

Validating Speed Data from Cummins Engine Sudden Deceleration Data Reports

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ABSTRACT

Electronic Control Modules (ECM) on Heavy Duty truck engines have the ability to control or monitor important engine and vehicle parameters. Examples of these parameters are fuel consumption, cruise control operation and oil pressure. Under certain conditions, many can also record parameters that are useful in accident reconstruction. Cummins engines are commonly found on highway tractors on the road today. In a heavy vehicle equipped with a Cummins engine, a hard brake application or a collision with an object can create a Sudden Deceleration Data (SDD) Report on the ECM. Since this data reports second-by-second speed information, it can be very useful in the analysis of an accident. Establishing the reliability of this information is important, if it is to be used by an accident investigator. This paper explores the data recorded on a Cummins engine ECM created during a series of acceleration, cruising, and braking tests.

INTRODUCTION

As new vehicles replace older models, it is increasingly common for data to be recorded on modules onboard a vehicle. In certain passenger vehicles, data is recorded on an Airbag Control Module (ACM). The primary function of such modules is to deploy airbags or other safety equipment when required, while the primary function of an ECM is to control engine operation. However, most North-American truck engine manufacturers currently produce engines with ECMs that have data recording capability. In January 2005, Cummins Engine Corporation released ECM software which enabled their ISX and ISM engines to record

Sudden Decelerations. Cummins also made it possible to update existing engines built after October 2002 to have this capability. Before January 2005, an option called Road Relay was required. The threshold used by Cummins to trigger a record is a decrease in speed of 9 mph in 1 s (-0.41 g). When the ECM detects a speed reduction at or above this threshold, a SDD Report is created. Up to three reports can be stored on the ECM at one time; any subsequent report would overwrite an existing one from memory. Each report contains data for 59 seconds preceding the trigger, and for 15 seconds afterward. SDD Reports contain the following parameters: Time (s), Vehicle Speed (mph), Engine Speed (rpm), Engine Load (%), Throttle (%), Brake Status, Clutch Status, Cruise Status and Lamp Status. As such, they can be extremely useful in understanding the events leading up to and immediately following an accident. It is possible for a SDD Report to be created even without brake activation. An impact with a large heavy object, such as a bridge pillar or a tractor trailer, can generate the necessary deceleration to create a report.

This paper presents the results of testing which was done to compare Cummins ECM data to independent GPS-based position-time data. In the course of the testing, an issue was discovered in the SDD Report data from the ISX 07 engine. This issue is also discussed in this paper.

METHODOLOGY



The tractor used was a 2009 International Lonestar equipped with a Cummins ISX 07 engine, shown above. The engine serial number was 79276995, and the ECM code was AV10050.17. This tractor had specifications similar to a typical highway tractor on the road today. It was operated in bobtail configuration; that is, without a trailer attached. The Racelogic V-BOX III data collection unit, serial number 001375, was powered by a 12V adapter. Its GPS antenna was mounted on the roof of the tractor. As such, the speed data recorded by the V-BOX was independent of the tractor's sensors or operation. A laptop computer was connected to the V-BOX and was used to set up and monitor its operation. The data-logging ability was used to record three parameters in real time. The first of these was the voltage from a contact switch taped over the brake pedal. The other two parameters were the signal voltages of the tractor brake pedal switch and the accelerator pedal. Clamp-on leads were used for those, and were connected to the V-BOX via a junction box.

A second laptop computer was used to run the Cummins Insite 7.01.0.307 and PowerSpec 4.0.3.0 software. A Cummins Inline 5 adapter allowed it to be connected to the tractor via the diagnostic connector on the dashboard. It is also possible to connect directly to a Cummins ECM using additional wiring harnesses.

The Insite software has a data logging feature called Data Monitor / Logger (DML) which created data files at a recording frequency of approximately 2 Hz. The data collection was started and stopped manually for each test run. The V-BOX unit sampling rate was 100 Hz. It began recording automatically when it sensed movement, and was stopped manually at the end of each test run. The SDD Report data was downloaded

from the ECM using PowerSpec after each run. All three data sources were combined in a spreadsheet, making it possible to begin the analysis.

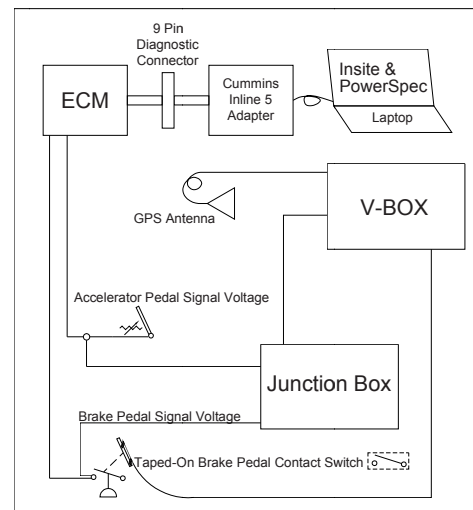


Figure 1 Field Test Wiring

A diagram describing the field test wiring is shown in Figure 1.

TESTING

The driver drove the instrumented tractor, following the steps outlined in Figure 2, while two passengers operated the test equipment. The roadway was dry, straight and level. In each test, heavy braking to a stop was done so that a SDD Report would be created. After each test run, the ECM was downloaded, and the data from the DML and V-BOX were saved. A total of eleven runs were done. The testing involved initial speeds between 10 mph to 55 mph. Tests # 1 to 4 were done with initial speeds at or above 40 mph. In Tests # 5 to 8, where the initial speeds were lowest, the goal was to determine if there were circumstances where a SDD Report would not be created, despite exceeding the 9 mph/s threshold.

Test runs # 9 to 11 were power-interruption tests. The goal was to simulate the loss of electrical power to the ECM shortly before and during the heavy braking. Such power losses can occur in actual crashes, and the testing was designed to determine what the effect would be on the SDD Reports.

Test #	Description
1 & 2	Accelerated heavily to 40 mph, held 40 mph for approximately 5 s, braked heavily to a stop
3	Accelerated moderately to 40 mph, held 40 mph for approximately 5 s, braked heavily to a stop
4	Accelerated heavily to 55 mph, held 55 mph for approximately 5 s, braked heavily to a stop
5	Slow acceleration to 15 mph, held for several seconds, braked heavily to a stop
6	Slow acceleration to 12.5 mph, held for several seconds, braked heavily to a stop
7	Slow acceleration to 10 mph, held for several seconds, braked heavily to a stop
8	Slow acceleration to 10.5 mph, held for several seconds, braked heavily to a stop
9	Held 30 mph for several seconds, turned key off, applied brake heavily to a stop
10	Held 30 mph for several seconds, braked heavily to a stop. The key was turned off for approximately 1 s while braking then returned to the on position before the vehicle came to a stop.
11	Held 30 mph for several seconds, braked heavily to a stop. The key was turned off just before the vehicle came to a stop.

Figure 2 Test Descriptions

DATA ANALYSIS

The V-BOX data was considered the baseline to which the other data could be compared. The instant in time when the brake pedal signal voltage began to change was taken as a close indication of when the brake pedal was depressed. The 100 Hz V-BOX data allows this instant to be known within 0.01 s. The other data was synchronized to it, using the parameters shown in Figure 3. The SDD Report data shows the brake status change as Off to On. The SDD Report data is reported at 5 Hz, which yields a 0.20 s uncertainty when synchronizing it with the V-BOX data. Two lines were plotted on the speed versus time graphs, to show the extremes of the uncertainty range. They were labeled 'SDD Report' and 'SDD Report Limit'. The DML data was synchronized to the V-BOX using the change in the brake pedal position from Released to Depressed. The uncertainty range for that data is 0.50 s, given the approximate 2 Hz rate of the DML data. The second line on the graphs was labeled 'DML Limit'. Figure 4 in the Appendix has numerical data from Test #1 showing the data after it was synchronized. The change in the V-BOX brake pedal switch voltage occurs between 39.05 s and 39.06 s. The 0.20 s and 0.50 s ranges explained earlier are represented by bolded rectangles in the figure.

While throttle information was recorded, it was not required for synchronization. This also made it unnecessary to account for the differing units of the throttle data; SDD Report data uses percentage while V-BOX and DML use voltage.

Parameter	Values	
	Released	Applied
Brake Pedal Switch Voltage (V-BOX-monitored)	0.9 V to 1.2 V	0.2 V
Brake Pedal Taped-On Contact Switch (V-BOX)	0 V	1.0 V
Brake Status (PowerSpec Sudden Deceleration Data Report)	Off (represented by "-")	On
Brake Pedal Position Switch (Insite Data Monitor / Logger)	Released	Depressed

Figure 3 Brake Status Terminologies

There was some fluctuation in the V-BOX-monitored brake pedal switch voltages, but it was insignificant compared to the voltage drop when the brake pedal was depressed.

TEST RESULTS

It became apparent that the SDD Report data was unusual since it did not contain a 9 mph/s speed reduction, as expected. The V-BOX data confirmed that this threshold had actually been met or exceeded. Through subsequent correspondence with Cummins technical support personnel, we learned that there was a calibration error in the data reporting rate on SDD Reports on all ISX 07 and ISM 07 engines built for the 2007 EPA certification. The engine in the test tractor was affected by this.

Normally, SDD Reports include 59 s of data before the trigger point and 15 s afterward, at a rate of 1 Hz. However, the calibration error causes the 75 data points to be recorded at 5 Hz, therefore data is created every 0.2 s, and the total time period is only 14.8 s. The scaling problem was corrected by dividing the time scale by exactly 5. For example, the data shown at -59 s actually occurred at -11.8 s. Cummins advised that affected units have ECM codes beginning with either "AT" or "AV" and that none of their earlier engines have the error. Cummins is working on a calibration update to resolve the issue.

Graphs of selected test runs are shown in the Appendix. Figures 5 and 6 show speed versus time for Test # 1. The uncorrected Sudden Deceleration data is included in Figure 5, for reference. Except as noted, the SDD Report data in each graph is corrected data.

Figure 6 shows the Test # 1 speed versus time data in more detail. Error was introduced primarily because of under-representation of speed data due to wheel lock-up while braking, and also due to the lower sampling rates and whole number rather than decimal precision of the SDD Report and DML data.

In this testing, the DML feature was set to the Real Time acquisition rate, and about 15 variables were selected to be recorded. The Real Time setting causes the software to continuously request data from the ECM, and it records it as it received from the ECM at the fastest possible rate. Through later discussions with Cummins technical support personnel, it was learned that the DML feature works well for up to about seven variables, but if more are selected a time lag can occur between the time data is requested to when it is actually recorded. The DML data is generally consistent with the V-BOX and SDD Report data, but has more error compared to the SDD Report data.

The following example is data from Test #1. Three seconds before coming to a stop, the tractor was traveling 30.8 mph (V-BOX) and was undergoing heavy braking. From the graph, the SDD Report speed is 29.5 mph and the DML speed is 32 mph; an error in each case of less than 5%. At 5.5 s before stopping, the speed is 40.5 mph (V-BOX). The SDD Report and DML speeds are 40 mph, which is an error of less than 2%. The percentage error at lower speeds is significantly higher. At approximately 0.4 s before coming to a stop, the V-BOX speed is 4.2 mph, the SDD Report speed is 5.2 mph and the DML speed is 6.8 mph. The errors at that time are 30 % and 66%, respectively.

A second example is from Test #4, which is shown in Figure 7. Three seconds before stopping, the V-BOX speed was 32.7 mph. The SDD Report speed was 30.1 mph; a difference of 2.6 mph and a percentage difference of approximately 8 %. The DML speed was 33.5 mph; a difference of 0.8 mph and approximately 2 %. Before braking began, the speeds were within 1 mph of each other. As in the earlier example, the percentage errors are much higher at lower speeds. The potential difference in speeds should be considered before relying on speed data below 10 mph from a heavy braking event in an analysis.

Figures 9 and 10 show data from Test #2.

There are some points on the graphs that show an apparent over-reporting of the speed data, though this occurs at lower speeds, where there is a higher percentage error. It is predominantly on the DML data, which likely exhibited a time lag as discussed earlier.

Often, an accident investigator is called upon to determine what speed a vehicle was traveling at before an impact occurred. This testing has shown that Cummins Sudden Deceleration Data Reports do provide accurate and useful information in this regard. This is especially true when steady speeds are involved, since the error is lowest at that time. There is more error during heavy braking, and it tends to increase as the speed decreases.

In other investigations, the determination of an impact location is most important. A distance versus time relationship can be calculated from speed versus time data. This is true since the initial velocity [v_i], final velocity [v_e], and the time between the two speeds are all known. The acceleration [a] and distance traveled during the time period [t] can be calculated by using the equations for constant acceleration:

$$a = (v_e - v_i) / t$$

$$d = (v_e^2 - v_i^2) / 2a$$

These equations allow a cumulative distance to be shown graphically against time. Data from Test #1 is shown in Figure 8. Time zero represents the instant the vehicle came to a stop. The V-BOX data is unaffected by wheel slip and the above equations yield an accurate representation of position versus time. As expected, the under-reporting of speed in the SDD Report and DML data lead to under-reporting of the distance traveled as well. For example, the distance covered in the last 3 s is approximately 85 ft (V-BOX) but only approximately 50 ft for the SDD Report and DML data. As such, an investigator may still choose to calculate a position-time history from SDD Report data, but should do so with an understanding of the under-reporting effect.

This testing reinforces how ECM data analysis should be done in conjunction with available physical evidence such as tire marks and pavement scars, not instead of it.

The result of the power interruption tests was that a SDD Report was always created, though in Test # 9 the brake status in the report never did indicate that the brake pedal was depressed. This could mistakenly lead an investigator to conclude that the tractor was slowed solely by impact forces, or other forces, but not by braking. In Test # 9, all braking was conducted while the ignition key was in the off position. It was off for a longer