The Seven S-Curves of Adelaide - Part 4

Posting Date: 9 October 2012

Further to our continuing efforts to examine the differences in seven S-Curves on Adelaide Street north of London, Ontario, this latest article provides results of our additional testing with a vehicle instrumented with multiple video cameras and an accelerometer. In addition, a large protector was attached to the vehicle's steering hub and data of steering wheel rotations will also be presented.

It may be recalled that in the first article of this series we presented photos of each of the seven S-Curves.

In Part 2 we discussed the instrumentation used on our test vehicle and discussed the procedures we used to conduct the testing. We also presented some preliminary results.

In Part 3 we presented the results from two drive-throughs of all seven curves. We discussed the fact that the first three curves south of Ilderton Road were of better design than the four curves north of Ilderton Road.

It is clear from this testing that not all curves are the same. In fact there are substantial differences in the design of curves even though they may contain the same warning sign on their approach. The issue can be narrowed to studying just two of the curves, Curve 3 and Curve 4, because this is where the transition takes place between the better-designed curves south of Ilderton Road and the worse-designed curves north of that road. Let us re-examine some photos of each curve before we present our additional data.

The following three photos on Pages 2 and 3 show the views of Curve 3. These are followed by four photos on Pages 3 and 4 showing Curve 4.

Figure 1: Curve 3

Figure 2: Curve 3

Figure 3: Curve 3

Figure 4: Curve 4

Figure 5: Curve 4

Figure 6: Curve 4

Figure 7: Curve 4

It may be recalled from previous articles that we drove northbound through these curves with our cruise control set at 90 km/h and we attempted to minimize our steering inputs while also attempting to keep the vehicle in the middle of the lane. An accelerometer documented the lateral acceleration during these tests. In comparison to the four northern curves we noted the following characteristics of the first three which were of better design:

1. The lateral acceleration was substantially lower in the first three curves .

2. The transition between the two opposite curves of the S-curve was longer such that the change in the lateral acceleration occurred over a longer time and distance.

3. The curve warning sign was placed further back from the curve.

In Part 3 we commented that reading of the lateral acceleration values directly from the display rather than obtaining the data from a stored file caused some difficulty as the display of the values was sometimes blurred and this might cause some error/variance in the documented data. We suspected that performing several runs would reduce some of that variance since the data in Part 3 was only based on two runs. The data in the present article is the average of 4 runs so the smoothing of the data should start to be seen. The chart on Page 6 shows the data from Curve 3 while the chart on Page 7 contains the data from Curve 4. It can be agreed that the differences are substantial.

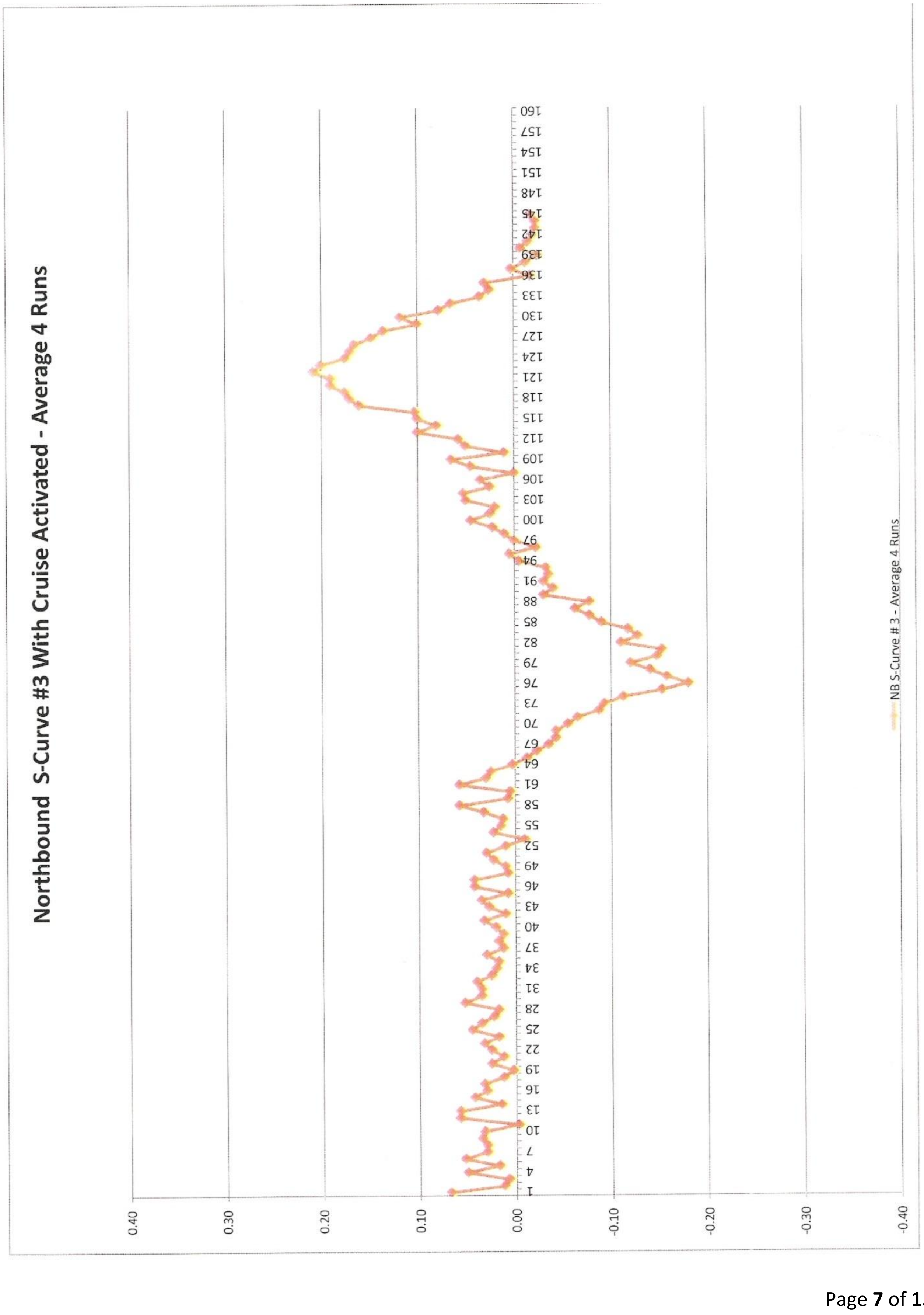
The chart from Curve 3 shows a fairly steady acceleration at the beginning of the data collection as the lateral acceleration pulses between 0.0 g and 0.5 g. We stated earlier that this slightly positive value may be due to the cross fall in the lane which is normally about 2 percent. As the data passes observation 60 we see the change to a negative acceleration as the vehicle begins to travel into the right curve. We can also see a relatively mild change from a -0.19 g to a 0.20 g peak from observation 75 through to observation 122, or about 47 observations. Recall that our video was shot at 30 frames per second and we documented the lateral acceleration every 5 frames, so there were 6 observations taken every second. So the 47 observations encompasses a time of about 7.8 seconds during which the acceleration changes from the negative peak to the positive peak. At 90 km/h, or 25 metres per second, this change would take place in about 196 metres. So these values demonstrate some fairly mild conditions that a driver should experience without much of a challenge.

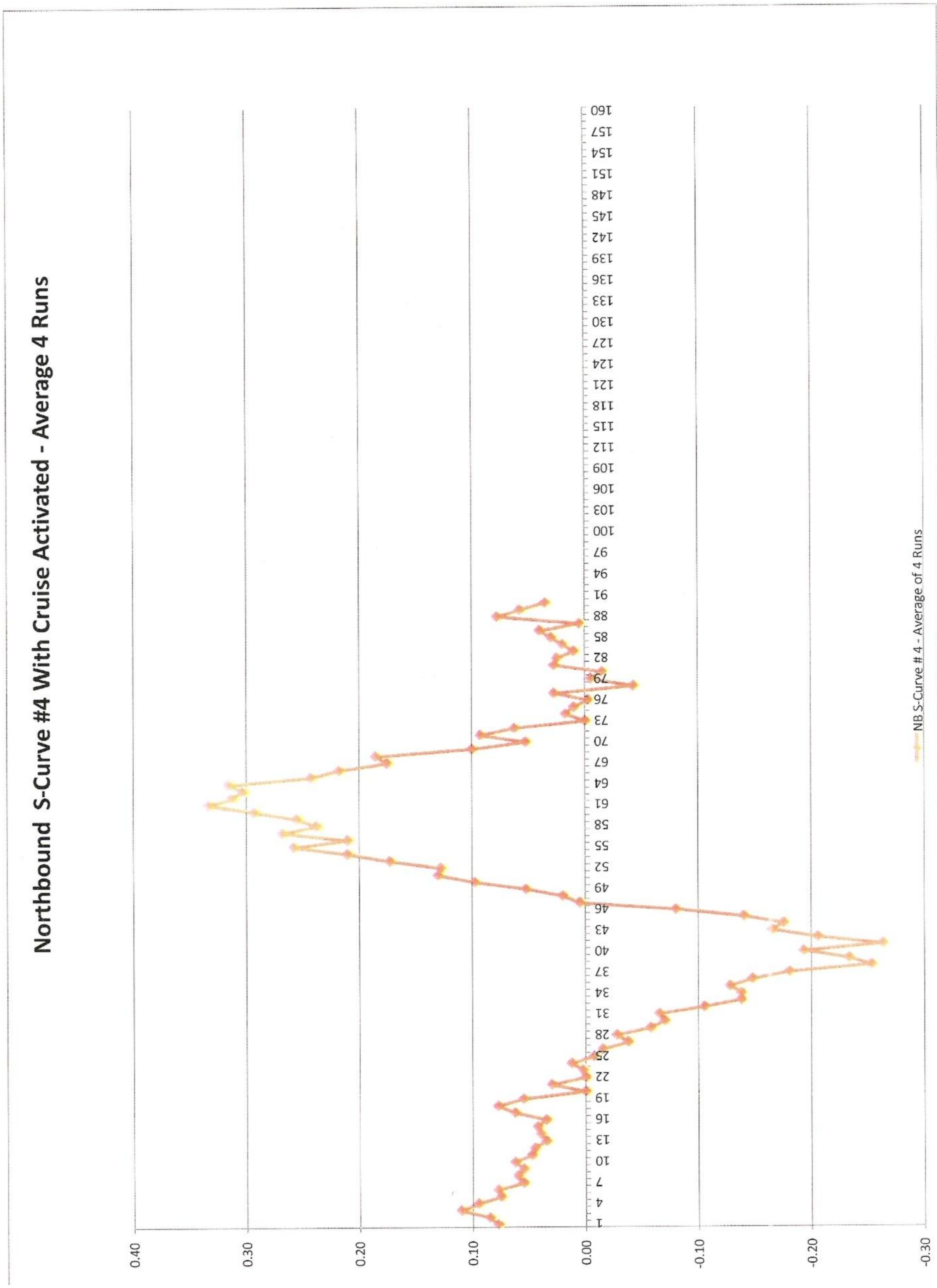
Conversely, the chart from Curve 4 shows that the curve warning sign is very close to the start of the curve because we see the change in the data occurring toward negative acceleration only about 18 observations into the chart. The negative acceleration reaches its peak at about observation 40 and this peak is about -0.26 g. Then we see a very sudden transition from this negative peak to the positive peak of about 0.32 g at about observation 60.

Thus the absolute value of the lateral acceleration in Curve #4 changes by about 0.58 g in about 20 observations, or 3.3 seconds, or a distance of about 83 metres. In contrast, in Curve # 3 the absolute value of the lateral acceleration changed by about 0.39 g in about 47 observations, or 7.8 seconds or 196 metres. These are substantial differences between the two curves.

Our research has confirmed the obvious fact that drivers in general travel faster than the posted speed limit when approaching such curves thus they are selecting a higher level of risk than what the designers of a curve recommend. When an occasional change occurs in the circumstances, these risky drivers are more likely to lose control of their vehicles and crash. This is what official reports refer to a collisions resulting from driver error. While this driver behaviour problem exists, there is little discussion of the fact that curves with very divergent characteristics are identified with the same warning sign, thus not providing the driver with sufficient information about those differences. In a very large percentage of incidents drivers appear to be capable of adjusting well to such inconsistent warnings and to all roadway deficiencies in general. Thus very few experiences of passing through inconsistent roadway curves actually result in collisions. The very low probabilities of a crash can make it difficult to conclude that one curve is substantially different than another. It is not until testing is conducted on such curves that we actually become aware of their differences.

While an accelerometer is capable of capturing differences in roadway characteristics there are some simple devices that also mimic the results of the accelerometer.

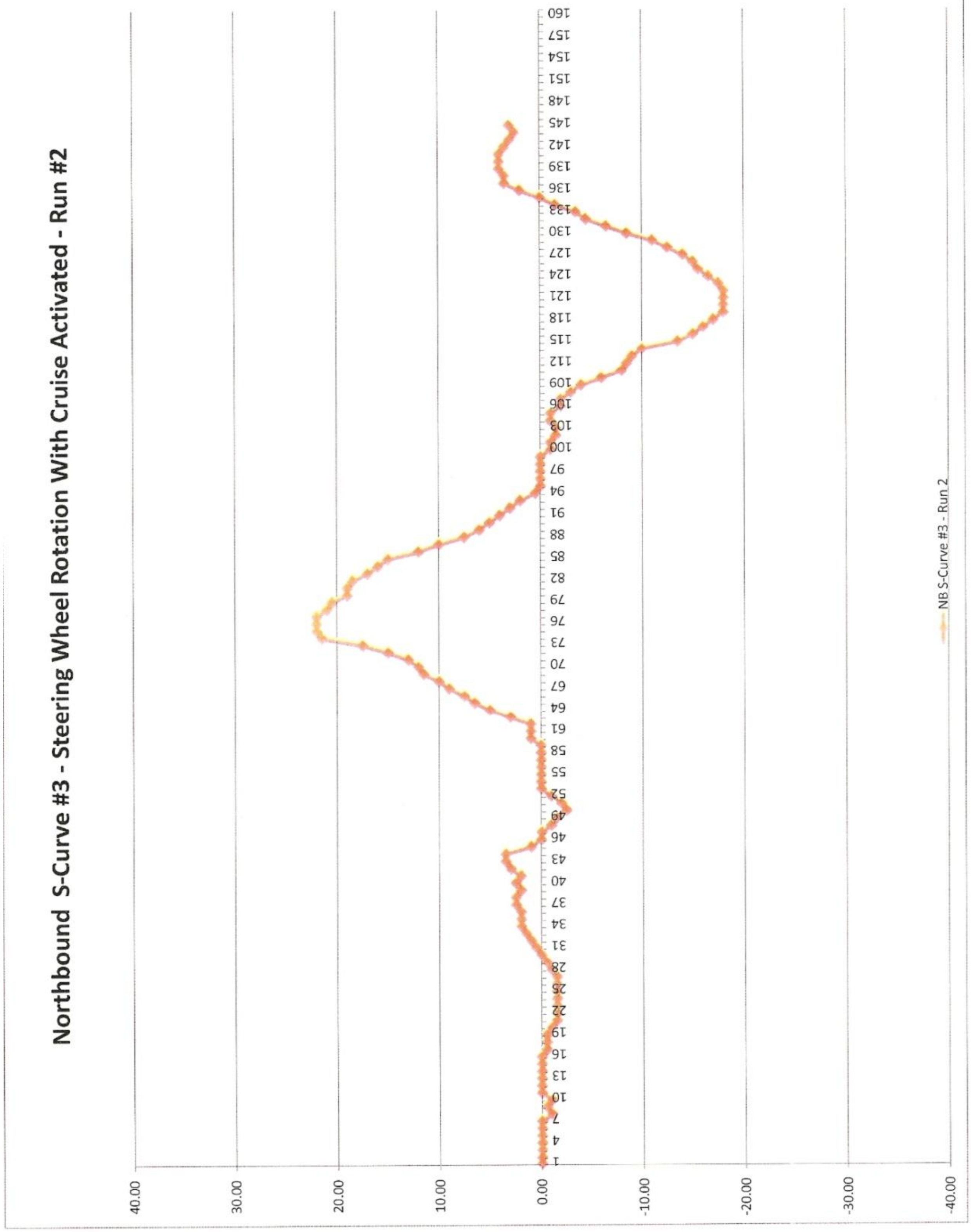

Northbound S-Curve #3 With Cruise Activated - Average 4 Runs
0.40
0.30
0.20
0.10
0.00
-0.10
-0.20
-0.30
-0.40
NB S-Curve # 3 - Average 4 Runs

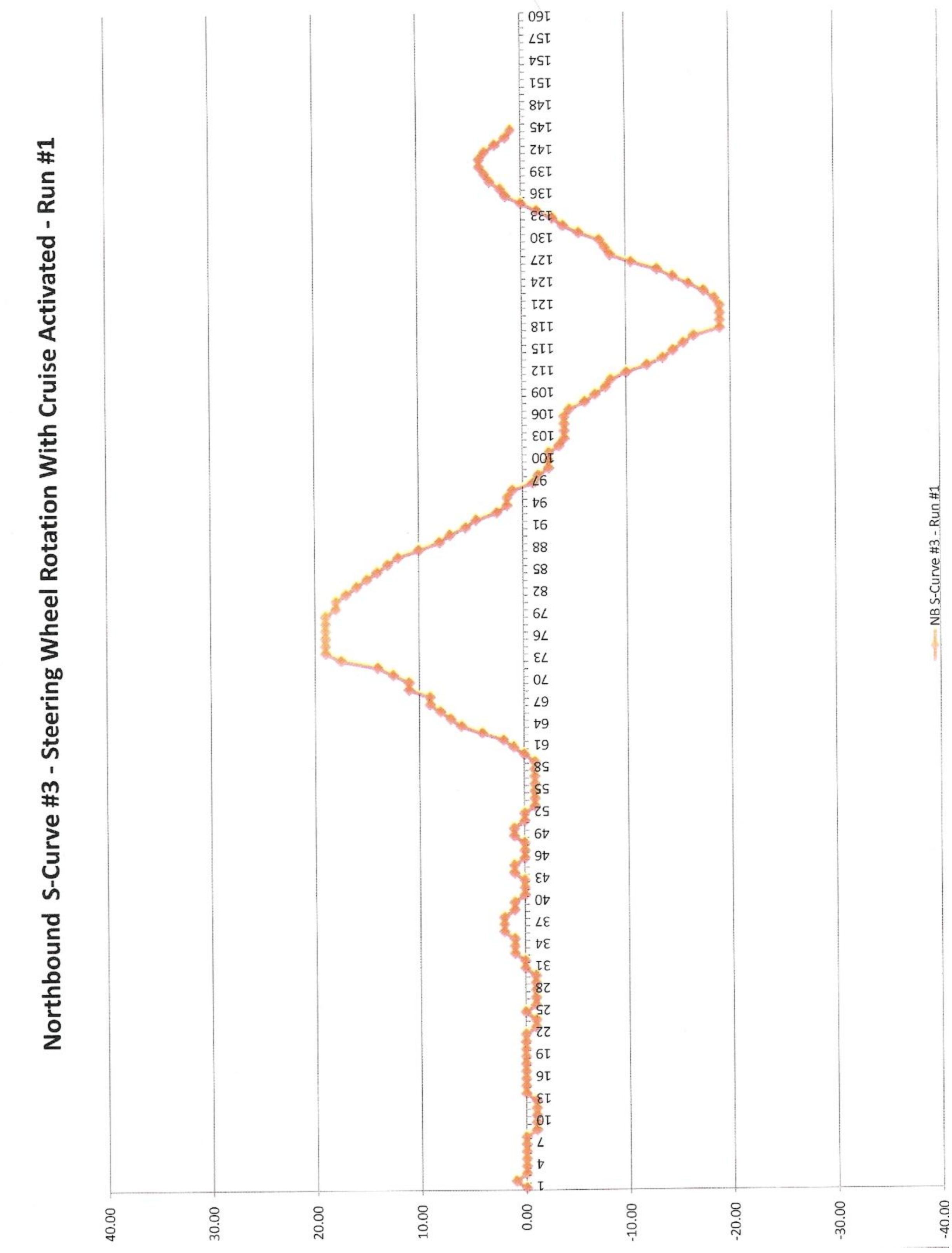


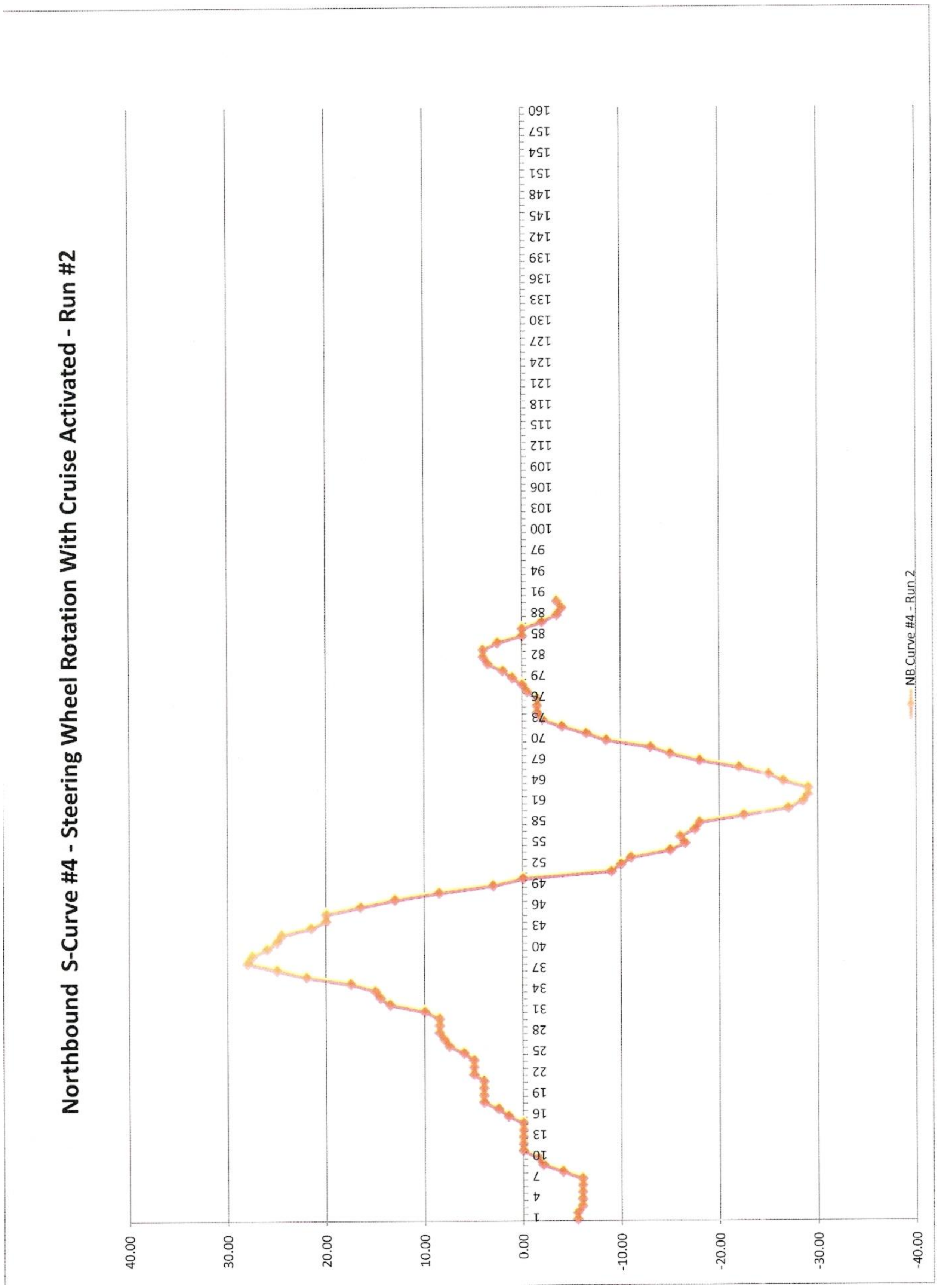
Northbound S-Curve #4 With Cruise Activated - Average 4 Runs
0.40
0.30
0.20
0.10
0.00
-0.10
-0.20
-0.30
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79
82
85
88
91
94
97
100
103
106
109
112
115
118
121
124
127
130
133
136
139
142
145
148
151
154
157
160
NB S-Curve # 4 - Average of 4 Runs

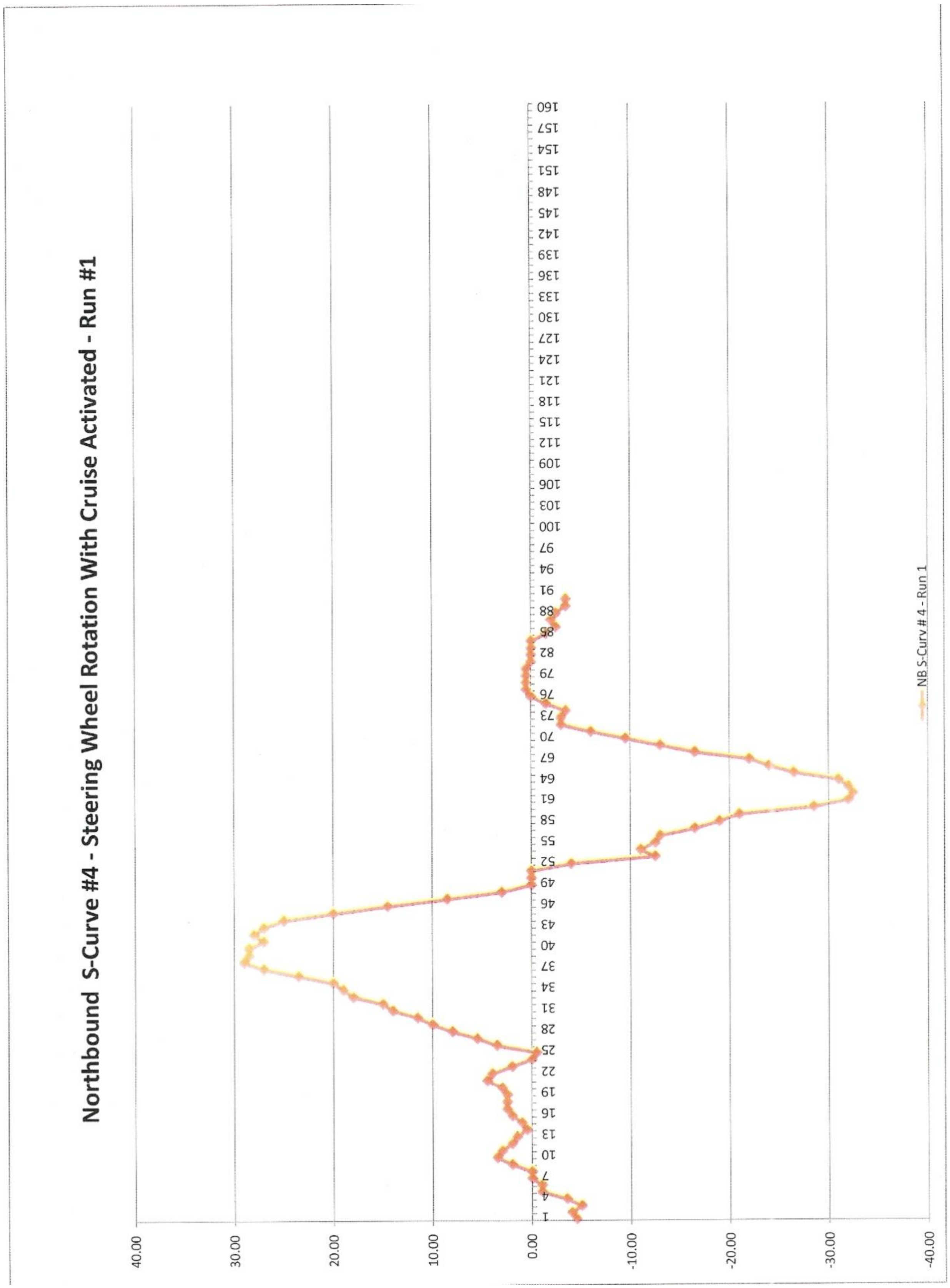
We have previously explored steering wheel motions by attaching a large protractor to the steering hub of our test vehicle , as shown in the two photos below.

The four charts on Pages 10 through 14 show the steering wheel angle as the vehicle made two passes through each of Curves 3 and 4


Northbound S-Curve #3 - Steering Wheel Rotation With Cruise Activated - Run #2
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91 94 97 100 103 106 109 112 115 118 121 124 127 130 133 136 139 142 145 148 151 154 157 160
NB S-Curve #3 - Run 2


Northbound S-Curve #3 - Steering Wheel Rotation With Cruise Activated - Run #1
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
NB S-Curve #3 - Run #1


Northbound S-Curve #4 - Steering Wheel Rotation With Cruise Activated - Run #2
NB Curve #4 - Run 2
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79
82
85
88
91
94
97
100
103
106
109
112
115
118
121
124
127
130
133
136
139
142
145
148
151
154
157
160


Northbound S-Curve #4 - Steering Wheel Rotation With Cruise Activated - Run #1
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91 94 97 100 103 106 109 112 115 118 121 124 127 130 133 136 139 142 145 148 151 154 157 160
NB S-Curv # 4 - Run 1

As can be seen in the charts, the steering wheel rotations mimic the lateral acceleration values obtained from our accelerometer. Curve #3 required less steering input and the transition was more gradual between the right and left curves of the S-Curve. In contrast the data from Curve #4 shows more dramatic steering inputs that transitioned over a shorter time and distance. These results are not unexpected. There should be an obvious relationship between steering wheel inputs and the lateral accelerations that would be experienced by a test vehicle.

Our research into the varying characteristics of roadway curves is relevant toward understanding why some collisions may occur at curves of rural roadways. Consider a northbound driver who travels through the first three S-curves of Adelaide Street. These first three curves are of a similar design. The curve warning sign is approximately 250 metres prior to the commencement of each curve. The maximum lateral acceleration is generally below 0.20 g. There is a long time and distance between the two opposite curves of the S-curves where the lateral acceleration transitions from negative to positive. The consistency with which these design parameters are applied gives a driver an expectation that future curves will contain similar characteristics. But as the driver passes north of Ilderton Road and approaches Curve 4 the design parameters become quite different.

The curve warning sign at Curve 4 is located only a very short distance prior to the commencement of the curve. There are trees and bushes close to the road that make it difficult to see the layout of the curve. As the driver starts into the first curve to the right there is a sudden increase in the lateral acceleration to a peak of about -0.25 g. Then there is a rapid change in the lateral acceleration to a peak of over 0.30 g in the second portion of the S-curve to the left. Drivers who become familiar with the road can make better adjustments for these differences. But drivers who are new to the area could be surprised by these differences. Even drivers who have passed through Curve #4 on a number of occasions could be caught unprepared if certain changes, such as poor weather conditions, cause a difference in the speed at which a driver can travel through the curve.

It is more important to consider the implications of the differences in these curves to novice drivers and what training new drivers receive in Ontario. Licensed driving instructors in Ontario have no real training or understanding about the differences in rural curves. Most training that is passed onto young drivers is with respect to urban driving conditions, with possible travel onto controlled access freeways. But little time is spent teaching young drivers how to approach and drive through rural curves. Yet, when accident statistics are examined, the number of fatal collisions that occur on rural roadways looms large. Electronic stability control seems to be having some positive effect in controlling loss-of-control collisions with newer vehicles. Various collision avoidance technologies that detect lane departures and take control of vehicle before a driver can recognize a problem may also be of further advantage in the near future. But it is yet to be determined how quickly these technologies will affect collisions on rural roadways. Presently lane departure systems sample the position of the vehicle with respect to the lane edge lines to detect whether a vehicle is wandering out of a lane.

Will all the low volume roads be painted with such edge lines? What about gravel road surfaces where an edge line cannot be painted? There are a much larger number of low volume rural roads for each higher volume road and economics might prevent improvements from being made even though advanced technologies exist that could improve their safety. Whatever developments occur in the future it is necessary to inform the young drivers of today about the special dangers that exist at curves of rural roadways.

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