Maximum Accelerations in Reverse and Forward Gear to Simulate Unintended Acceleration Scenario

Posting Date: July 27-2015

A tragic fatal collision occurred at the Costco retail outlet in London, Ontario on July 25, 2014 in which two children were killed when a 2004 Chevrolet Monte Carlo reversed on the store's parking lot, at high speed, and drove through the front doors of the store. The driver of the vehicle was later charged with criminal offences even though she claimed that her foot became stuck underneath the brake pedal.

Figure 1: View of the entrance to the Costco retail store on Wellington Road in London, Ontario on July 24, 2014. Police tape surround the front doors where a red, 2004 Chevrolet Monte Carlo reversed at high speed killing two family members.

Testimony provided by investigating police indicated that data was obtained from the Monte Carlo's event data recorder ("Black Box").

The public was informed that the collision-involved vehicle travelled 58.7 metres from its initial parked position until it came to rest. At 5 seconds before impact the vehicle was travelling at 11 km/h, at 4 seconds 22 km/h, at 3 seconds 35 km/h, at 2 seconds 43 km/h and at 1 second 46 km/h. Police also stated that, at 5 seconds before the crash the throttle was a 100%, then 84 % at 3 seconds and at 100% again at 1 second before

impact. There was also no evidence of braking over the full 8 seconds of available pre-crash data.

Figure 2: View showing the direction from which the Monte Carlo reversed on its way toward the Costco front doors in the background. This photo was taken a few days after the incident.

To test these findings on June 1, 2015 Gorski Consulting conducted a short, maximum-acceleration test in reverse gear using a vehicle with a similar engine (3.8 litre). Our discussion and findings from that test were reported in an article ("Maximum Acceleration in Reverse Gear to Simulate Unintended Acceleration Scenario") posted on the Gorski Consulting website on June 6, 2015.

Subsequently, on July 13, 2015 two additional, maximum-acceleration rearward tests were performed, as well as two in a forward direction. These tests are the focus of the present article. The tests were performed at the same location as the original test, at the dead-end of Cheapside Street, in London, Ontario. The pavement at this location is relatively new asphalt, and the road is straight and level. Unlike the original test, an accelerometer was not attached to the test vehicle. Rather, a number of additional video cameras were placed on the vehicle as well as on two tripods along the vehicle's path.

The test area was marked at one-metre intervals over a distance of 50 metres. At ten metre intervals the distance was marked in large numerals (i.e. 10, 20, 30 etc.) so that they would be in clear view of the cameras. A video camera was placed adjacent to the brake and accelerator pedals so that the motions of the driver's foot could be determined during the acceleration and subsequent braking. The following figures provide some details of the preparations and running of the tests.

Figure 3: View looking west along the test site. Markers can be seen on the pavement at one-metre intervals. The left-front of the test vehicle can be seen at the lower right of the view.

Figure 4: View looking north at the start position of the test vehicle.

Figure 5: View looking east at an investigator standing next to the 50-metre marker of the test site with the test vehicle in the background prior to the testing.

Figure 6: View looking west along the markers of the testing area.

Figure 7: View of a GoPro camera attached to the left-fender of the test vehicle. After activating the recording the camera was rotated to point down toward the markers so that the vehicle's position could be determined during the test.

Figure 8: Example of the view from the camera mounted on the left front fender of the vehicle as it was accelerated through the test site. The vehicle's position could be determined by studying this video of the markers.

A total of seven video cameras were used. These views were incorporated into an Adobe Premiere video-editting program where the views were synchronized and displayed together on the computer screen. Analysis of these tests led to the selection of only 4 cameras views that we used to create the figures shown below. A view of the speedometer was determined to be useful to demonstrate the speed and status of the tachometer. A view showing the brake/accelerator pedals along with the driver's foot was deemed useful as it would show the position of the foot and depression/release of each pedal as the acceleration and braking took place. A third view from the 50 metre marker was deemed useful as it would show most of the vehicle's path along the test site but more importantly, near the end of the test as the vehicle reached its maximum acceleration and then commenced its deceleration to a stop. Finally the view of a camera mounted behind the left rear corner of the vehicle was useful in displaying the status of the brake lights as well as the position of the vehicle along its path.

Review of Test #1

Figure 9 (below) shows a screenshot taken from the computer screen with the four views combined in the Premiere project. This view was taken precisely at the start of Test #1 when the driver's foot was starting to release the brake pedal on its way to depressing the accelerator pedal. The driver attempted to complete this motion as quickly as possible.

Figure 9: Views from four video cameras at the start of Test #1. In the upper left is a view of the driver's foot at the time that it began to release the brake pedal. The status of the speedometer and tachometer can be seen in the upper right. The view from a camera positioned near the 50-metre marker is shown in the bottom right. The view of the exterior braking lights of the test vehicle is shown in the bottom left.

The numerical value of "00;29;05;23" is the timecode in the Premiere project. Thus the time being indicated is 00 hours, 29 minutes, 5 seconds and 23 frames of the 30-frames-per-second format of the video. We can examine the remaining figures and compare the change in the timecode to understand when each action has taken place during the test. In Figure 9 a piece of yellow tape has been placed to the left side of the brake pedal so that its position can be more easily detected in the video.

Figure 10 (below) shows the status of the test as the driver's foot makes contact with the accelerator pedal. Note that essentially nothing has changed in the four views except that the driver's foot has moved and that the timecode has now changed to read "00;29;06;00". Thus comparing the timecode in Figure 9 we know that a time of 7 frames has elapsed between the time that the driver began to release the brake pedal and the time that contact was made with the accelerator pedal. Seven frames amounts to about 0.23 seconds, therefore we know that it took this much time for the driver to move his foot from the brake pedal to the accelerator pedal - a fairly quick action.

Figure 10: Status when the driver's foot makes initial contact with the accelerator pedal.

Figure 11 shows the status of the views after the vehicle has accelerated rearward for 10 metres. The vehicle's speed has reached 22 km/h and the tachometer reads 2700 rpm. The timecode reads "00;29;08;18" thus a time of 2.83 seconds has elapsed since the driver began to release the brake pedal. Similarly, the elapsed time from when the driver touched the accelerator pedal was 2.60 seconds.

Figure 12 shows the status of the views after the vehicle has accelerated rearward for 20 metres. The vehicle's speed has reached 35 km/h and the tachometer reads 3000 rpm. The timecode reads "00;29;09;19" thus a time of 3.83 seconds has elapsed since the driver began to release the brake pedal. Similarly, the elapsed time from when the

driver touched the accelerator pedal was 3.60 seconds and the elapsed time from passing the 10 metre marker was 1.00 seconds.

Figure 11: View from Test #1 after the vehicle has accelerated for 10 metres.

Figure 12: View from Test #1 after the vehicle has accelerated for 20 metres.

Figure 13 shows the status just as the driver's foot begins to release from the accelerator pedal so as to commence braking. This occurs when the vehicle's speed has reached about 41 km/h and the tachometer reads about 3200 rpm. At this time the vehicle has travelled 27 metres. The timecode reads "00;29;10;04" therefore a time of 4.37 seconds has elapsed since the driver released the brake pedal or 4.13 seconds since the driver's foot made initial contact with the accelerator pedal.

Figure 13: Status of views when the driver's foot begins to release the accelerator pedal.

Figure 14 shows the status as the vehicle passes the 30 metre marker at a timecode of "00;29;10;12". Here the vehicle has accelerated to a speed of about 44 km/h and the tachometer reads about 3200 rpm. The elapsed time from initial release of the brake pedal is 4.63 seconds or 4.40 seconds since initial contact of the accelerator pedal.

Figure 15 shows the status as the driver's foot makes first contact with the brake pedal. The vehicle has reached a speed of about 47 km/h and the tachometer reads 3100 rpm. The timecode reads "00;29;10;22" thus a time of 4.97 seconds has elapsed since the driver initially leased the brake pedal or 4.73 seconds since the accelerator pedal was first contacted. At this time the vehicle has travelled 35 metres.

Figure 16 shows the status as the vehicle reaches the 40 metre marker. At this time the driver's foot is still compressing the brake pedal. The vehicle's speed has fallen to 44.5 km/h and the tachometer reads 2400 rpm. The timecode reads "00;29;11;04" thus a time of 5.37 seconds has elapsed since initial brake pedal contact or 5.13 seconds since initial contact of the accelerator pedal.

Figure 14: View from Test #1 after the vehicle has accelerated 30 metres.

Figure 15: Status at first contact of the brake pedal.

Figure 17 indicates that shortly after the vehicle passes the 40 metre marker the brake pedal has been depressed to its maximum. This occurs at timecode "00;29;11;07" or about 5.47 seconds after the brake pedal was initially released at the start of the test.

Figure 16: Status of Test #1 after the vehicle has travelled 40 metres.

Figure 17: Status of the views at full compression of the brake pedal which occurred just after the vehicle crossed the 40 metre marker.

At full compression of the brake pedal the vehicle is travelling about 44.5 km/h and the tachometer reads about 2250 rpm.

Figure 18 shows the status as the vehicle crosses the 50 metre marker. The brake pedal has been fully depressed. The vehicle is travelling at 42 km/h and the tachometer reads 1300 rpm. The timecode indicates "00;29;12;02" or an elapsed time of 6.3 seconds since the brake pedal was initially released or 6.07 seconds since first contact of the accelerator pedal.

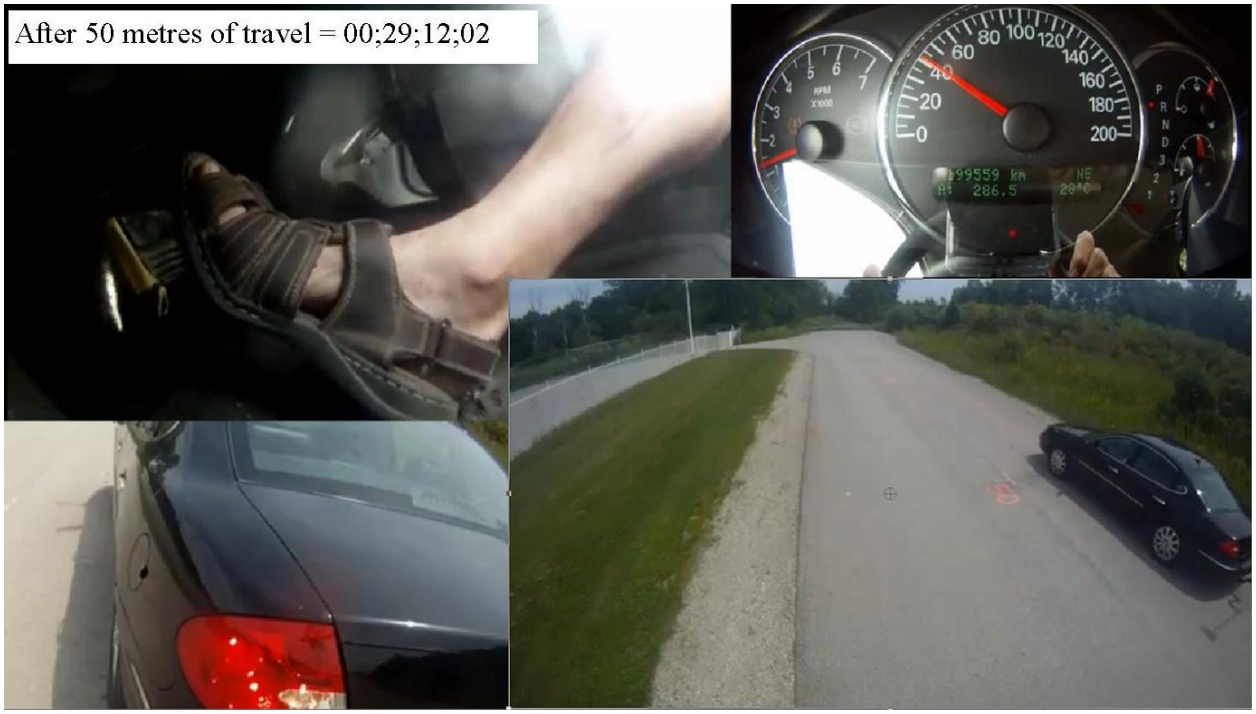

Figure 18: Status as the vehicle passes the 50 metre marker.

Figure 19 shows the status when the video cameras indicate that the test vehicle has come to a stop. At this time the speedometer still indicates a speed of 14 km/h and the tachometer reads about 850 rpm. The timecode indicates "00;29;13;17" or an elapsed time of 7.80 seconds from the initial release of the brake pedal or about 7.57 seconds since initial contact of the accelerator pedal.

Review of Test #2

A second test was performed under almost identical conditions. Figures showing the details of the test will not be included as they are very similar to what is visible in the figures from Test #1. In Test #2 there was a slight delay in release of the accelerator pedal and application of the brake. This led to maximum speed of about 52.5 km/h which was slightly higher than the 50.0 maximum speed attained in Test #1.

Figures 20 and 21 contain tables of the summary data from both tests.

Figure 19: Status when the video cameras indicate that the test vehicle has come to a stop.

Test 1 - Data From Maximum Rearward Acceleration of 2007 Buick Allure

Action	Timecode	Elapsed Time Between Events (Secs)	Cumulative Time (Secs)	Speed (km/h)	Tachometer (RPM)
Release Brake	00;29;05;23		0.00	0.0	800
		0.23			
Contact Accelerator	00;29;06;00		0.23	0.5	800
		2.60			
At 10 Metres	00;29;08;18		2.83	22.0	2700
		1.00			
At 20 Metres	00;29;09;18		3.83	35.0	3000
		0.53			
Release Accelerator	00;29;10;04		4.36	41.0	3150
		0.27			
At 30 Metres	00;29;10;12		4.63	44.5	3200
		0.33			
Contact Brake	00;29;10;22		4.96	47.0	3000
		0.40			
At 40 Metres	00;29;11;04		5.36	49.5	2400
		0.10			
Brake Full Compression	00;29;11;07		5.46	50.0	2200
		0.83			
At 50 Metres	00;29;12;02		6.29	42.0	1300
		1.50			
Stop	00;29;13;17		7.79	14.0	850

Figure 20: Summary data from Test #1

Test 2 - Data From Maximum Rearward Acceleration of 2007 Buick Allure

Action	Timecode	Elapsed Time Between Events (Secs)	Cumulative Time (Secs)	Speed (km/h)	Tachometer (RPM)
Release Brake	00;30;24;03		0.00	0.0	800
		0.20			
Contact Accelerator	00;30;24;09		0.20	1.0	800
		2.60			
At 10 Metres	00;30;26;27		2.80	23.0	2700
		0.97			
At 20 Metres	00;30;27;26		3.77	35.0	3000
		0.80			
At 30 Metres	00;30;28;20		4.57	44.0	3200
		0.37			
Release Accelerator	00;30;29;01		4.94	47.0	3300
		0.33			
At 40 Metres	00;30;29;11		5.27	50.0	3200
		0.03			
Contact Brake	00;30;29;12		5.30	50.5	3150
		0.57			
Brake Full Compression	00;30;29;29		5.87	52.5	2500
		0.13			
At 50 Metres	00;30;30;03		6.00	52.0	2300
		2.30			
Stop	00;30;32;12		8.30	14.0	850

Figure 21: Summary data from Test #2.

Data From Two Forward Accelerations

As a further comparison, two maximum accelerations were performed in a forward direction along the same path as the previously described rearward acceleration tests. The data from these tests are shown in Figures 22 and 23 below.

In the two forward acceleration tests the driver began to release the accelerator pedal .27 and .37 seconds respectively prior to the vehicle reaching the 50 metre marker. Thus this could be considered a maximum acceleration for a distance of 50 metres. From the initial contact of the accelerator pedal to the time when the vehicle reached the 50 metre marker the elapsed time was 5.40 seconds in both tests. The vehicle's speed noted on the speedometer at the 50 metre marker was 59 and 60 km/h, respectively. Since acceleration is defined as the change in velocity over time, the change in velocity was 16.67 metres per second in the time of 5.4 seconds, or an acceleration rate of 3.08 metres per second squared. This equates to an average of 0.31 g over the full 50 metre distance.

Test 1 - Data From Maximum Forward Acceleration of 2007 Buick Allure

Action	Timecode	Elapsed Time Between Events (Secs)	Cumulative Time (Secs)	Speed (km/h)	Tachometer (RPM)
Release Brake	00;33;42;07		0.00	0.0	800
		0.33			
Contact Accelerator	00;33;42;17		0.33	1.0	800
		2.50			
At 10 Metres	00;33;45;02		2.83	25.0	2900
		0.90			
At 20 Metres	00;33;45;29		3.73	37.5	3300
		0.73			
At 30 Metres	00;33;46;21		4.46	46.0	3700
		0.67			
At 40 Metres	00;33;47;11		5.13	54.0	4200
		0.33			
Release Accelerator	00;33;47;21		5.46	57.5	4400
		0.27			
At 50 Metres	00;33;47;29		5.73	60.0	4500
		0.10			
Contact Brake	00;33;48;02		5.83	61.0	4500
		0.33			
Brake Full Compression	00;33;48;12		6.16	63.0	4100
		4.20			
Stop	00;33;52;18		10.36	11.0	850

Figure 22: Summary data from first, forward, maximum acceleration test.

Test 2 - Data From Maximum Forward Acceleration of 2007 Buick Allure

Action	Timecode	Elapsed Time Between Events (Secs)	Cumulative Time (Secs)	Speed (km/h)	Tachometer (RPM)
Release Brake	00;35;28;24		0.00	0.0	800
		0.23			
Contact Accelerator	00;35;29;01		0.23	0.0	800
		2.43			
At 10 Metres	00;35;31;14		2.66	24.0	2850
		0.90			
At 20 Metres	00;35;32;13		3.56	37.0	3300
		0.73			
At 30 Metres	00;35;33;05		4.29	45.5	3700
		0.67			
At 40 Metres	00;35;33;25		4.96	53.0	4100
		0.23			
Release Accelerator	00;35;34;02		5.19	55.0	4250
		0.37			
At 50 Metres	00;35;34;13		5.56	59.0	4400
		0.43			
Contact Brake	00;35;34;26		5.99	61.0	3500
		0.40			
Brake Full Compression	00;35;35;08		6.39	63.0	2400
		5.40			
Stop	00;35;40;20		11.79	7.0	850

Figure 23: Summary data from second, forward, maximum acceleration test.

Another way to compare the test data to the values of event data recorder in the actual collision is to look at the status at 1-second intervals. This is shown in Figure24 below for the two rearward acceleration tests.

Vehicle Position at 1-Second Intervals

Test 1

Timecode at contact of accelerator pedal = 00;29;06;00
Timecode at contact brake = 00;29;10;22 or 34.5 metres

Elapsed Time	Location (Metres)	Speed (km/h)	Tachometer (rpm)
1 Second	0.8	2	2400
2 Seconds	5.3	14	2500
3 Seconds	13.5	28	2750
4 Seconds	24.7	40	3100
5 Seconds	38.2	49	2550
6 Seconds	49.2	43	1350

Test 2

Timecode at contact of accelerator pedal = 00;30;24;09
Timecode at contact brake = 00;30;29;12 or 40.9 metres

Elapsed Time	Location (Metres)	Speed (km/h)	Tachometer (rpm)
1 Second	0.8	2	2400
2 Seconds	5.4	14.5	2500
3 Seconds	13.6	28	2750
4 Seconds	24.8	40	3100
5 Seconds	38.9	49.5	3200
6 Seconds	52	50	1900

Figure 24: Status of Vehicle at 1-Second Intervals.

Tire marks were generated during the four tests. The marks produced during the two forward accelerations were readily visible for approximately 2 metres followed by very faint marks for a longer distance. Tire marks were also produced during the initial portion of rearward accelerations although they were faint and difficult to detect. Tire marks were also visible during the braking portion of all four tests. The following figures provide a visual record of the tire marks.

Figure 25: View looking east toward the start location of the four tests. The two forward accelerations were performed to the left (north) of the line of markers while the two rearward accelerations were performed to the right.

It must be appreciated that the visibility of these marks varies depending on the direction from which they are viewed and the environmental conditions at the time of viewing. The photos in these figures were taken on a sunny day and this makes the tire marks less visible. On a cloudy day the marks would likely be more visible than what is shown.

Figure 26: View, looking east, at the two sets of tire marks produced during the two forward accelerations.

Figure 27: View, looking east, at the area where the two rearward accelerations were commenced. Although difficult to detect, faint tire marks were produced.

Figure 28: View, looking west, at the tire marks produced by the left front tire of the test vehicle during the two forward accelerations.

Figure 29: View, looking west, at the tire marks produced by the right front tire of the test vehicle during the two forward accelerations.

Figure 30: View, looking west, at the location of the two rearward acceleration marks.

Figure 31: View, looking west along the braking tire marks produced during the latter portion of the rearward acceleration tests.

Figure 32: View of tire marks produced during braking. The tire marks to the left of the line of markers are those from the rearward accelerations while those to the right are from the forward accelerations.

Discussion of Results

Due to the unpredictability of maximum acceleration in a rearward direction the tests did not replicate the time and distance achieved in the actual collision at the London Costco retail outlet. The collision-involved vehicle reportedly travelled 58.7 metres from its initial parked location to the location where it came to rest against a concrete pillar inside the front doors of the store. In contrast the motion of the test vehicle in the two rearward tests was tracked over a distance of only 50 metres.

Additionally, in rearward Test #1 the driver contacted the brake pedal at about 34 metres while in rearward Test # 2 the brake contact occurred at about 41metres. Whether this is comparable to the actions of the collision-involved driver may be a matter of debate. For example, in the actual collision, police did not report the full data set with respect to the throttle position. It was reported that at 5 seconds before impact it was at 100%, at 3 seconds before impact it was at 84% and at 1 second before impact it was at 100% again.

In the actual collision the last speed data point at one second before "impact" indicated that the vehicle was travelling 46 km/h. News media speculated that the likely impact speed was about 50 km/h. As a comparison, the maximum speed reached in the two tests was 50 and 52.5 respectively before braking became effective to reduce the speed. The maximum speeds in the tests were likely similar to the actual impact. This indicates that the type of acceleration experienced by the collision-involved vehicle must also have been similar to the two tests. What may differ is how the acceleration was achieved since in the actual collision there was reportedly no contact of the brake pedal throughout the 8 seconds of data whereas braking was used in the two tests.

The reported values of 100% and 84% throttle in the actual collision appear to be rather high. Although the reporting of the data is incomplete it suggests that, if the vehicle was being accelerated at this level of throttle throughout the length of its travel then the collision-involved vehicle should have reached a higher maximum speed. This is so because similar maximum speeds were achieved in the tests although solid braking was involved in the latter part of the tests.

The elapsed time from initial release of the brake pedal up to time when the vehicle reached the 50 metre marker was 6.29 and 6.00 seconds respectively. In the actual collision the vehicle's event data recorder had the capability to store braking data for up to 8 seconds before impact. Yet police indicated that the vehicle's event data recorder (EDR) did not record any brake application throughout those 8 seconds. For these conditions to exist the Monte-Carlo in the actual collision would have had to start its motion at least 8 seconds before it travelled the 58.7 metres.

We can compare the data in Figure 24 with the police-reported EDR data by making a simplifying assumption. This being that a collision occurred about one second after the last row of data (i.e. at 6 seconds) in the 2 tests. Thus, the data at 6 seconds would be 1 second before impact, the 5 seconds would be 2 seconds before impact, and so on. Now, the police indicated that, at 5 seconds before impact the Monte Carlo was

travelling 11 km/h. This would be the same as the 2-seconds row of data in Figure 24. That row indicates that the test vehicle was travelling 14 km/h, or faster than the 11 km/h in the actual collision. Yet the test vehicle only commenced it motion two seconds prior while in the actual collision the Monte Carlo started its acceleration at least 2 seconds earlier because there was no evidence of any brake application and the driver must have had her foot on the brake upon starting the vehicle.

Furthermore there some evidence to suggest that during high accelerations there is a lag in the speedometer needle's motion as evidenced when the test vehicle came to a halt yet the speedometer was still reading between 7 and 14 km/h. This was visible in all four tests (two reversing and two forward). Thus if we believe that this lag exists then the actual speed of the test vehicle at 2-second row of data (or 5 seconds before the imaginary impact) would likely be higher than the 14 km/h shown by its needle and this could be substantially higher than the 11 km/h reported in by the Monte Carlo's EDR. In all it suggests that the driver of the Monte Carlo likely did not press the accelerator pedal fully to the floor at the beginning of its motion.

There is further unusual data from the EDR. For example, it was reported that at 2 seconds before impact the Monte Carlo was travelling 43 km/h and then at 1 second before impact it was only travelling 46 km/h. In other words, the vehicle only managed to increase its speed by 3 km/h between the two final data points before impact. Yet, the throttle data, although incomplete, indicated that 3 seconds before impact the throttle was a 84% and at 1 second before impact it was 100%. Whatever the value might be at 4 seconds, which was not reported, it is unlikely to be a low value such as 0% or even 20%, because the difficulty in bringing it back to 100% in just one second. Even if the throttle position was very low at 4 seconds before impact, it cannot explain the small increase in speed. This is exemplified by looking at the data from all four tests, which is shown in Figure 25 below.

Change in Speed in 1 Second After Releasing Accelerator Pedal

	Speed at Release of Accelerator Pedal (km/h)	Speed 1 Second After Release of Accelerator Pedal (km/h)	Increase In Speed (km/h)
Rearward Test 1	41.0	49.5	8.5
Rearward Test 2	47.0	52.5	5.5
Forward Test 1	57.5	64.0	6.5
Forward Test 2	55.0	62.5	7.5

Figure 33: Change in test vehicle's speed 1 Second after release of accelerator pedal.

In the above tests the driver immediately began braking after release of the accelerator pedal. The only exception is Forward Test 2 where there was a delay in brake application such the vehicle was coasting during the full second. However in the remaining 3 tests braking was taking place during part of that 1 second. For example, in Rearward Test 1 the brake was contacted 0.6 seconds after the accelerator pedal was

released. In Rearward Test 2 the brake pedal was contacted 0.36 seconds after the accelerator pedal was released, and in Forward Test 1 the brake pedal was contacted 0.37 seconds after the accelerator pedal was released. So in these three tests there was braking taking place in that 1-second period after the accelerator pedal was released, yet the vehicle still managed to increase speed in that second by 8.5, 5.5 and 6.5 seconds respectively. In other words, not only was the accelerator full released and there the throttle should have dropped to 0%, but there was also braking involve, yet the vehicle still managed to increase speed higher than the 3 km/h speed increase in the actual collision. So why did this take place? Even Forward Test 2, when the vehicle was allowed to coast after releasing the brake pedal, the vehicle still managed to increase its speed by 7.5 km/h in that 1 second. If the throttle was anywhere near 84% to 100% at 3 seconds and 1 seconds before impact, the Monte Carlo should not be increased its speed by only 3 km/h but it should have done so at the rates indicated in the four tests. Thus some explaining should have been required during the trial. Unfortunately the details of what was said and by whom with respect to the EDR data, was never reported.