

Data Extraction Methods and their Effects on the Retention of Event Data Contained in the Electronic Control Modules of Detroit Diesel and Mercedes-Benz Engines

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ABSTRACT

The Electronic Control Modules (ECMs) aboard many on-highway commercial motor vehicles contain event data useful to the investigation and reconstruction of motor vehicle collisions [1,2,3,4]. Methods of extracting such event data include: connecting to the ECMs through the vehicle's Off-Board Diagnostics Connector (a 6 or 9 pin connector typically found inside the vehicle near the driver's seat); connecting directly to any ECMs while they are still connected to the engine; and connecting directly to the ECMs after they are removed from the engine (a method typically referred to as a Bench image). This research is an attempt to document the effects of these data-extraction methods on the retention of the event data contained in the ECMs of the on-highway commercial motor vehicle engines manufactured by Detroit Diesel and Mercedes-Benz. In particular, the different data extraction methods listed above were compared to determine what effect, if any, the methodologies had on the preservation of ECM event data. The testing showed that the Last Stop Record and Hard Brake event data were not affected by data-extraction methodology, whereas Diagnostic Records produced as a result of fault codes could be affected by data extraction methodology.

INTRODUCTION

After an accident, collision investigators are called upon to extract or image the event data contained in the ECMs of on-highway commercial motor vehicles. The event data contained in the ECMs of Detroit Diesel and Mercedes Benz engines have been described in the prior literature [5,6], but research into the area of data extraction methods has been limited. For Detroit Diesel and Mercedes Benz engines, the event data usually includes Hard Brake events, a Last Stop Record, and Diagnostic Records. In a given case, both a personal computer (PC) running software from Detroit Diesel and a RP1210A-compliant serial link adapter are used to communicate with the Detroit Diesel and Mercedes Benz engine ECMs to image the event data. For a vehicle that has sustained no or very little damage as a result of the collision, communication with the ECM is established via the vehicle's Off-Board Diagnostics Connector, which is typically located near the driver's seat of the vehicle. In this paper, this extraction method will be referred to as a "Diagnostic Connector" image.

The condition of the on-highway commercial motor vehicle after a collision will vary depending on the severity of the crash. A vehicle having sustained severe damage may prevent the investigator from communicating with the engine ECM(s) through the Diagnostic Connector. However, it is possible to

remove the ECM(s) from the vehicle and to use a cable to connect the PC and serial link adapter directly to ECMs. This type of data extraction is typically referred to as a “Bench” image and will be thus referred to in this paper. Connecting the cable directly to the ECM(s) and performing a Bench image, without any sensors connected to the ECM(s), will cause new Diagnostic Records to be written. These new files will, in turn, overwrite any existing records that may have been related to the collision event. Existing literature confirms the idea that performing a Bench image will cause Diagnostic Records to be overwritten, but due to the publication date, only older ECM models such as the Detroit Diesel DDEC-IV and Mercedes Benz VCU/PLD are covered [5]. The newer DDEC-V, DDEC-VI, and DDEC-10 ECMs are not discussed in this available reference. Furthermore, the literature does not address the effect of performing a Bench image on the retention of other event data that may be contained in the ECMs [4-5].

In this research, a third method for extracting the event data was investigated. This method consisted of leaving the ECM(s) on the vehicle and to disconnect only the ECM harnesses required to connect the cables directly to the ECMs. In this paper, this extraction method will be referred to as an “On-Truck” image. In an On-Truck image, many of the ECM sensors are still connected to the ECMs, thereby preventing many diagnostic faults from occurring.

Another area researched in this paper was the effect of active diagnostic codes or fault codes being created as a result of an accident and then studying the effect of the three data extraction methods (i.e., Diagnostic Connector, On-Truck, and Bench) on the retention of the event data contained in the ECMs when active fault codes are present in the ECMs. The two active fault codes chosen for this research were a Low Coolant Level fault and a Low Oil Pressure fault. The Low Coolant Level and Low Oil Pressure faults were chosen due to these faults being common faults that are created as a result of an accident with an on- highway commercial motor vehicle.

METHODOLOGY

The three data-extraction methods were performed on engines from Detroit Diesel and Mercedes-Benz under two conditions: The first with no active fault codes present in the ECMs, and the second with active fault codes present during the three data extraction methods. The testing was conducted on March 29, 2010 and October 14, 2010, at the Fox Valley Technical College in Appleton, Wisc., and on August 31, 2010, at Johnson & Towers in Baltimore, Md. The ECMs tested were Detroit Diesel DDEC-IV and DDEC-V and Mercedes Benz VCU/PLD. Detroit Diesel DDEC-VI ECM was not included in this research since it does not record Diagnostic Records. A Detroit Diesel DDEC-10 ECM was not available at the time the testing was performed for this

research, but this ECM should be considered for future research, since it does record Diagnostic Records. Details about the vehicles, engines, and engine simulator used for this research are contained in [Appendix A](#). The Detroit Diesel software used for the ECM imaging was Detroit Diesel Diagnostic Link (DDDL) version 6.45 and Detroit Diesel Electronic Controls (DDEC) Reports version 7.0.

For a DDEC-V ECM, there are two electrical harnesses that connect to the ECM: the Engine Harness and the Vehicle Interface Harness. For the On-Truck image data extraction method for DDEC-V, only the Vehicle Interface Harness was disconnected from the ECM. For a DDEC-IV ECM, there are a total of six electrical harnesses that connect to the ECM. For the On-Truck image data extraction method for DDEC-IV, only the Vehicle Interface Harness Connector and the Power Harness Connector were disconnected from the ECM. The Mercedes-Benz engines tested contained two ECMs, a Vehicle Control Unit (VCU) and a Pumpe Liene Dusse (PLD) or Engine-Resident Control Unit (ECU) as it is termed by Detroit Diesel. For the VCU ECM, there are either three or four connectors that connect to this ECM; for the PLD ECM, there are two connectors that connect to this ECM. For the On-Truck image data-extraction method for VCU and PLD ECMs, only the 21-Pin Vehicle Harness Connector was disconnected from the VCU ECM for this data-extraction method.

DDEC-IV & DDEC-V - NO ACTIVE FAULT CODES

Tests with no active fault codes present were conducted on a 2006 and a 2007 Freightliner Columbia 120, both with Detroit Diesel Series 60 engines with DDEC-V ECMs; a Detroit Diesel Series 60 training engine with a DDEC-V ECM, and an engine simulator with a DDEC-IV ECM. A “Baseline” image of the ECM was performed through the Diagnostic Connector, and the data was reviewed to check for any active fault codes present in the ECM and to determine if the ECM contained two Hard Brake events, one Last Stop Record, and three Diagnostic Records. If active fault codes were present, they were repaired, and if the ECM did not contain two Hard Brake events, one Last Stop Record, and three Diagnostic Records, the engine was operated and these event data created as needed to populate the ECM with such records. These steps were repeated between the data extraction methods. The first data extraction method was performed with a Diagnostic Connector image followed by the On-Truck image, followed by the Bench image. The data obtained from the three data extraction methods were compared to data extracted during the Baseline image, noting any differences in data resulting from the selected extraction method.

DDEC-IV & DDEC-V - WITH ACTIVE FAULT CODES

Tests with active fault codes present were conducted on the Detroit Diesel Series 60 training engine with a DDEC-V ECM and the engine simulator with a DDEC-IV ECM. Again, a Baseline image of the ECM was performed through the Diagnostic Connector and the data was reviewed to check if there were any active fault codes present in the ECM and to determine if the ECM contained two Hard Brake events, one Last Stop Record, and three Diagnostic Records. If active fault codes were present, they were repaired and if the ECM did not contain two Hard Brake events, one Last Stop Record, and three Diagnostic Records, the engine was operated and these event data were created as needed to populate the ECM with these records. These steps were repeated between the data extraction methods. In addition, tests were conducted on a 2002 International 9400i with a Detroit Diesel Series 60 engine with a DDEC-IV ECM and a 2006 Freightliner Century Class with a Detroit Diesel Series 60 engine with a DDEC-V ECM to verify the results found with the Detroit Diesel Series 60 training engine with a DDEC-V ECM and the engine simulator with a DDEC-IV ECM.

To create the active faults for DDEC-V, first the electrical connector to the Coolant Level sensor for the engine was disconnected, and then connected to another Coolant Level sensor placed in a container of water. Similarly, the electrical connector to the Oil Pressure sensor for the engine was disconnected and then connected to another Oil Pressure sensor. An air hose was mounted to this Oil Pressure sensor, and regulated air pressure supplied to the air hose. The engine was then started and operated; after operating for several minutes, the Coolant Level sensor was removed from the container of water, which caused an active Low Coolant Level fault code. A valve to the air hose was opened, which vented the air pressure being sensed by the Oil Pressure sensor and caused an active Low Oil Pressure fault code. A PC was connected to the Diagnostic Connector and the Snapshot mode of DDDL was used to record, via Event Markers, the time when the Coolant Level sensor was removed from the water, when the valve to the air hose was opened, and also when the faults became active. These faults caused the engine to shut down and then the ignition key was turned off. These steps were repeated between the data extraction methods. The ignition key was then turned on, and one of the three data extraction methods was applied to image the ECM. Again, the order of the data extraction methods was a Diagnostic Connector image followed by the On-Truck image, followed by the Bench image. The data obtained from the three data extraction methods were compared to data extracted during the Baseline image and differences between extraction method and the baseline extraction were noted.

Shown in [Figure 1](#) is the DDEC-IV Engine Simulator used for testing. With the engine simulator, the simulated ignition

key was switched on, and the dial for the simulated throttle turned to increase the engine speed and run the simulated engine. After operating the simulated engine for several minutes, active faults were created by simply turning the dials associated with the Coolant Level and Oil Pressure sensors. A PC was connected to the Diagnostic Connector, and the Snapshot mode of DDDL used for Event Markers to record both when the dials to the Coolant Level sensor and the Oil Pressure sensor were turned, and when the faults became active. The simulated ignition key switch was then turned off. These steps were repeated between the data extraction methods. The simulated ignition key switch was then turned on, and one of the three data extraction methods was applied to image the ECM. Again the order of the data extraction methods was a Diagnostic Connector image followed by the On-Truck image, followed by the Bench image. The data obtained from the three data extraction methods were compared to data extracted during the Baseline image, with differences between the extraction method and baseline extraction noted.



Figure 1. DDEC-IV Engine Simulator

MBE VCU/PLD

Tests both with and without active fault codes present were conducted on a Mercedes-Benz MBE 4000 training engine with a VCU and PLD ECMs. The testing procedure was identical to the testing performed on the DDEC-V ECMs, except that a fourth data extraction method was added due to there being two ECMs (i.e., VCU and PLD) on the engine. This fourth data extraction method was a variation of the On-Truck image data extraction method and consisted of disconnecting the 21-Pin Vehicle Harness from the VCU, then connecting the cable to VCU, and then turning the ignition key to the ON position at the same time power was applied to the VCU through the cable. By turning on the ignition key, this provided power to the PLD. This fourth data extraction method was referred to as an “On-Truck with Ignition Key On” image. The On-Truck image and Bench image data extraction methods were performed only on the



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VCU ECM. Although there is a cable to connect directly to a PLD ECM, the PLD cannot be accessed with DDDL and DDEC Reports software and therefore, the On-Truck image and Bench image data extraction methods were not performed on the PLD ECM. In addition, tests were conducted on a 2005 Western Star 4900FA and two 2005 Freightliner Columbia 120, all with Mercedes-Benz MBE 4000 engines with VCU and PLD ECMs to verify the results found with the Mercedes-Benz MBE 4000 training engine.

SUMMARY OF RESULTS

A comprehensive presentation of the results of the testing is contained in [Appendix B](#). A main observation of the testing results revealed that none of the extraction methods tested had any effect on the two Hard Brake events or the Last Stop Record event data stored in the ECMs. Testing with no active codes present in the ECMs revealed that the Diagnostic Connector image extraction method neither changed nor overwrote any of the existing Diagnostic Records stored in the ECMs. Testing with no active codes present in the ECMs revealed that the other extraction methods (On-Truck, On-Truck with Ignition Key On, and Bench) always overwrote at least one Diagnostic Record, and that the Bench image extraction method always overwrote all three existing Diagnostic Records.

Testing with active fault codes revealed that the time needed to set an active Low Coolant Level fault code was 15 to 16 seconds for DDEC IV, 16 to 17 seconds for DDEC V, and 3 to 4 seconds for MBE VCU/PLD. Testing with active fault codes revealed that the time needed to set an active Low Oil Pressure fault code was 6 seconds for DDEC IV, 5 to 6 seconds for DDEC V, and 2 to 3 seconds for MBE VCU/PLD. In addition, after creating the Low Oil Pressure fault code with the engine running, this fault became inactive after the ignition key was cycled from on to off and then back on - an oil pressure of zero is a normal condition for an engine that is not running and has power to the ECMs.

Testing with MBE VCU/PLD ECMs showed that while performing either an On-Truck image or Bench image, that neither the internal ECM clock nor the calibration file for the ECMs is accessible via these extraction methods. Whereas, performing an On-Truck with Ignition Key On image both the internal ECM clock and the calibration file were accessible. This was due to there being no connection or power to the PLD ECM. Testing showed that the internal ECM clock and the calibration file are contained in the PLD ECM, and that the DDEC Reports is contained in the VCU ECM.

Testing with active fault codes showed that none of the existing Diagnostic Records were overwritten with the Diagnostic Connector image extraction method for DDEC-IV or DDEC-V. Conversely, with MBE VCU/PLD at least one

of the existing Diagnostic Records was overwritten with the Diagnostic Connector image extraction method. Testing with active codes present in the ECMs revealed that the other extraction methods (On-Truck, On-Truck with Ignition Key On, and Bench) always overwrote at least two Diagnostic Records, and that the Bench image extraction method always overwrote all three existing Diagnostic Records. Thus performing a Bench image will always overwrite the three existing Diagnostic Records, erasing event data that may have been related to the collision under investigation.

Testing with active fault codes showed that for DDEC-IV and DDEC-V, an active fault code will create a Diagnostic Record, but subsequent applications of power to these ECMs will not create new Diagnostic Records even though the number count for the active fault increments upward. The exception to this finding was an active Idle Validation Switch fault on a DDEC-V ECM, which created new Diagnostic Records for subsequent applications of power to this ECM. Further testing would be needed to determine if this exception would also apply to DDEC-IV ECMs that are equipped with an Idle Validation Switch. There may be other active faults that behave in this manner, but were beyond the scope of this research. Thus an active fault, such as low oil pressure or low coolant level, created as a result of a crash and remaining active will not create a Diagnostic Record that overwrites the Diagnostic Records related to the collision.

Testing with active fault codes showed that for MBE VCU/PLD, an active fault code will create a Diagnostic Record, and subsequent applications of power to these ECMs will create Diagnostic Records that overwrite existing ones. This is an important finding for the collision investigator who performs a Diagnostic Connector image on a vehicle with a DDEC-IV or DDEC-V ECM, which will neither change nor erase any of the event data present in the ECM even if an active fault, such as low oil pressure or low coolant level, was caused in the crash and remains active during the time of the image. Notably, the same is not true for the collision investigator who performs a Diagnostic Connector image on a vehicle with MBE VCU/PLD ECMs.

CONCLUSIONS

This paper has researched the effects of different data extraction methods and the presence of active fault codes on the retention of the event data contained in the ECMs of the on-highway commercial motor vehicle engines manufactured by Detroit Diesel and Mercedes-Benz. The following conclusions were noted:

1. None of the extraction methods tested had any effect on the two Hard Brake events or the Last Stop Record event data stored in the ECMs.
2. Testing with no active codes present in the ECMs revealed that the Diagnostic Connector image extraction method