at $3,500 Installed Cost (years)			Payback Period at $5,000 Installed Cost (years)		
Avoided Idle (hours)	at Fuel Cost of $3.00 /gal	at Fuel Cost of $4.00 /gal	at Fuel Cost of $5.00 /gal	at Fuel Cost of $3.00 /gal	at Fuel Cost of $4.00 /gal	at Fuel Cost of $5.00 /gal
1 Hour	33.9	22.2	16.5	48.4	31.7	23.6
2 Hours	11.2	8.3	6.6	15.9	11.8	9.4
3 Hours	6.7	5.1	4.1	9.5	7.3	5.9
4 Hours	4.8	3.7	3.0	6.8	5.3	4.3

Table 6 - Simple Payback Including Engine and DFCH Maintenance Costs

Several cost assumptions were required to calculate payback including maintenance costs. A cost of $157 per oil change was used based on requiring 28 quarts of oil at $2.00 per quart, 1 oil filter costing $20.00, 8% sales tax, and 1 hour of labor at $75.00/hour. A 5000 mile oil change interval was used. Engine rebuild was assumed to cost $10,000 and occur every 150,000 miles. Converting each hour of avoided idling to 6 miles of engine wear (based on 6 mpg), oil changes and engine rebuilds add $0.0314 and $0.0667, respectively, to the cost of idling. Our maintenance experience with the DFCH was extremely positive; however, we project an annual cost of $107 to service air and fuel filters ($30.00 + sales tax + 1 hour labor).

The price of a conventional school bus today is around $85,000-95,000. To incorporate the DFCH into the vehicle during manufacture, or to prep the vehicle for DFCH installation during manufacture, is the most efficient method of adding a heater. This adds less than 5% to the total cost of the vehicle, and minimizes downtime after placing the vehicle in service. The purchase price of the heater can be included in the funding method for the vehicle purchase price, and therefore reduces cash outlay. The DFCH should have a long lifespan, and could be removed from the vehicle at time of sale and retrofitted into a newer vehicle.

However, there are several other motivators for installing DFCH systems in one's fleet. There are intangible benefits, such as increased safety from more rapid defrost, reduce driver discomfort, and increased driver retention. In some jurisdictions, the potential exposure to $22,500 fines from idling and up to one year imprisonment should be sufficient justification alone for installing DFCH systems in all commercial vehicles [ATRI, 2008].

Almost anyone that is a frequent driver in the Northeast has seen other motorists leaving for work in the morning with the silver dollar size hole scraped in the frost covering their windshield, struggling vainly to see the road until the defrosters sufficiently clear the windshield. While school bus drivers are professionals, the challenges of maintaining a schedule combined with the delays associated with getting themselves to the bus garage on frigid or inclement weather days often create the temptation to leave the terminal before the windshield is fully defrosted. This is also compounded by the fact that the modern diesel engine does not produce significant heat output if it is not being operated under load. Preheating the engine coolant gives a significant safety benefit by speeding the ability to clear the majority of the windshield.

A significant challenge in achieving and maintaining a comfortable cabin temperature in a full size school bus comes in part from the sheer size of the cabin, the large amount of windows, and the relatively thin, poorly insulated walls. All the seating and interior walls "cold soak" overnight and help resist efforts to warm the cabin. These factors add to the challenges and discomforts faced by a school bus driver in the winter months. Driving a large vehicle in inclement weather and poor road conditions is stressful in its own right, without the additional challenges of being in a cold cockpit trying to keep warm. Our testing has shown that DFCH preheating allows the cabin temperature to rise significantly just by circulating warm coolant through the under seat and defroster heater units, even without the benefit of the blower motors operating. This means the driver has the benefit of entering a warmer cabin, and then has warm air that can immediately start circulating in the cabin upon starting the vehicle. This certainly makes the winter driving experience less stressful, and aids in driver retention. It can also be said that the drivers feel that the Company is looking out for their well being and investing in improving driver comfort.

Additionally, DFCH heating may solve an operational problem, such as running with engines so efficient that insufficient reject heat is provided to adequately warm the passenger cabin and meet minimum cabin temperature requirements. This issue was experienced on the NYSERDA/NYPA hybrid school bus project busses currently operating in the Brown Transportation school bus fleet, under partnership with Schenectady City Schools. One of the most obvious benefits of a hybrid vehicle is reduced fuel consumption. A portion of the energy in the fuel burned by the engine ends up in the vehicle cooling system as reject heat. A side effect of this reduction in reject heat comes in the winter, when there is not as much engine heat available to heat cabin. The increased efficiency of the Hybrid and the reduced engine load caused passenger complaints in the hybrid fleet in their first winter of operation in the NYPA Project fleet. This necessitated the installation of DFCH on the project busses. While these busses benefited from the availability of preheating, it was the ability to provide supplemental heat during vehicle operation that really was most significant use of the DFCH on the Hybrid busses.

There are also less easily quantifiable benefits such as reduced starting system maintenance, reduced engine wear, and a concomitant reduced engine rebuild interval. One of the biggest maintenance challenges of cold weather operation comes from wear and tear on the vehicle batteries, starting and charging system components. Diesel engines are known to be harder to start than their gasoline burning counterparts. Improvements in electronic control technology, and changes in engine designs have made marked improvements in cold start abilities of diesel engines, but this is still a significant challenge as the temperatures approach the single digits. Extended periods of engine cranking have an adverse effect on starter and battery life, and historically, the winter operating season typically has the most unscheduled replacement of starting and charging system components. A preheated engine cranks over with considerably less effort than a cold engine and also starts firing much quicker. These two factors place less wear and tear on the starting system.

The 36 DFCH equipped test busses represent about 26 percent of the Brown Transportation large school bus fleet. In the 6 month winter operating period from October 1- March 31 for the 2008-2009 winter and 2009-2010, 26 school busses required starter replacements. The DFCH project busses only required 3 starters, or 11.5% of the total. During the same two winter operating period, 24 school busses had battery replacements. Batteries were replaced in 5 of the DFCH project busses, or 20.8% of the total. Both of these numbers are below the 26% of the fleet that the test busses compromise. It should be noted that a large percentage of the Brown Transportation fleet is equipped with electric block heaters and does benefit from some level of preheating. But, the maintenance data does seem to suggest that the DFCH busses require less starting system maintenance than the rest of the fleet. It is also generally accepted in maintenance circles that much of the engine wear over the life of a diesel engine comes at cold start up. This coupled with the fact that a large percentage of total engine life is spent idling seem to indicate that cold starts and prolonged idling are limiting factors on total engine life.

There may be engine efficiency gains from supplemental heating, but it is not known if these gains would offset the fuel cost required for supplemental heater operation. Finally, last but not least, are the environmental benefits possible when using DFCH systems. We estimate that Brown Coach avoided creating nearly 22 tons of CO_2 through the saving of 1958 gallons of diesel fuel. There will also be reductions in NO_x and PM, however, these are difficult to quantify given dependencies on fuel and after-treatment.

Although it is well accepted that cold start emissions are higher than hot start emissions, and this is generally confirmed in Frank et al [Frank, 2004], it was not possible to quantify emissions reductions avoided from starting an engine that had been pre-heated with a DFCH in contrast with un-preheated cold-start engine emissions. This could make an excellent topic for additional study.

5. CONCLUSIONS & RECOMMENDATIONS

Installation of diesel fired coolant heaters (DFCH) has proven to be an effective method to preheat vehicles and provide supplemental heat during the drive cycle. If coupled with additional battery capacity, these heaters are capable of providing inter-run auxiliary heating which will reduce the need for idling to maintain a comfortable temperature in the cabin.

The Proheat X45 worked well in this application with very few service requirements. The error code diagnostics validate the very low number of component faults and our service experience with these heaters was very favorable.

Driver acceptance of the heaters was good and mechanic and maintenance feedback was positive, as well.

A major benefit of the DFCH is that they do not require potentially costly infrastructure improvements to bring in power, or escalate service to demand metering (also costly), as would be necessary were the alternative of electrical immersion block heating used for engine preheating.

Accelerated defrost capability resulting from a hot coolant loop brought heat to the windshield even before the vehicle defrost fans were run or the engine started. This also provides a quick rise in interior cabin temperature for improved driver comfort and a marked improvement in safe vehicle operations.

While it may not be possible to make an economic justification for DFCH installation on idle reduction fuel savings alone, other savings in maintenance and repair costs, combined with other benefits to the environment, safety, personnel, and passengers will have to be considered. Potential unexpected costs, such as fines for idling non-compliance, should be considered, as well.

As a result of this study, we would recommend the development of programs that offset the incremental cost of DFCH installation, and recommend this in any new school bus purchases, and as a consideration for retrofit onto existing vehicles. This is particularly useful on buses that will overnight off-site, and it also offers potential utility in disaster situations where the electricity supply may be unreliable.

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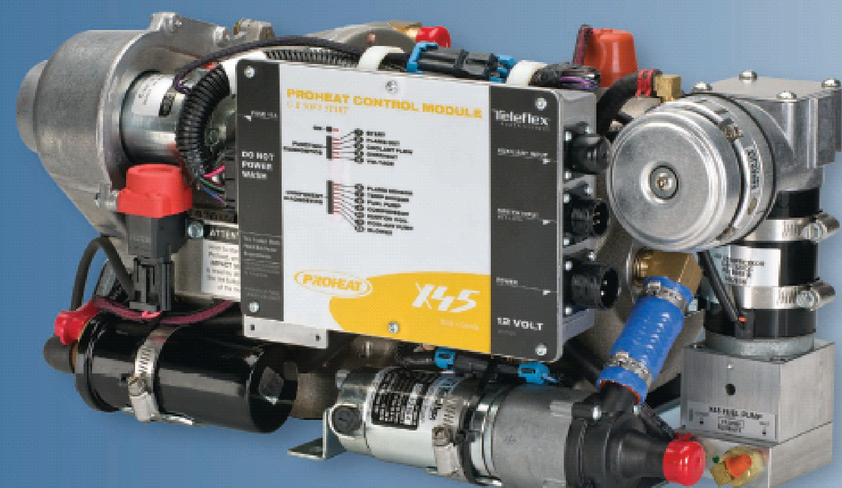
APPENDIX A – TELEFLEX PROHEAT X45 SPECIFICATIONS

(Source: http://www.proheat.com/PDFs/SL9161.pdf, used with permission.)

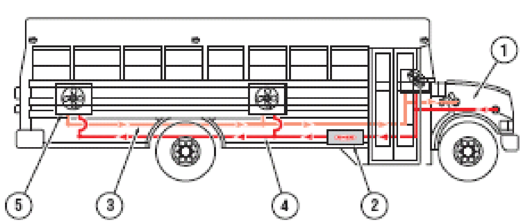
PROHEAT X45

THE COOLANT HEATER OF CHOICE FOR SCHOOL BUSES



POWERFUL AND RUGGED AUXILIARY COOLANT HEATER DESIGNED FOR SCHOOL BUSES

Proheat X45 is a powerful, diesel-powered school bus pre-heating solution for quick and reliable cold weather starting. The heater becomes part of the school bus heating system, supplying added heat for passengers while reducing fuel costs and emissions from unnecessary engine idling. An integrated pump circulates heated coolant to warm the engine block, making starting easier while reducing start-up engine wear. Proheat X45 features an onboard control panel that displays heater status, while an optional digital timer for inside the bus adds convenient timer-based starting of the heater. The heater also complies with National Highway Traffic Administration standards to ensure maximum safety for bus passengers. With more than 15 years in the field, its rugged and field serviceable design has proven reliable in even the most extreme temperatures.



1 Engine
2 Proheat X45 Heater
3 Return to Engine
4 Supply from Proheat X45
5 Fan

Optional Timer

AT A GLANCE

COOLANT HEATER FEATURES

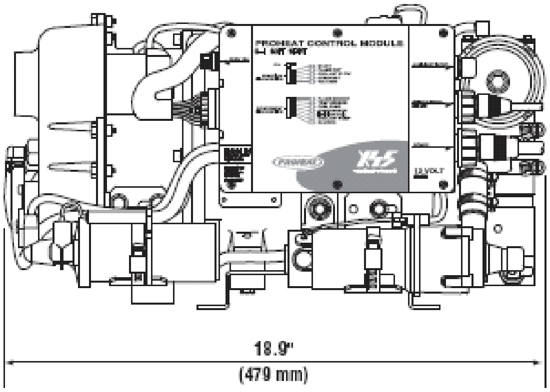
- 13kW (45,000 BTU)
- Electronic control panel displays heater status
- Integrated coolant pump
- Flexible mounting options
- Complies with National Highway Traffic Safety standard FMVSS 301 S5.5 and S5.6
- Two year parts and labor warranty

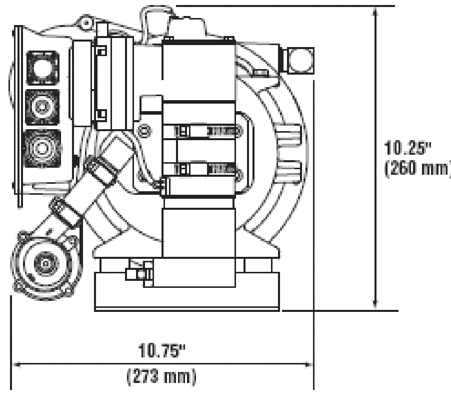
TIMER FEATURES

- Timed or manual start of X45 heater from inside the school bus
- Easy-to-read digital display
- Programmable, multi-event 7-day timer
- Surface-mount design

Teleflex POWER SYSTEMS

SPECIFICATIONS





MODEL	X45-12
RATING	13 kW (45,000 BTU)
OPERATING VOLTAGE RANGE	10.0 – 15 VDC
CURRENT	7.5 A
FUEL CONSUMPTION (Average to Maximum)	0.1 – 0.32 gal/hr. (0.4 – 1.2 L/hr.)
COOLANT FLOW	8.0 gal/min. (30 L/min.)
COOLANT TEMPERATURE (at heater)	150 to 185 °F (65 to 85 °C)
OPERATING TEMPERATURE RANGE	- 40 to 122 °F (-40 to 50 °C)
FUEL TYPES	ULSD, Diesel #1, Diesel #2, Kerosene
IGNITION TYPE	Electronic spark ignition
HEAT EXCHANGER CAPACITY	1 quart (.98 liter)
WEIGHT heater only with enclosure	40 lb (18 kg) 55 lb (25 kg)
DIMENSIONS – HEATER (L x W x H)	18.9 x 10.75 x 10.25 inches (479 x 273 x 260 mm)
DIMENSIONS – ENCLOSURE (L x W x H)	20.5 x 12.5 x 11 inches (520 x 320 x 280 mm)
WARRANTY	Two years parts and labor
REGULATORY COMPLIANCE	National Highway Traffic Safety Standard FMVSS 301 S5.5 and S5.6

Please Note: Specifications are subject to change without notice.

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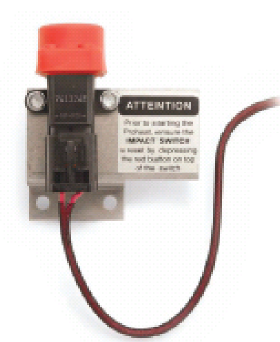
PROHEAT X45 SCHOOL BUS KITS	PART NUMBER
SCHOOL BUS HEATER KIT Electronic controller, coolant pump, mounting base, impact switch, 3/4" coolant hose, 3/4" to 1" brass reducers (2)	PH0408
INSTALLATION KIT Power wire harness, fuel pick-up and hose, control wire harness, exhaust system, nuts, bolts, washers for mounting	PK0300

OPTIONAL COMPONENTS	PART NUMBER
ALUMINUM ENCLOSURE BOX (diamond plate)	PK0200
ALUMINUM ENCLOSURE BOX (plain finish)	PK0300
7 DAY DIGITAL TIMER	PK0001

Electronic Controller

An impact switch automatically shuts the heater off in the event of a vehicle roll-over.



Enclosure (diamond plate)

APPENDIX B – HEATER WIRING TABLE

CIRCUIT	TERM STRIP	COLOR	TO
12 V IGN	1		TO SUPPLEMENTAL HEAT TOGGLE SWITCH COMMON, TO TIMER BACKLIGHT(GREY)
12 V BATTERY TO HEATER	2	RED	TO 20 AMP FUSE THEN SOLENOID BATTERY TERMINAL, 5 AMP FUSE TO MOMENTARY SWITCH COMMON, TO TIMER (RED), TO DIAGNOSTIC PORT (RED) (This keeps timer from losing memory.)
GROUND TO HEATER	3	BLACK	TO CHASSIS GROUND
12 V FROM HEATER	4	RED	NOT USED
GROUND FROM HEATER	5	BLACK	TO SWITCH LIGHT GROUND, TO TIMER GROUND(BLACK), TO DIAGNOSTIC PORT(BLACK)
ON SIGNAL TO HEATER	6	GREEN	TO MOMENTARY "OFF"(CANCELS PREHEAT), TO TIMER(GREEN), TO DIAGNOSTIC PORT(GREEN)
OPERATIONAL SIGNAL FROM HEATER	7	WHITE	TO SWITCH INDICATOR LIGHT POWER, TO TIMER(WHITE), TO DIAGNOSTIC PORT(WHITE)
AUX A	8	WHITE	TO SUPPLEMENTAL HEAT TOGGLE SWITCH "ON" WHEN IGNITION ON
AUX B	9	BLACK	TO MOMENTARY SWITCH "ON" FOR 90 MIN PREHEAT

APPENDIX C – DRIVER SURVEY

Bus#______

Diesel Fired Coolant Heater School Bus Driver Survey

Several of the school buses Brown Coach operates were equipped with a diesel fired coolant heater to provide engine and cabin preheating. As part of the research project to evaluate the performance of these heaters, we'd greatly appreciate any input you can share on the survey below. THANKS!

1. How often did you drive a vehicle equipped with a diesel fired coolant heater last winter:

☐ Never ☐ Occasionally ☐ Most Always ☐ Not sure what this is

2. Did the cabin heat up more quickly in the morning before leaving the garage?

☐ No ☐ Not sure ☐ Yes

3. Did bus windows defrost quicker than you were used to when driving other buses (not equipped with this type of heater)?

☐ No ☐ Not sure ☐ Yes

If Yes, approximately how much quicker did the windows defrost? ______minutes.

4. Were you able to idle the bus less because the auxiliary heater would help keep the cabin warm, or warm it more quickly?

☐ No ☐ Not sure ☐ Yes

If Yes, approximately how many minutes of idling were reduced? ______minutes.

5. How often did you run the heater fans while the engine was off to warm the cabin (such as while waiting between runs)?

☐ Never ☐ Occasionally ☐ Often ☐ Always

6. How interested are you in driving a bus equipped with a diesel fired coolant heater next winter:

☐ Not interested ☐ Don't care ☐ Definitely prefer this

Comments (good or bad) about your experience with these heaters would be most helpful:

____

____

____

____

APPENDIX D – DRIVER SURVEY RESPONSES

Brown Coach Driver Survey Responses

Bus	Q1 - Drive DFCH freq.				Q2 - Cabin heat rate			Q3 - Defrost Quicker				Q4 - Able to Idle Less				Q5 - Heater Fans w/Engine Off				Q6 - Want DFCH Next Winter		
	Never	Occasionally	Most Always	Not Sure	No	Not Sure	Yes	No	Not Sure	Yes	If yes, how much (min)	No	Not Sure	Yes	If yes, how much (min)	Never	Occasionally	Often	Always	Not Interested	Don't Care	Definitely Prefer
181			1				1			1	5			1	10			1				1
182			1				1			1	5			1	10				1			1
183			1				1			1	5			1	10			1				1
184			1				1			1	5			1	na		1					1
185			1				1			1	10			1	20		1					1
186			1				1			1	5			1	15		1					1
221			1				1			1	10			1	20	1						1
222			1				1			1	5			1	15		1					1
223			1				1			1	5			1	10	1						1
224			1				1			1	10			1	10	1						1
300(b)			1				1			1	10			1	na		1					1
301(h)			1				1			1	10			1	na		1					1
302(h)			1				1			1	10			1	10		1					1
347			1				1			1	6			1	10	1						1
349			1				1			1	na			1	na		1					1
352			1				1			1	5			1	20		1					1
353			1				1			1	3			1	15		1					1
354			1				1			1	5			1	na		1					1
357			1				1			1	5			1	10		1					1
358			1				1			1	5			1	20		1					1
359			1				1			1	5			1	10	1					1	
360			1				1			1	5			1	15	1						1
361			1				1			1	5		1		na		1					1
362			1				1			1	5			1	10		1					1
362			1				1			1	5			1	10		1					1
363			1				1			1	5			1	20		1					1
364			1				1			1	15			1	na	1						1
Summary	0	0	27	0	0	0	27	0	0	27	6.5	0	1	26	13.5	7	17	2	1	0	1	26
%	0.0%	0.0%	100%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	100%	Avg.	0.0%	3.7%	96.3%	Avg.	25.9%	63.0%	7.4%	3.7%	0.0%	3.7%	96.3%

Notes: (b) - Baseline bus for NYPA Hybrid Project
(h) - NYPA Hybrid Bus
na - No Answer Provided

APPENDIX E – DFCH DATA COLLECTION SUMMARY

The following tables summarize download data collected as part of the DFCH project. Note that each unit has a fixed length event log, so it is possible that data records for the same vehicle either overlap or in some cases experience a gap in data. This is a function of vehicle utilization and the generation of event codes by the X45 heater. Examination of the duty cycle in the data below revealed setup/configuration issues with some of the initial installations showing very low duty cycles.

Brown Coach Diesel Fired Coolant Heater Data Collection Summary

Bus	Download Date	Filename	Ending Power Hours	Starting Power Hours	Approx Data Start Date	Total Hours	Flame Hours	Duty Cycle (%)	Total Cycles
153	7/28/2009	C12153.HIS	9044.107472	526.981194	8/7/2008	49.64886	29.98803	60%	166
154	7/29/2009	C12154.HIS	14398.40886	2310.850083	3/12/2008	125.2247	43.47536	35%	405
154	8/21/2008	C10154.HIS	6720.636722	0	11/14/2007	83.18981	21.49472	26%	279
181	7/28/2009	C12181.HIS	8718.9055	3647.890389	12/28/2008	145.8106	66.51306	46%	631
181	8/21/2008	C10181.HIS	3337.379306	1298.632361	5/28/2008	106.6256	45.91864	43%	519
181	3/17/2008	C00181.HIS	2111.781444	834.700306	1/23/2008	81.55919	37.80586	46%	356
182	8/1/2009	C12182.HIS	10626.32683	8259.632667	4/24/2009	465.1413	207.6434	45%	1492
182	8/21/2008	C10182.HIS	4126.064361	2623.063556	6/19/2008	254.1856	90.60994	36%	1089
183	8/1/2009	C12183.HIS	7210.06516	5578.425444	5/25/2009	112.2151	40.40275	36%	407
183	8/21/2008	C10183.HIS	1061.186056	0	7/7/2008	3.958778	0.120278	3%	0
184	8/1/2009	C12184.HIS	7561.404556	5068.584722	4/19/2009	268.9566	189.0967	70%	243
184	3/17/2008	C00184.HIS	165.579778	0	3/10/2008	0.224028	0.134528	60%	0
185	7/28/2009	C12185.HIS	8170.953417	5379.282528	4/2/2009	113.5283	67.22831	59%	319
185	3/17/2008	C00185.HIS	793.423361	0	2/12/2008	3.3295	0.510639	15%	0
186	7/28/2009	C00186.HIS	7697.27075	5422.588	4/24/2009	234.285	124.7527	53%	597
186	3/17/2008	C00186.HIS	431.002194	0	2/28/2008	28.91131	14.49278	50%	82
220	7/30/2009	C12220.HIS	11474.55556	0	4/7/2008	20.75653	8.925861	43%	39
220	8/6/2008	C10220.HIS	2881.174556	0	4/7/2008	5.254639	0.046139	1%	6
221	7/28/2009	C12221.HIS	14661.27789	10285.66619	1/26/2009	225.359	139.9851	62%	517
221	8/7/2008	C10221.HIS	6222.910056	0	11/21/2007	54.31378	32.93697	61%	102
222	8/1/2009	C12222.HIS	9385.07225	5444.482639	2/17/2009	174.9576	91.81356	52%	498
222	8/8/2008	C10222.HIS	1991.296306	0	5/17/2008	46.16486	24.86958	54%	144
222	3/17/2008	C00222.HIS	791.619444	0	2/13/2008	24.83831	12.81081	52%	76
223	8/1/2009	C12223.HIS	11571.14217	6769.560722	1/12/2009	282.3527	153.7573	54%	750
223	8/8/2008	C10223.HIS	2978.030361	656.988639	5/3/2008	128.6957	64.54053	50%	365
223	3/17/2008	C00223.HIS	1752.717972	0.450667	1/3/2008	93.34117	43.44603	47%	265
224	7/27/2009	C12224.HIS	10546.08531	6409.793722	2/4/2009	172.9876	109.6409	63%	591
224	8/7/2008	C10224.HIS	2051.958056	0	5/13/2008	0.405833	0.188694	46%	0
345	7/28/2009	C12345.HIS	20856.85806	17217.61311	2/26/2009	469.2115	257.7079	55%	1556
345	8/7/2008	C10345.HIS	12338.86436	8170.178	2/15/2008	225.3668	145.4603	65%	576
345	3/13/2008	C01345.HIS	8817.699639	7776.413139	1/29/2008	215.6647	142.4141	66%	549
345	1/25/2008	C08345.HIS	7657.088611	6602.245444	12/12/2007	142.7057	98.15258	69%	347
345	1/24/2008	C09345.HIS	7633.067889	6601.367472	12/12/2007	141.8787	97.344	69%	347
345	1/23/2008	C00345.HIS	7609.101833	6576.906583	12/10/2007	139.352	95.55586	69%	340
345	1/3/2008	C02345.HIS	7131.322917	6078.939722	11/20/2007	105.9527	75.15247	71%	226
346	7/31/2009	C12346.HIS	10068.59458	5309.446444	1/13/2009	128.3071	57.81989	45%	660
346	8/21/2008	C10346.HIS	1926.385167	0	6/1/2008	2.7725	0.215806	8%	4
347	7/27/2009	C12347.HIS	10035.97253	5707.549278	1/27/2009	165.5634	75.1715	45%	938
347	8/6/2008	C10347.HIS	1516.577	0	6/3/2008	0.270361	0.193028	71%	1

Brown Coach Diesel Fired Coolant Heater Data Collection Summary - Continued

Bus	Download Date	Filename	Ending Power Hours	Starting Power Hours	Approx Data Start Date	Total Hours	Flame Hours	Duty Cycle (%)	Total Cycles
348	8/1/2009	C12348.HIS	20021.25486	16468.14361	3/5/2009	448.9019	312.1354	70%	847
348	8/7/2008	C10348.HIS	11445.34331	7099.845333	2/7/2008	204.3801	152.7894	75%	346
348	3/13/2008	C00348.HIS	7924.171056	6435.380694	1/10/2008	162.4656	124.3739	77%	249
349	7/28/2009	C12349.HIS	20200.80653	16064.36386	2/5/2009	464.715	234.6441	50%	1193
349	8/7/2008	C10349.HIS	11678.10958	7460.470972	2/13/2008	190.972	133.8838	70%	395
349	3/13/2008	C00349.HIS	8284.123889	7028.470972	1/20/2008	169.9292	122.4503	72%	342
350	8/3/2009	C12350.HIS	11504.43108	1545.4525	6/14/2008	24.97411	6.351972	25%	84
350	8/8/2008	C10350.HIS	3612.766056	185.47275	3/18/2008	15.31806	3.940417	26%	52
351	7/27/2009	C12351.HIS	10179.84683	6020.800556	2/3/2009	183.7122	86.13939	47%	813
351	8/21/2008	C10351.HIS	2020.731389	0.000028	5/28/2008	0.976361	0.019083	2%	2
352	8/1/2009	C12352.HIS	16676.98375	13891.94008	4/6/2009	402.0658	166.3899	41%	2139
352	8/21/2008	C10352.HIS	9862.715139	7891.080278	5/30/2008	181.5805	52.61833	29%	1235
352	3/17/2008	C00352.HIS	8636.516722	7348.084194	1/23/2008	179.8844	52.55722	29%	1234
353	8/1/2009	C12353.HIS	10884.23897	7293.501389	3/4/2009	447.6033	91.67211	20%	4382
353	8/7/2008	C10353.HIS	2538.079278	1123.622917	6/9/2008	122.0671	25.9545	21%	1142
353	3/17/2008	C00353.HIS	1173.751167	330.627806	2/10/2008	78.61581	17.54042	22%	699
354	8/1/2009	C12354.HIS	15574.53772	13040.59036	4/17/2009	376.6129	164.8492	44%	1731
354	8/8/2008	C10354.HIS	8402.866139	5974.097083	4/28/2008	127.2254	59.72608	47%	506
354	3/17/2008	C00354.HIS	7203.532361	5910.823194	1/23/2008	126.2788	59.22364	47%	504
355	7/31/2009	C12355.HIS	10415.36114	5109.690778	12/21/2008	149.5367	68.578	46%	761
355	8/6/2008	C10355.HIS	1803.256833	0	5/22/2008	1.634861	0.281389	17%	0
356	7/28/2009	C12356.HIS	9842.34925	4511.629194	12/17/2008	137.2714	67.27681	49%	759
356	8/6/2008	C10356.HIS	1302.912944	0	6/12/2008	0.235083	0.120389	51%	0
357	8/1/2009	C12357.HIS	7236.967472	5994.381389	6/10/2009	668.1444	51.08381	8%	5706
357	8/7/2008	C10357.HIS	937.441139	0	6/28/2008	158.4033	9.999611	6%	1313
358	7/27/2009	C12358.HIS	11569.09839	9443.970639	4/29/2009	222.2326	131.4395	59%	598
358	8/22/2008	C10358.HIS	4562.656556	0	2/13/2008	27.69153	17.19872	62%	105
359	8/1/2009	C12359.HIS	8543.770528	4903.128639	3/2/2009	147.6706	57.70331	39%	221
359	8/21/2008	C10359.HIS	1734.665944	58.974556	6/12/2008	98.91908	35.17103	36%	155
359	3/17/2008	C00359.HIS	508.571694	0	2/24/2008	55.09503	21.25933	39%	83
360	7/28/2009	C12360.HIS	8344.223556	6009.960917	4/21/2009	288.9727	112.9061	39%	1134
360	8/22/2008	C10360.HIS	1541.610556	0	6/18/2008	72.72206	32.26892	44%	336
360	3/17/2008	C00360.HIS	316.349722	0	3/3/2008	13.45711	8.267861	61%	47
361	7/28/2009	C12361.HIS	9048.189833	6363.372528	4/7/2009	274.1898	151.8257	55%	960
361	8/21/2008	C10361.HIS	2327.579444	0	5/16/2008	61.09158	30.22403	49%	197
361	3/17/2008	C00361.HIS	1102.085556	0	1/31/2008	23.26664	9.974667	43%	53
362	8/1/2009	C12362.HIS	6174.849861	2860.383111	3/15/2009	158.7256	61.7015	39%	922
362	8/8/2008	C10362.HIS	1877.005806	0	5/21/2008	32.35772	9.340111	29%	83
362	3/17/2008	C00362.HIS	650.312972	0	2/18/2008	12.30528	4.388861	36%	36
363	7/27/2009	C12363.HIS	10374.77739	6333.869528	2/8/2009	306.8123	147.166	48%	588
363	8/22/2008	C10363.HIS	2233.662694	0	5/20/2008	0.406917	0.213333	52%	0
364	7/27/2009	C12364.HIS	10472.02183	5472.577556	12/30/2008	149.4184	96.66517	65%	692
364	8/6/2008	C10364.HIS	1951.938694	0	5/16/2008	0.555389	0.229944	41%	0
365	7/30/2009	C12365.HIS	19240.47636	7740.003278	4/6/2008	193.9138	115.1724	59%	511
365	8/6/2008	C10365.HIS	10647.55231	6814.003667	2/28/2008	164.9846	98.53094	60%	449
366	7/28/2009	C12366.HIS	12669.91714	8563.882917	2/6/2009	251.6633	135.2831	54%	699
366	8/7/2008	C10366.HIS	4173.320194	0	2/15/2008	58.53042	28.21072	48%	152
367	7/27/2009	C12367.HIS	11772.05	2853.565556	7/20/2008	174.4544	97.32183	56%	697
367	8/6/2008	C10367.HIS	3408.670111	1458.314389	5/16/2008	127.0126	69.03553	54%	500
367	3/17/2008	C00367.HIS	2182.064167	770.704056	1/18/2008	103.6338	60.58908	58%	433

APPENDIX F – TELEFLEX PROHEAT .HIS FILE FORMAT INTERPRETATION

While Teleflex offers an interface that displays heater status, directly interpreting the codes in the file is extremely helpful for data analysis. The following summarizes our understanding of the file format used in the X45 Proheat .HIS file and was derived by contrast with data observed in corresponding Datalink program output. There may be additional codes in the Datalink files that were not observed and therefore not recorded here, so care should be taken when using the following information.

Timestamp data is retained as a floating point time in the data file. Additionally, there appears to be a timer corresponding to battery power being applied to the X45 unit that is not revealed in the standard Datalink interface. This is very useful in correlating events to calendar time and can be decoded as follows:

Floating point time in file to clock time:
Hours = int(FPtime) (floor fcn in matlab)
Remainder = fptime - hours
Min = int(60*remainder)
Sec = 60*(remainder*60-min)

In excel:
Hours: =INT(M5)
Minutes: =INT((M5-Q5)*60)
Seconds (rounded to tenths): =INT((((M5-Q5)*60 - INT((M5-Q5)*60))*60)*10)/10
Where M5 = Floating point hours and Q5 = Hours

Each file appears to have a file header comprised of the following:

OWNER (BROWN) <CRLF>
Download date: (mm/dd/yyyy) <CRLF>
Heater S/N: (nnn) <CRLF>
PCM S/N: (Cmmnnn) <CRLF>
? (0), Cycles(int), Flame hours(float), Total hours(float), Event (0|1|2|4 observed), State (101..110), Flame? (int?), ?? (nn.n? temperature?), Coolant Temperature degC (+/-nn.n), Input voltage FI? (nn.n), Input Voltage IN? (nn.n, usually 0 except at download), ?? (0), Power Hours (float, not displayed on current datalink sw) [,on first line only add: model code?? (nn), Firmware version (nnnn), (nn, hex)] <CFLF>

State Codes Appear to be:
101 OFF
102 ON
103 STANDBY
104 PRE RUN
105 PRE CHECK
106 IGNITION
107 RUN
108 RE IGNITION
109 PURGE
110 SHUTDOWN

State/Event Combos appear to dictate textual output on Datalink program, summary of observed combos follows:

State / Event => Textual Result
0 0 => Download
105 (precheck) 103 (cycled on) => Cycled On
107 (run) 104 (cycled off) => Cycled Off
101 (off) 101 (switched on) => Switched On
110 (shutdown) 102 (switched off) => Switched Off

103 (standby) 102 (switched off) => Switched Off
106 (ignition) 102 (switched off) => Switched Off
109 (purge) 102 (switched off) => ?Switched Off?
106 (ignition) 001 => Start Error (1)
108 (reignition) 002 => Flameout Error (2)
105 (precheck) 004 => overheat error (4)
Others not observed: expect that error codes correlate with table on manual p. 4-6 and presented in Table 1 of this report.

APPENDIX G – VBA ANALYSIS CODE

The following code was created for research purposes and is neither considered to be production code nor intended for distribution to end-users. It is provided here for reference only, and results obtained by executing this code are the basis for analysis worksheets in the Data Analysis.xls Excel spreadsheet provided on the CD included with this report.

```
Sub Eval_Heater()
'Eval_Heater is the primary subroutine for evaluating the results of X45 .HIS files

Dim Ev$, St$, S$, S2$, SheetName$, SheetAnalysis$
Dim Evint, Stint, HtrStarts, cyclesrowoffset As Integer
Dim E(1 To 15) As Integer
Dim ET(1 To 15) As Integer
Dim StopTime$, Ctemp$, Ptime$
Dim STdouble As Double
Dim cycletime(1 To 1000) As Double
Dim cycletemp(1 To 1000) As Double
Dim Ertest As Integer
Dim Done As Boolean
Dim i, x, y As Integer
Dim w, wSheet As Worksheet
Dim R As Range

'index through all sheets in workbook, searching for sheets names beginning with Cxxxxx
'for each of these, either add a corresponding sheet prefixed with Axxxxx for analysis results
'or overwrite existing results should one of these sheets exist

'init counter for tracking error totals across all sheets
    For i = 1 To 15
      ET(i) = 0
    Next i

For Each w In Worksheets
  w.Select
  'code to run on all worksheets is here
  SheetName$ = w.Name
  If Left(SheetName$, 1) = "C" Then
    'code to run only on data set sheets is in here
    'create a new sheet for analysis results if it does not already exist
    SheetAnalysis$ = "A" + Right(SheetName$, Len(SheetName$) - 1)
    On Error Resume Next
    Set wSheet = Sheets(SheetAnalysis$)
    If wSheet Is Nothing Then 'Doesn't exist
      Sheets.Add.Name = SheetAnalysis$
      Sheets(SheetAnalysis$).Select
        'MsgBox "Worksheet does not exist", _
        '  vbCritical, "doesnt exist"
        Set wSheet = Nothing
        On Error GoTo 0 'disables error handler in procedure
    Else 'Does exist
      Sheets(SheetAnalysis$).Select
      'MsgBox "Sheet does exist - doing nothing", _
      '  vbInformation, "does exist"
      Set wSheet = Nothing
      On Error GoTo 0
    End If
```

```
x = 5          'First Data Row
Done = False
'init error count array
For i = 1 To 15
  E(i) = 0
Next i
HtrStarts = 0

While Not Done
  Ev$ = GetCellValue(SheetName$, "E", x)
  St$ = GetCellValue(SheetName$, "F", x)
  Evint = Val(Ev$)
  Stint = Val(St$)

  If Ev$ = "" Then
    Done = True
  Else            'Not Done
    For i = 1 To 15
      If Evint = i Then
        E(i) = E(i) + 1
        ET(i) = ET(i) + 1
      End If
    Next i
    If Stint = 107 Then  'accept Evint with 107, as can be accompanied by error code
      StopTime$ = GetCellValue(SheetName$, "M", x)
      STdouble = Val(StopTime$)
    End If
    'Switched off with shutdown
    If Stint = 110 And Evint = 102 Then
      StopTime$ = GetCellValue(SheetName$, "M", x)
      STdouble = Val(StopTime$)
    End If
    'Switched off with standby
    If Stint = 103 And Evint = 102 Then
      StopTime$ = GetCellValue(SheetName$, "M", x)
      STdouble = Val(StopTime$)
    End If
    'Switched off with ignition
    If Stint = 106 And Evint = 102 Then
      StopTime$ = GetCellValue(SheetName$, "M", x)
      STdouble = Val(StopTime$)
    End If
    'Switched off with purge
    If Stint = 109 And Evint = 102 Then
      StopTime$ = GetCellValue(SheetName$, "M", x)
      STdouble = Val(StopTime$)
    End If
    'catch start of burner, calculate on time, and grab coolant temperature
    If Evint = 103 And Stint = 105 Then
      HtrStarts = HtrStarts + 1
      Ctemp$ = GetCellValue(SheetName$, "I", x)
      cycletemp(HtrStarts) = Val(Ctemp$)
      Ptime$ = GetCellValue(SheetName$, "M", x)
      cycletime(HtrStarts) = STdouble - Val(Ptime$)
    End If
```

```
      End If
      x = x + 1
    Wend

    'now report results on the analysis sheet
    Sheets(SheetAnalysis$).Select
    Set R = Application.Worksheets(SheetAnalysis$).Range("A1")
    R.Value = "Analysis for " & SheetName$

    'Range("A1").Select
    'Range("A1").Activate
    'ActiveCell.Value = "hello"
    For i = 1 To 15
      S2$ = Str(i + 2): S2$ = Right(S2$, Len(S2$) - 1)
      S$ = "B" & S2$
      Set R = Application.Worksheets(SheetAnalysis$).Range(S$)
      R.Value = Str(E(i))
      S$ = "A" & S2$
      Set R = Application.Worksheets(SheetAnalysis$).Range(S$)
      R.Value = "Error #" & Str(i)
    Next i
    S$ = "B18"
    Set R = Application.Worksheets(SheetAnalysis$).Range(S$)
    R.Value = Str(HtrStarts)
    S$ = "A18"
    Set R = Application.Worksheets(SheetAnalysis$).Range(S$)
    R.Value = "Htr Starts"
    S$ = "A20"
    Set R = Application.Worksheets(SheetAnalysis$).Range(S$)
    R.Value = "Start#"
    S$ = "B20"
    Set R = Application.Worksheets(SheetAnalysis$).Range(S$)
    R.Value = "run time"
    S$ = "C20"
    Set R = Application.Worksheets(SheetAnalysis$).Range(S$)
    R.Value = "start coolant temp"
    cyclesrowoffset = 20
    For i = 1 To HtrStarts
      S2$ = Str(i + cyclesrowoffset): S2$ = Right(S2$, Len(S2$) - 1)
      S$ = "B" & S2$
      Set R = Application.Worksheets(SheetAnalysis$).Range(S$)
      R.Value = Str(cycletime(i))
      S$ = "C" & S2$
      Set R = Application.Worksheets(SheetAnalysis$).Range(S$)
      R.Value = Str(cycletemp(i))
      S$ = "A" & S2$
      Set R = Application.Worksheets(SheetAnalysis$).Range(S$)
      R.Value = "Heat Cycle #" & Str(i)
    Next i
  End If
Next
'now report results on the Error Totals sheet
SheetAnalysis$ = "Error Totals"
Sheets(SheetAnalysis$).Select
Set R = Application.Worksheets(SheetAnalysis$).Range("A1")
R.Value = "Error Totals for All Sheets"
```

```
For i = 1 To 15
  S2$ = Str(i + 2): S2$ = Right(S2$, Len(S2$) - 1)
  S$ = "B" & S2$
  Set R = Application.Worksheets(SheetAnalysis$).Range(S$)
  R.Value = Str(ET(i))
  S$ = "A" & S2$
  Set R = Application.Worksheets(SheetAnalysis$).Range(S$)
  R.Value = "Error #" & Str(i)
Next i
End

End Sub

Function GetCellValue(ByVal Sheet As String, ByVal Col As String, ByVal Row As Integer) As String

    Dim S$, S2$
    Dim R As Range

    S2$ = Str(Row): S2$ = Right(S2$, Len(S2$) - 1)
    S$ = Col & S2$
    Set R = Application.Worksheets(Sheet).Range(S$)
    GetCellValue = R.Value

End Function
```

APPENDIX H – NYS DOT MEMO REGARDING DFCH INSTALLATIONS

Memorandum from NYSDOT Regarding Auxiliary Heater Requirements

Mike Smith, Passenger Carrier Safety Bureau

This memorandum supersedes the March 2001 memo on the same subject. The information provided below is taken from the installation guidelines used for a recent NYSERDA program and is to be used for all heaters installed after 1 August 2009.

Please note that these guidelines apply only to new installations. It is not our intention to require the retrofit of any previously installed equipment.

1. Fuel oil fired auxiliary heaters, supplemental heat application.

Auxiliary fuel-fired supplemental heating systems are permitted provided they comply with the following:

(A) The auxiliary heating system shall utilize the same type fuel as specified for the vehicle engine.

Fuel lines are to be metal, Aero-quip metal braid reinforced, or Synflex tubing equal to vehicle manufacturer's standard utilizing pre-existing fittings on the fuel tank. Additional fuel tank penetrations are not permitted. If there are no available fittings on the tank one may be added provided that it is put in place in a manner approved by the tank manufacturer.

Any fuel line passing through the vehicle frame rail will do so using a metal bulkhead fitting or a grommet that prevents any abrasion damage to the fuel line.

Short flexible lines are permitted at the fuel tank and heater assembly only for vibration isolation.

All flexible lines are to be hose assemblies with crimped or threaded fittings. Barbed fittings and hose clamps are not acceptable.

(B) The heaters are to be mounted in an enclosure behind the bus's left rear wheels or between the rear frame rails and connected to the vehicles cooling system via the existing hot water heater circuit.

The heater manufacturers recommended low voltage circulator pump is to be mounted in the heater enclosure if it is not an integral part of the heater.

Coolant hose used is to be equal in size and specification to the vehicle manufacturer's.

Any frame penetrations necessary to mount the unit are to be done following vehicle manufacturers established procedures.

(C) An auxiliary heating system, when connected to the engine's cooling system, may be used to preheat the engine coolant, preheat the passenger compartment, and/or add supplementary heat to the bus's cabin heating system.

(D) Auxiliary heating systems shall be installed pursuant to the manufacturer's recommendations.

Exhaust shall be routed through solid tubing flexible welded stainless tubing Clevaflex Mini E 30 mm is also acceptable. Spiral wound flex tubing is not permitted. Exhaust tubing is to be properly clamped and supported. Exhaust routing shall generally be parallel to the vehicle exhaust to its discharge end and may not be directed in a manner that will endanger bus passengers.

A 1/8 inch hole shall be drilled in the lowest point of the heater exhaust system if the pipe does not slope continuously downward from the heating unit to the discharge end.

(E) Auxiliary heating systems which operate on diesel fuel shall be capable of operating on #1, #2, blended, or Bio Diesel fuel in grades up to B 20 without the need for combustion system adjustment.

(F) Auxiliary heating systems shall be low voltage with a minimum output of 40,000 BTU /hr.

(G) Auxiliary heating systems and their installation shall comply with all applicable Federal Motor Vehicle Safety Standards, including FMVSS 301, 49CFR393.77, as well as all applicable SAE standards.

(H) Each installation shall include an easily operated 7 day programmable timer to control the heater operating cycle.

(I) An operator or dealer installing multiple units should contact the local NYSDOT Supervising Motor Vehicle Inspector for guidance on the initial installation and ensure that all subsequent installations are identical to the first.

(J) Each Operator's location having heaters installed shall be provided operation and maintenance training including operation, service / overhaul, and parts manuals for the equipment provided.

2. Fuel Oil fired auxiliary heaters, Pre-heat application.

Auxiliary fuel-fired pre-heat systems are permitted, provided they comply with the following:

(A) The auxiliary heating system shall utilize the same type fuel as specified for the vehicle engine. The unit must be able to use # 2 diesel, #1 Diesel, any blend of # 1 & 2, and Bio Diesel in grades up to B 20 with no adjustment of the combustion system. Fuel lines are to be the same as described in item 1 A

(B) The heaters are to be frame mounted and connected to the engine's cooling system using the same size and specification hose as original equipment on the vehicle. Under hood (firewall) mounting if these devices is not permitted. The heater manufacturers recommended low voltage circulator pump is to be mounted within the heater enclosure if it is not an integral part of the heater.

(C) An auxiliary heating system, when connected to the engine's cooling system, shall be used to preheat the engine coolant. Heaters used in this application may not be operated when the bus engine is in operation.

(D) Auxiliary heating systems shall be installed pursuant to the manufacturer's recommendations. Exhaust shall extend through solid tubing to left or street side edge of the body skirt and may not be directed in a manner that will endanger bus passengers. Clevaflex Mini E 30mm Stainless flex tubing properly clamped and supported is acceptable. A 1/8 inch drain hole is to be drilled in the low point of the exhaust pipe if it does not slope continuously downward from the heater to the discharge end of the pipe.

(E) Auxiliary heating systems shall be low voltage with a minimum output of 10,000BTU /hr.

(F) Auxiliary heating systems and their installation shall comply with all applicable Federal Motor Vehicle Safety Standards, including FMVSS 301, 49CFR393.77, as well as applicable SAE standards.

(G) Each installation shall include an easily operated 7 day programmable timer to control the heater operating cycle

(H) An operator or dealer installing multiple units should contact the local NYSDOT Supervising Motor Vehicle Inspector for guidance on the initial installation and ensure that all subsequent installations are identical to the first.

(I) Each Operator's location having heaters installed shall be provided with operation and maintenance training including operating, service/overhaul, and parts manuals for the equipment provided.

APPENDIX I – DFCH COSTS

Item	Part number	Qty	List Price
Proheat XL45-12	PH0403	1	$2,200.00
Proheat Timer	PK0001	1	$208.99
Timer Bracket	950261K	1	$17.78
Side Mount frame kit	PK0152	1	$222.22
Impact Switch	PK0055	1	$60.00
Fuel Check Valve	PK0059	1	$101.01
Aux Power Cable	903026K	1	$51.01
Remote Diagnostic port		1	$148.15
On-Off-On Mom. Switch	56-2697	1	$34.97
Indicator Light		1	$12.57
switch connector		1	$12.00
Tail Pipe Assy		1	$45.00
Tail Pipe Hangers		3	$45.00
Misc fittings and connectors		1	$50.00
Freight		1	$100.00
Subtotal			$3,308.70
Sales Tax @ 8.25%			$272.97

Table 7 - DFCH Equipment Costs

Install labor was calculated at 12 hours x $85/hr, or $1020.00.

In a retail environment, it would be reasonable to expect a 30% premium applied on the labor portion of these installations. Consequently the total costs per DFCH installation are estimated at $5000 with sales tax.

APPENDIX J – HEATER DATA FILES

Each heater data file occupies in excess of 500 lines of data, and there are multiple downloads for the 36 vehicles in this study. It is consequently space prohibitive to include this data in a printed format. The raw data files are included on the attached CD, and this data is also included in the Data Analysis.xls spreadsheet on worksheet tabs that are prefixed with “Cxxxxx”.

Sample data is shown in Figure 15 and all data is included on the CD accompanying this report.