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Vehicle Crush Stiffness Values

Crash Test Data, Data Problems, and Common Misconceptions

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Vehicle Crush Stiffness Values

Crash Test Data, Data Problems, and Common Misconceptions

by

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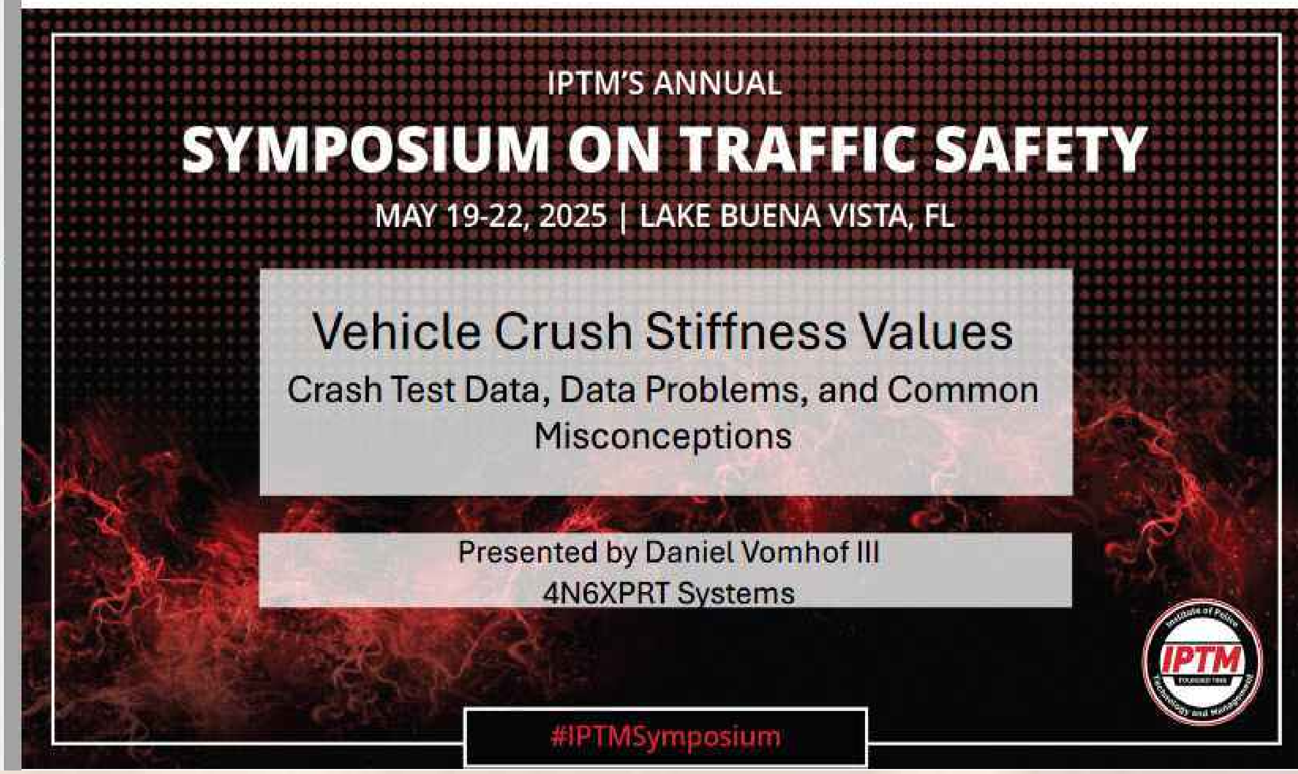
Vehicle Crush Stiffness Values

Introduction to Presentation

First some "Intro" .... Bookmarks are available

- **Crash Test Data - Data Problems - Common Misconceptions**
- ***Definition of Terms used by this Author***
- **Speaker Resume**
- Kinetic Energy Equivalent Speed: What Is It? Why Calcualte It? How to Calculate It
- Crush Factor: A Validity Analysis (Frontal)
- NHTSA Test # 9859 - 2011 Volkswagen Jetta
- NHTSA Test # 9718 - 2009 Hyundai Accent
- Speed Evaluation Report - Florida Case Study
- Speed Evaluation Report - California Case Study



Vehicle Crush Stiffness Values

Crash Testing and Available Vehicles

Why can’t I get data for my specific year/make/model from the NHTSA Crash Test database?

Several Reasons -

- NHTSA is required to purchase the vehicles off of dealer lots at the going price.
- This is part of the reason you don't normally see the “high end” vehicles being crash tested .... it's a budget thing.
- For the same reason (budget), NHTSA will typically only test the vehicles in the first or second year of a major change, and then not test them again until the next major change.

Vehicle Crush Stiffness Values

Crash Testing and Available Vehicles

- Thus, while you might have a 2019 vehicle, you will have to base the stiffness values on a test of a 2017 vehicle.

What tests are typically available for a given vehicle?

- Typically there will be 1-2 tests for Front, 1-2 tests for side (again, typically on the driver's side) and post-1998 1 or no tests on the Rear.
- There may also be a number of tests that are not full vehicle tests. They are for airbag deployment, restraints, etc. These are not full vehicle tests in order to help save on costs.

Vehicle Crush Stiffness Values

Crash Testing and Available Vehicles

▸ The reasons for the lack of Rear testing is two-fold -

▸▸ First, a saving on money so that more testing of these other types can be completed.

▸▸ Second, a decision was made by NHTSA that people “were no longer getting seriously injured” in rear end collisions, so money would be better allocated to other testing.

Additionally, when there ARE rear tests available, it is not uncommon for the online database to be missing some or all of the data needed for calculating stiffness values. This data can sometimes be found in the contractor report, but ... may be limited as to what data is available (such as MAXIMUM crush only).

Vehicle Crush Stiffness Values

Crash Testing and Available Vehicles

So what tests ARE available?

▸ Using the 2009 model year as an example -

▸▸ There are a total of 196 tests available in the NHTSA database for the 2009 model year.

▸▸ Of those 196 tests, 86 of the tests have one or more crush depths recorded and reported in the database. The remaining 110 tests have no crush depths reported in the database. These are tests that either have no crush to report, such as static airbag tests, or have no crush measurements required as a part of the testing per contract.

▸▸ Based on the reported impact angle, 40 of the tests with reported crush are side impact tests.

Vehicle Crush Stiffness Values

Crash Testing and Available Vehicles

▸▸ Again, based on the reported impact angle, 12 of the 196 tests are rear impact fuel integrity tests, and again, NONE of these tests have any reported crush depths, as they are not required to have any per the crash testing contract (as reported/stated to me by several different testing representatives and or NHTSA representatives).

▸▸ So lets count the numbers ... 86 tests with measurement data, 40 of which are side tests, leaving 46 as frontal tests. If one assumes 2 frontal tests and 2 side tests per model, one being a full barrier and one a pole test, that means only ~23 models crash tested within the 2009 model year for frontal impact, and ~20 tested for side impact.

▸▸ The limited number of tests, in combination with the lack of measurement data in some of the tests, limits what an accident reconstruction professional can at times accomplish.

Vehicle Crush Stiffness Values

Crash Testing and Available Vehicles

▸▸ The limited data also can force compromises between what a perfect world would expect, and what can be done with the data available.

This can be compared to what is known as the CSI effect, where it is expected that DNA is run in mere hours, and a total case wrapped up in 50 minutes .... or 1 hour when you add in commercials.

The limited data is also why one operating as an Expert in Accident Reconstruction should understand and be able to explain the limitations, and why the compromises were necessary when they become necessary.

Vehicle Crush Stiffness Values

Crash Testing and Available Vehicles

There are other testing organizations throughout the world. Why are the stiffness values calculated primarily (only?) based on testing by NHTSA?

- The primary reason for this is that the other NCAP testing done by agencies other than NHTSA do not publish things such as crush depths. They may also be missing things like weight and closing speed. Without this data, the stiffness values cannot be calculated.
- For this reason (NHTSA data “only”) the crash testing is based on vehicles intended for sale in the U.S./Canada. Vehicles specific to other countries are not commonly (or at all) tested.

Vehicle Crush Stiffness Values

Speed

What speed(s) are reported in the NHTSA Crash Test database?

- The NHTSA database reports CLOSING SPEED.
  - The database does not report any Δv for a test.
  - The database does not report any exit speeds or after/post impact speeds for a test.
  - The database does not report any Damage energy speeds for a test.
  - The database does not report any stiffness values for a test.

If any of this data is desired, it must be calculated from the rest of the test data, or extracted from instrumentation data.

Vehicle Crush Stiffness Values

Speed- Fixed Barrier Tests

What speed should be used in calculating stiffness values?

- The common designation in the published formulas is Δv_{test} ... however ... the actual Δv is seldom/never the speed to be used in the calculations.
- the reason that the Δv is not the appropriate speed is a many layered answer. We will first look at the case of the fixed barrier (primarily frontal) testing, and then we will look at the movable barrier (primarily side/rear) testing.

Vehicle Crush Stiffness Values

Speed- Fixed Barrier Tests

- Point 1 - First, remember that **The Law of Conservation of Energy** says that energy is neither created nor destroyed.

So, for an example, a vehicle with a mass of 1000 comes into a barrier at a speed of 35 mph, is crushed, and bounces back at a speed of 4 mph.

Closing speed = 35 mph = 51.33 fps

Δv speed = S_f - S_i (i.e. - $\text{Speed}_{\text{Post impact}}$ - $\text{Speed}_{\text{Pre impact}}$)

Δv speed = (-4) - 35 = -39 mph = -57.2 fps

Lets remember that $KE=1/2 * m*v^2$

So, in this example, the total energy coming into the barrier is $KE=1/2 * m*v^2 = 1/2*1000*51.33^2 = \sim 1{,}317{,}384$

<u>THIS IS THE TOTAL ENERGY COMING INTO THE SYSTEM!!</u>

Vehicle Crush Stiffness Values

Speed- Fixed Barrier Tests

If the Δv is used, the system energy becomes

KE=1/2 * m * v^2 = ½ * 1000 * $(-57.2)^2$ = ~1,635,920

Completing the calculations -

Closing Speed system energy = ~1,317,384

Δv Speed system energy = ~1,635,920

Result is 318,536 units of energy MORE at the end of the test than there was coming into the test

Thus, using the Δv violates **The Law of Conservation of Energy** as energy has been "created" during the test due to the impact with the barrier.

Vehicle Crush Stiffness Values

Speed- Fixed Barrier Tests

- Point 2 - The Crash Test database maintained by NHTSA does not contain the “bounce back” speed.

This speed MIGHT be contained in the contractor report, but often times is not.

This speed COULD probably be extracted from the instrumentation, but which and how many of the sensors are you going to use to establish the speed?

This speed could also, perhaps, be extracted from the vehicle CDR/EDR in the more recent testing ... IF the CDR/EDR is downloaded. For the majority of the tests this is not the case.

- Point 3 - For the same amount of crush, the higher the speed, the stiffer the vehicle. Since the Δv speed is higher than the Closing Speed, using the Δv speed will result in higher stiffness values from the crash test which in turn results in a higher calculated speed in the subject collision.

Vehicle Crush Stiffness Values

Speed- Fixed Barrier Tests

Since a commonly heard "mantra", especially within Law Enforcement is "Minimum Speed" .... a stiffer vehicle is undesirable.

- Point 4 - given that what we ACTUALLY want is the Energy, expressed as a speed, that went into crushing the vehicle, thought should be given to possibly using the Closing Speed absolute value -the Bounce Back speed absolute value. Thus -

V_{test} = |Closing Speed| - |Bounce Back Speed|

$V_{test} = |35|-|-4| = 31$

Again, Same Crush, LOWER speed, SOFTER stiffness, LOWER subject collision speed.

Vehicle Crush Stiffness Values

Speed - Fixed Barrier Tests

CAUTION -

Point 4 is not being promulgated as a recommended practice, rather it is suggested for thought and something to test.

If the expert feels they can explain it, they might want work with it, OTHERWISE, use the Closing Speed in the fixed barrier tests.

- Point 5 - going back to the fact that the “bounce back” speed is not commonly/easily available, for standardization in the calculation process, using the Closing Speed in the Fixed Barrier collisions is proposed as the “proper” speed to use when calculating stiffness values.

Vehicle Crush Stiffness Values

Speed - Moving Barrier Tests

When are Moving Barriers used?

- The Moving Barrier Tests are typically a Side or Rear test. However, there are some frontal barrier tests with moving barriers as well. These are typically a Pole Test.

So, the Closing Speed is there, is that the speed that I use?

- In a word .... NO.
- The Closing Speed is the only speed shown for these tests in the NHTSA database.
- Using the closing Speed will give erroneously high stiffness values, as use of the Closing Speed assumes that all of the incoming Energy is absorbed by crushing the Target Vehicle.
- However, we KNOW that both the barrier and the target vehicle continue "down stream" post impact.

Vehicle Crush Stiffness Values

Speed - Moving Barrier Tests

- Thus, some of the incoming speed (energy) is retained by the barrier post impact, some of the speed (energy) is picked up/gained by the target vehicle post impact, and some of the speed (energy) goes into causing damage to the target vehicle as well as the barrier.
- Assuming that all of the Closing Speed (energy) went into causing the damage is an error that has been made by many. It is also the reason that the authors of Expert AutoStats® developed the Crush Factor (CF) value of CF=27 for the Rear and Side estimations of Bullet Vehicle speed based on Target Vehicle Damage only.
- Again, the speed to be used is the Damage Energy Speed (i.e. - the Energy that went into crushing the vehicle, expressed as a speed). This author likes to call that speed KEES (Kinetic Energy Equivalent Speed).

Vehicle Crush Stiffness Values

Speed - Moving Barrier Tests

Other authors will refer to the speed with various equivalents of KEES, such as BEV (Barrier Equivalent Velocity), BES (Barrier Equivalent Speed), EES (Energy Equivalent Speed), DES (Damage Equivalent Speed) as well as other similar terms. In the end, it boils down to using the energy expressed which causes the damage, as a speed, **NOT** the Δv of either the barrier or the target.

Is this Damage Energy Speed given in the Crash Test information?

- Again, in a word .... NO.
- As with the Fixed Barrier Tests, the Post Impact Speed MIGHT be able to be extracted from the Instrumentation Data. However, neither this, nor the Δv, is the Damage energy Speed.

Vehicle Crush Stiffness Values

Speed - Moving Barrier Tests

- To illustrate this, we will examine 3 crash tests conducted in 2023 at the Pennsylvania State Police conference.

All 3 tests were instrumented, although not all of the instruments recorded the full collision.

- CT1 and CT2 were a combined test where the bullet vehicles, 2001 Ford Escorts, were pulled into the target vehicles at the same time by the same vehicle.
- CT1 had a 2001 Ford Escort hitting the front of a 2005 Mercury Sable at about 53 mph.
- CT2 had a 2001 Ford Escort hitting the passenger side of a 1993 Buick Park Avenue at about 57 mph.
- Even though both Escorts were in theory traveling at the same speed, since they were pulled by the same vehicle, they had different instrumented closing/impact speeds.

Vehicle Crush Stiffness Values

Speed - Moving Barrier Tests

- The difference in instrumented closing speed of the two Escorts illustrates some of the variance that can be found even in instrumented tests.
- CT3 had a 2000 Chevrolet Cavalier hitting the Rear of a 2004 Saturn Ion at about 66 mph.

Since the model for calculating speed from damage assumes that both vehicles reach a common speed/velocity at the damage centroid, one can calculate the post impact speed of both vehicles using an inline momentum calculation.

$W1*S1 + W2*S2 = W1*S3 + W2*S4$

A common Post Impact Speed is assumed so $S3=S4$

if $S2 = 0$, then S3 can be calculated as

$S3 = [W1*S1 / (W1 + W2)]$

Vehicle Crush Stiffness Values

Speed - Moving Barrier Tests

Then, knowing S3, a Δv for each vehicle can be calculated as follows:

$\Delta v1 = S3 - S1$ And $\Delta v2 = S3 - S2$

These speeds can then be compared to the instrumented Δv's to see if the calculated post impact speed is "good enough" to continue with the comparison.

The KEES speed is calculated as

$KEES = SQR[(Wt_{Bullet} * Speed_{Bullet}\hat{}2) / (Wt_{Bullet} + Wt_{Target})]$

A paper discussing why and how the KEES is calculated can be found on the 4N6XPRT Systems web site on the Papers and Publications page. It is also available on the Conference Material page from which this presentation can be downloaded, and will be discussed at the end of the presentation.

Vehicle Crush Stiffness Values

Speed - Moving Barrier Tests

CT1 -

Bullet = Escort, Wt = 2506 pounds, Impact Speed ~53 mph, Instrumented Post Impact Speed ~ 18.7 mph

Target = Sable, Wt = 3228 pounds, Impact speed = 0 mph, Instrumented Post Impact Speed ~ 26.7 mph

Calculated Common Post Impact Velocity (V3) ~23.2 mph

Escort Δv - Instrumented = 34.3 mph, V3-V1 = -29.8 mph

Sable Δv - Instrumented = 26.7 mph, V3-V1 = 23.2 mph

$KEES_{Sable}$ = SQR[(2506*53^2) / (2506+3228)]

$KEES_{Sable}$ = 35.04 mph

Now, Compare the KEES to the Δv's first of the Sable, since that is what the KEES applies to, and then to the Escort.

Vehicle Crush Stiffness Values

Speed - Moving Barrier Tests

It can be clearly seen that the KEES speed is NOT the Δv speed for the Sable. While not as clear in this test, due to the Instrumented Escort Δv being close in magnitude to the KEES speed, it can also be seen that most likely the Escort Δv is not the KEES speed for the Sable either. Further, it can be seen that the calculated common post impact velocity (V3) is relatively close in magnitude to the post impact speed for both the Escort and the Sable.

PSP 2023 - CT1								
	2001 Escort	2005 Sable						
Pre -								
Weight (lbs)	2506	3228		W1 * V1	W2 * V2	=	(W1+W2)	* V3
Speed (mph)	53	0		132818	0		5734	* V3
						V3 =	(W1 * V1) / (W1 + W2)	
Post -						V3 =	**23.16**	
Weight (lbs)	2506	3228						
Speed (mph)	18.7	26.7						
Delta-v Meas	34.3	26.7						
Delta-v Calc	29.84	23.16						
KEES =	SQR (Wt bar * Spd Bar ^2) / (wt bar + Wt Targ)							
KEES Targ =		**35.04**						

Vehicle Crush Stiffness Values

Speed - Moving Barrier Tests

CT2 -

Bullet = Escort, Wt = 2568 pounds, Impact Speed ~57 mph, Instrumented Post Impact Speed ~ 23.2 mph

Target = Park Ave, Wt = 3491 pounds, Impact speed = 0 mph, Instrumented Post Impact Speed ~ 25.6 mph

Calculated Common Post Impact Velocity (V3) ~24.2 mph

Escort Δv - Instrumented = 33.8 mph, V3-V1 = -32.8 mph

Park Ave Δv - Instrumented = 25.6 mph, V3-V1 = 24.2 mph

$KEES_{ParkAve}$ = SQR[(2568*57^2) / (2568+3491)]

$KEES_{ParkAve}$ = 37.11 mph

Now, Compare the KEES to the Δv's first of the Park Ave, since that is what the KEES applies to, and then to the Escort.

Vehicle Crush Stiffness Values

Speed - Moving Barrier Tests

It can be clearly seen that the KEES speed is NOT the Δv speed for the Park Ave. It can also be clearly seen that the Escort Δv is not the KEES speed for the Park Ave either. Further, it can be seen that the calculated common post impact velocity (V3) is close in magnitude to the post impact speed for both the Escort and the Park Ave.

PSP 2023 - CT2								
	2001 Escort	93 Park Avenue						
Pre -								
Weight (lbs)	2568	3491		W1 * V1	W2 * V2	=	(W1+W2)	* V3
Speed (mph)	57	0		146376	0		6059	* V3
						V3 =	(W1 * V1) / (W1 + W2)	
Post -						V3 =	**24.16**	
Weight (lbs)	2568	3491						
Speed (mph)	23.2	25.6						
Delta-v Meas	33.8	25.6						
Delta-v Calc	32.84	24.16						
KEES =	SQR (Wt bar * Spd Bar ^2) / (wt bar + Wt Targ)							
KEES Targ =		**37.11**						

Vehicle Crush Stiffness Values

Speed - Moving Barrier Tests

CT3 -

Bullet = Cavalier, Wt = 2597 pounds, Impact Speed ~66 mph, Instrumented Post Impact Speed ~ 32.2 mph

Target = Ion, Wt = 2786 pounds, Impact speed = 0 mph, Instrumented Post Impact Speed ~ 31.3 mph

Calculated Common Post Impact Velocity (V3) ~31.8 mph

Cavalier Δv - Instrumented = 33.8 mph, V3-V1 = -34.2 mph

Ion Δv - Instrumented = 31.3 mph, V3-V1 = 31.8 mph

$KEES_{Ion}$ = SQR[(2597*66^2) / (2597+2786)]

$KEES_{Ion}$ = 45.84 mph

Now, Compare the KEES to the v's first of the Ion, since that is what the KEES applies to, and then to the Cavalier.

Vehicle Crush Stiffness Values

Speed - Moving Barrier Tests

It can be clearly seen that the KEES speed is NOT the Δv speed for the Ion. It can also be seen that the Cavalier Δv is not the KEES speed for the Ion either. Finally, it can be seen that the calculated Post Impact Common Velocity (V3) is quite close to the Post Impact Velocity of both the Cavalier and the Ion.

PSP 2023 - CT3								
	2000 Cavalier	2004 ION						
Pre -								
Weight (lbs)	2597	2786		W1 * V1	W2 * V2	=	(W1+W2)	* V3
Speed (mph)	66	0		171402	0		5383	* V3
						V3 =	(W1 * V1) / (W1 + W2)	
Post -						V3 =	**31.84**	
Weight (lbs)	2597	2786						
Speed (mph)	32.2	31.3						
Delta-v Meas	33.8	31.3						
Delta-v Calc	34.16	31.84						
KEES =	SQR (Wt bar * Spd Bar ^2) / (wt bar + Wt Targ)							
KEES Targ =		**45.84**						

Vehicle Crush Stiffness Values

Speed - Δv_{test}

But the commonly published formulas refer to Δv as one of the variables?

- As stated previously, the reason Δv is not the appropriate speed to be used is a many layered answer.

We have already seen examples of how/why Δv is not appropriate, as it is not the Damage Energy Speed, lets now look at Δv specifically in depth.

- Δv is a linear calculation, commonly calculated as

$\Delta v = S_f - S_i$ where S_f = Speed final and S_i = Speed initial.

The other component of the Δv is that within physics Δv is a vector value defined as change in speed, direction, or both. Within the field of Accident Reconstruction, Δv is commonly treated as a scalar value and the change in direction component is typically ignored.

Vehicle Crush Stiffness Values

Speed - Δv_{test}

- When applied to calculating Stiffness values, some have used the incoming barrier speed as the Initial speed, and the calculated vehicle departure speed as the final speed to arrive at their Δv, and then use the absolute value of that speed.
- Problem, and it is significant. Crush is ENERGY. Remember, $KE=1/2*m*v^2$. Where is the v^2 in a Δv calculation?
- It doesn't exist. If we look at our three test crashes, and compare the Δv_{test} calculated in the manner described previously, and compare them to the KEES speed, we get -

CT1 - Δv = |23 - 53| = 30 mph	KEES = 35 mph
CT2 - Δv = |24 - 57| = 33 mph	KEES = 37 mph
CT3 - Δv = |32 - 66| = 34 mph	KEES = 46 mph

Vehicle Crush Stiffness Values

Speed - Δv_{test}

- As can be seen, the Δv calculation will typically result in lower, sometimes MUCH lower speeds for the Stiffness Calculations.
- While the lower speed can be "good" if the intent is to try and establish a minimum or "floor" speed, this approach illustrates a lack of understanding of what is going on in crush, stiffness values, and the calculations of the various values/numbers.
- Again - Speed from Δv is a **LINEAR** value/calculation. Speed from crush is an **ENERGY** calculation and thus has a **SQUARED** term as part of its calculation.
- The choice to use the variable term Δv_{test} within the published formulas relating to speed from crush calculations is an unfortunate one, as it has led to several misunderstandings regarding the mechanics of the calculations.

Vehicle Crush Stiffness Values

Speed - Δv_{test} - Additional "Fallout" - CF

- There are other stiffness values besides the CRASH III A-B-G values which are used in speed from crush calculations. One of these types of values is the Crush Factor (CF) as published in the Expert AutoStats® program
- The CF value is calculated in the same way that a "drag factor" is calculated from test skids:

$$\mathbf{CF = Speed^2 / 30 * Crush}$$

where the Crush distance is the Maximum Crush in feet and the Speed is the Crush Energy Speed (KEES) in mph.

- If the Δv is used instead of the Crush Energy Speed (KEES), lower to significantly lower values for CF are then calculated, as can be seen from our three test crashes on the following slides.

Vehicle Crush Stiffness Values

Speed - Δv_{test} - Additional "Fallout" - CF

- First, some explanations/definitions-

  - Within Expert AutoStats® publication a value of CF=21 is recommended to calculate a KEES speed based on the maximum crush.

  - Within Expert AutoStats® publication a value of CF=27 is recommended to calculate a BULLET speed based on the maximum crush to only the TARGET vehicle.

This CF=27 is a fallout from initially trying to calculate the CF values based on the Closing Speed and the target damage, taken verbatim from the NHTSA Crash Test database.

The following screens will show a comparison of the Test Specific CF calculated based on the various Δv's and Test KEES, followed by a back calculation of speed using the default CF values found in Expert AutoStats®.

Vehicle Crush Stiffness Values

Speed - Δv_{test} - Additional "Fallout" - CF

PSP 2023 - CT1					
	2001 Escort	2005 Sable	2005 Sable		
Max Crush					
inches		27			
feet		2.25			
			Closing - PIS		
Delta-v Meas	34.30	26.70			
Delta-v Calc	29.84	23.16	29.84		
Test Specific CF based on Delta-v			Closing - PIS		
Delta-v Meas	17.4	10.6			
Delta-v Calc	13.2	7.9	13.2		
KEES Target =		35.04			
Test Specific **CF** based on KEES		**18.2**			
				Compare to	
CF = 21		**37.6**		**35.04**	**KEES mph**
CF = 27		**42.7**		**53**	**Closing mph**

Vehicle Crush Stiffness Values

Speed - Δv_{test} - Additional "Fallout" - CF

- Examining the data for CT1, we can see that the CF value based on the various Δv's is lower to significantly lower than the CF based on the KEES. This makes sense given that the KEES speed is higher to significantly higher than the Δv speeds.
- The Δv which would normally be used based on crash testing would be the one in the third column which is calculated in the spreadsheet as Closing Speed - PIS (Post Impact Speed).
- It can be seen that in this test using the Δv instead of the KEES to calculate a Test Specific CF will underestimate the KEES speed by a large, potentially significant, amount.
- The default CF=21 only slightly overestimates the KEES speed in this test (~2.6 mph over). The CF=27 underestimates the closing speed of the bullet vehicle (11-12 mph under).

Vehicle Crush Stiffness Values

Speed - Δv_{test} - Additional “Fallout” - CF

	PSP 2023 - CT2					
		2001 Escort	93 Park Avenue	93 Park Avenue		
	Max Crush					
	inches		33			
	feet		2.75			
				Closing - PIS		
	Delta-v Meas	33.80	25.60			
	Delta-v Calc	32.84	24.16	32.84		
Test Specific CF based on Delta-v				Closing - PIS		
	Delta-v Meas	13.8	7.9			
	Delta-v Calc	13.1	7.1	13.1		
	KEES Target =		37.11			
Test Specific **CF** based on KEES			**16.7**			
					Compare to	
	CF = 21		**41.6**		**37.11**	**KEES mph**
	CF = 27		**47.2**		**57**	**Closing mph**

Vehicle Crush Stiffness Values

Speed - Δv_{test} - Additional "Fallout" - CF

- Examining the data for CT2, we can see that the CF value based on the various Δv's is lower to significantly lower than the CF based on the KEES. This makes sense given that the KEES speed is higher to significantly higher than the Δv speeds.
- The Δv which would normally be used based on crash testing would be the one in the third column which is calculated in the spreadsheet as Closing Speed - PIS (Post Impact Speed).
- It can be seen that in this test using the Δv instead of the KEES to calculate a Test Specific CF will underestimate the KEES speed by a large, potentially significant, amount.
- The default CF=21 only slightly overestimates the KEES speed in this test (~4.5 mph over). The CF=27 underestimates the closing speed of the bullet vehicle (~10 mph under).

Vehicle Crush Stiffness Values

Speed - Δv_{test} - Additional “Fallout” - CF

		PSP 2023 - CT3				
			2000 Cavalier	2004 ION	2004 ION	
		Max Crush				
		inches		33.7		
		feet		2.81		
					Closing - PIS	
		Delta-v Meas	33.80	31.30		
		Delta-v Calc	34.16	31.84	34.16	
Test Specific **CF** based on Delta-v					Closing - PIS	
		Delta-v Meas	13.6	11.6		
		Delta-v Calc	13.8	12.0	13.8	
		KEES Target =		45.84		
Test Specific **CF** based on KEES				**24.9**		
						Compare to
		CF = 21		**42.1**		**45.84**	**KEES mph**
		CF = 27		**47.7**		**66**	**Closing mph**

Vehicle Crush Stiffness Values

Speed - Δv_{test} - Additional “Fallout” - CF

- Examining the data for CT3, we can see that the CF value based on the various Δv’s is lower to significantly lower than the CF based on the KEES. This makes sense given that the KEES speed is higher to significantly higher than the Δv speeds.
- The Δv which would normally be used based on crash testing would be the one in the third column which is calculated in the spreadsheet as Closing Speed - PIS (Post Impact Speed).
- It can be seen that in this test using the Δv instead of the KEES to calculate a Test Specific CF will underestimate the KEES speed by a large, potentially significant, amount.
- The default CF=21 slightly underestimates the KEES speed in this test (~3.7 mph under). The CF=27 underestimates the closing speed of the bullet vehicle (~18 mph under).

Vehicle Crush Stiffness Values

Speed - Δv_{test} - Additional “Fallout” - CF

- The effect of using Δv instead of KEES for calculating the CF values will be seen in any other stiffness value calculation. The CF values were used for this illustration due to the ease of calculation.
- The “last” issue on this is that, as we have seen, crush calculations are not linear in nature. Therefore, basing stiffness values on Δv, a linear/scalar calculation, is erroneous, and will lead to erroneously underestimating speed based on crush sustained in a crash.
- Due to speed from crush being an energy calculation, which is not linear, to this author’s knowledge there is no way to DIRECTLY calculate a Δv from crush. Even the apparent linear “Rules of Thumb” (1 mph per 1 inch of crush) are referring to the KEES, not the Δv.

Vehicle Crush Stiffness Values

Crash Test Contractor “Issues”

Why do some of the Frontal tests have a PDOF of 180?

- When reviewing the NHTSA Crash Test database, one needs to remember that the contractors conducting the tests are not, for the most part, trained in accident investigation.
- For that reason, a frontal test, which should have a PDOF of 0, which is the direction of the Force Vector outwards from the vehicle, is assigned a PDOF of 180, since the force is acting to crush the parts of the vehicle towards the rear.
- For this reason, the author tends to rely on the VDI (Vehicle Damage Index) clock position more than the PDOF - i.e. - 12 = Front, 03 = Passenger side, 06 = Rear, and 09 = Driver Side.

Vehicle Crush Stiffness Values

Crash Test Contractor “Issues”

For Front and Rear tests, why would we want to use the vehicle width instead of the Indentation length for the crush length?

- First, you can identify what a vehicle width is, you cannot necessarily identify where the two ends of the Indentation length are positioned on the vehicle.
- Second, the NHTSA definition of “Indentation Length” is a measurement from the start of Induced damage on one side, through the contact damage, to end of Induced damage on the other side, as long as it does not exceed the overall width of the vehicle.

With that said/identified, there are a suspiciously large number of tests with a 60 inch indentation length, consistent with contact only damage.

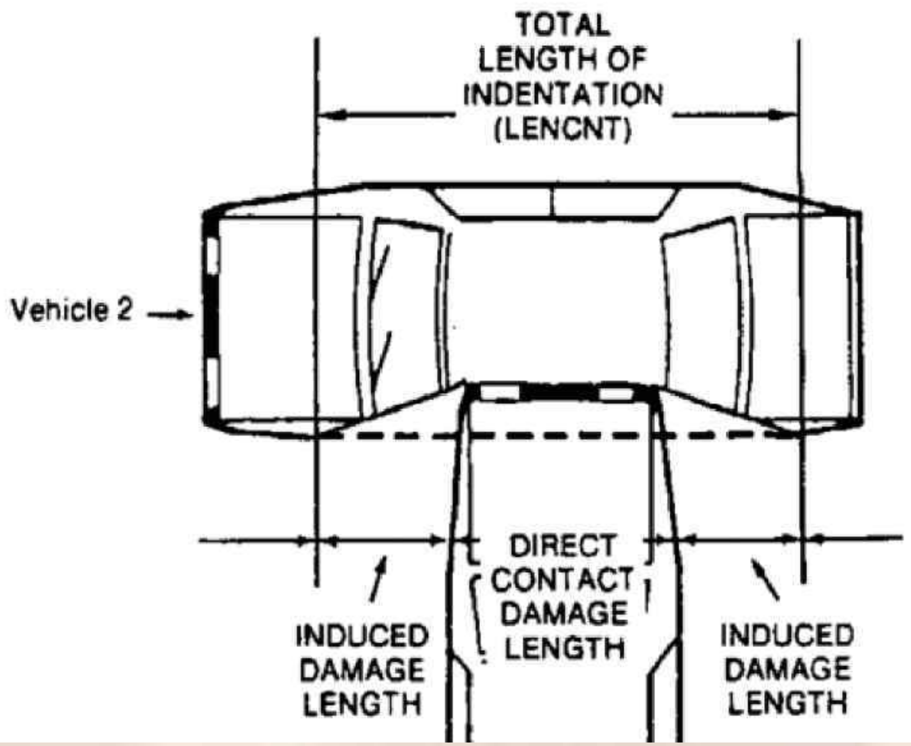
Vehicle Crush Stiffness Values

Crash Test Contractor "Issues"

55. LENCNT — Total Length of Indentation

Integer, millimeters, 0 or positive

LENCNT is the length of the total contact damage incurred by the vehicle. ***Figure 2-10***, on the next page, shows an example of how the total length of the indentation is the combination of direct and induced damage.



Vehicle Crush Stiffness Values

Crash Test Contractor "Issues"

- For these reasons the author prefers to use the vehicle width instead of the indentation length for the crush length when calculating stiffness values.
- An additional benefit of using the vehicle width over the indentation length is the greater length will result in slightly softer stiffness A-B values, resulting in slightly more conservative ultimate speeds but with a basis that the user can explain, and is not based upon an "error".

Vehicle Crush Stiffness Values

Crash Test Contractor "Issues"

Why doesn't the AVERAGE CRUSH stated by a contractor in a contractor report match the average calculated in the "normal" CRASH III formula?

- The average crush calculated in the CRASH III formula

$$Crush_{avg} = (c_1 + 2^*c_2 + 2^*c_3 + 2^*c_4 + 2^*c_5 + c_6) / (2^*5)$$

Provides what is known as a TRAPEZOIDAL average. The average calculated by the contracting agencies is most commonly a SIMPLE average.

$$Crush_{avg} = (c_1 + c_2 + c_3 + c_4 + c_5 + c_6) / 6$$

Again ... the Contractors are not Accident Reconstructionists and are, to a certain extent, working under different "rules".

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

This case came out of Australia, and is a collision initially between an Isuzu 2013 FRR600 Box Truck (front) and a 2015 Hyundai I30 (similar to Elantra) “Sedan” (Hatchback - rear). Subsequent to the rear impact, the Hyundai was struck on the left side by the front of a 2013 Volkswagen Amarook (similar to Ford Ranger/Chevrolet Colorado) “Utility” (pickup) travelling in the opposite direction.

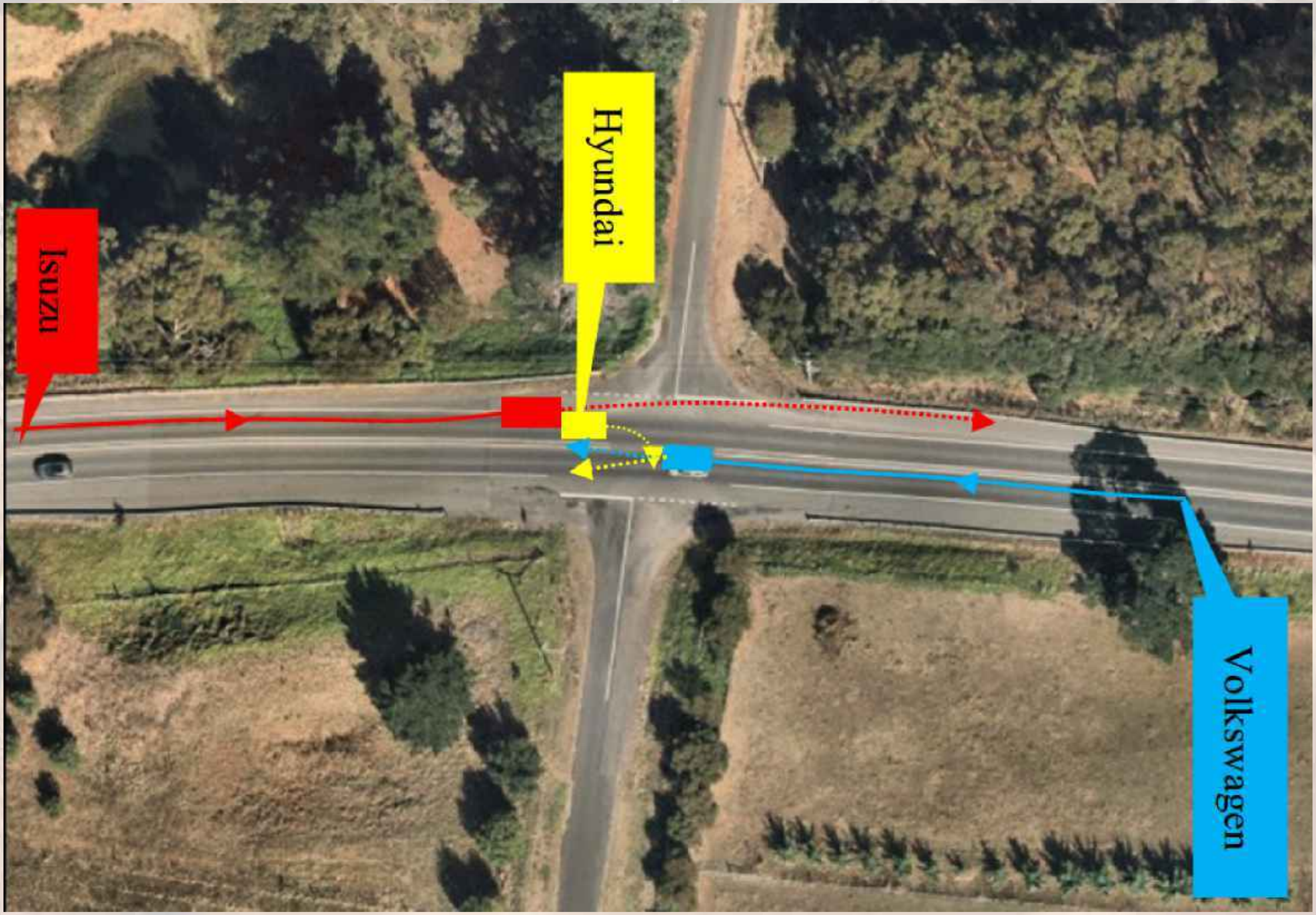
The Hyundai was slowing or stopped prior to making a right turn (similar to a left in the U.S.A.).

As a result of the initial collision, the Hyundai was rotated to the right (clockwise) and pushed into the oncoming traffic lane and thus the Volkswagen’s path.

Due to power loss or some other reason, there was no CDR/EDR data recorded by the Hyundai. The Volkswagen was not supported, and the Isuzu did not have an CDR/EDR.

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

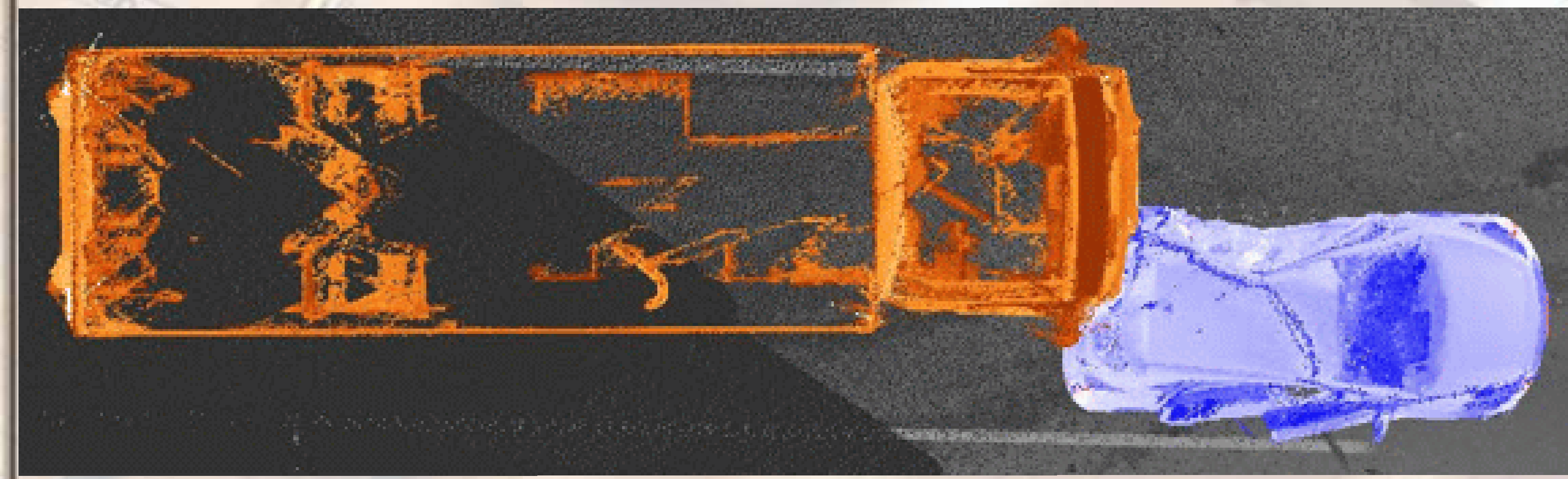


Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems



Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

The speed limit for the Isuzu is posted as 80 kph (~ 50 mph).

It was deemed necessary to try and determine a speed for the Isuzu, however,

- Speed determination via CDR/EDR was unavailable.

- Speed calculations through the use of momentum were complicated due to the multiple impacts in opposite directions.

Therefore, speed calculations using crush were deemed to be the most appropriate.

- Due to the large number of vehicles that are unable to have good A-B-G values calculated due to the lack of crash tests, the CF is reportedly used extensively.

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

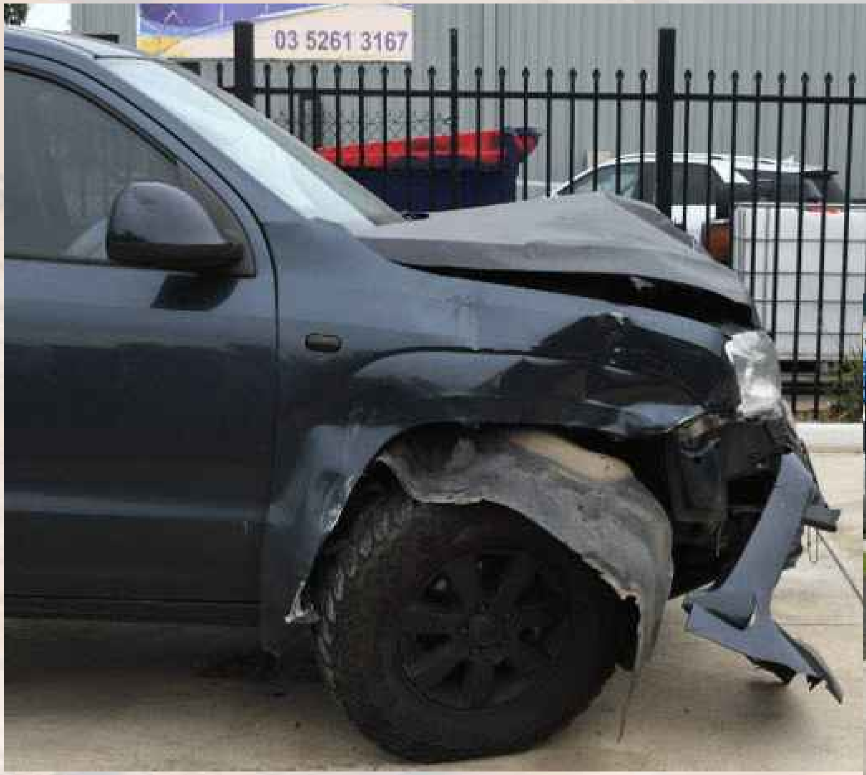
Maximum Crush to the rear of the Hyundai was reported at ~0.58 meters (~1.9 feet).

No crush depth for the Isuzu was reported.

No crush depth for the Volkswagen was reported.

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems



Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

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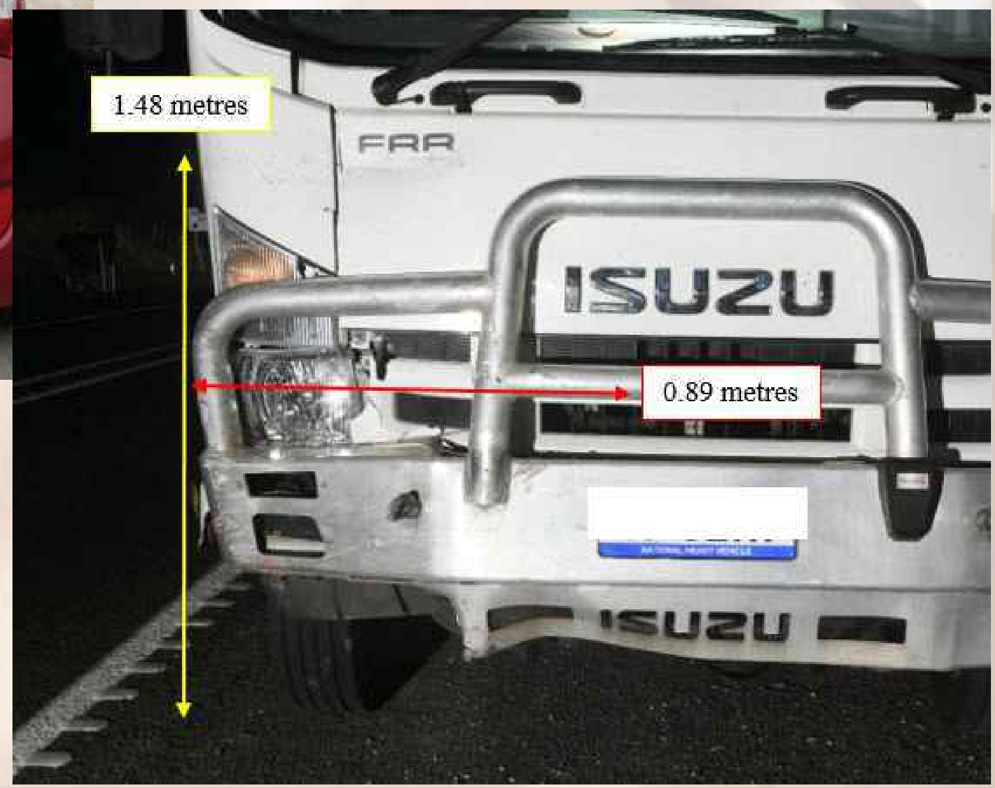
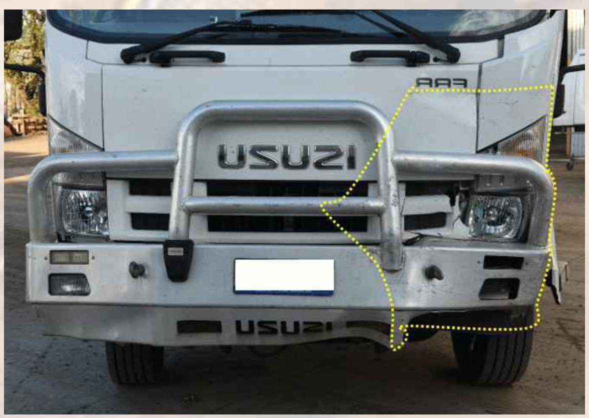
Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems



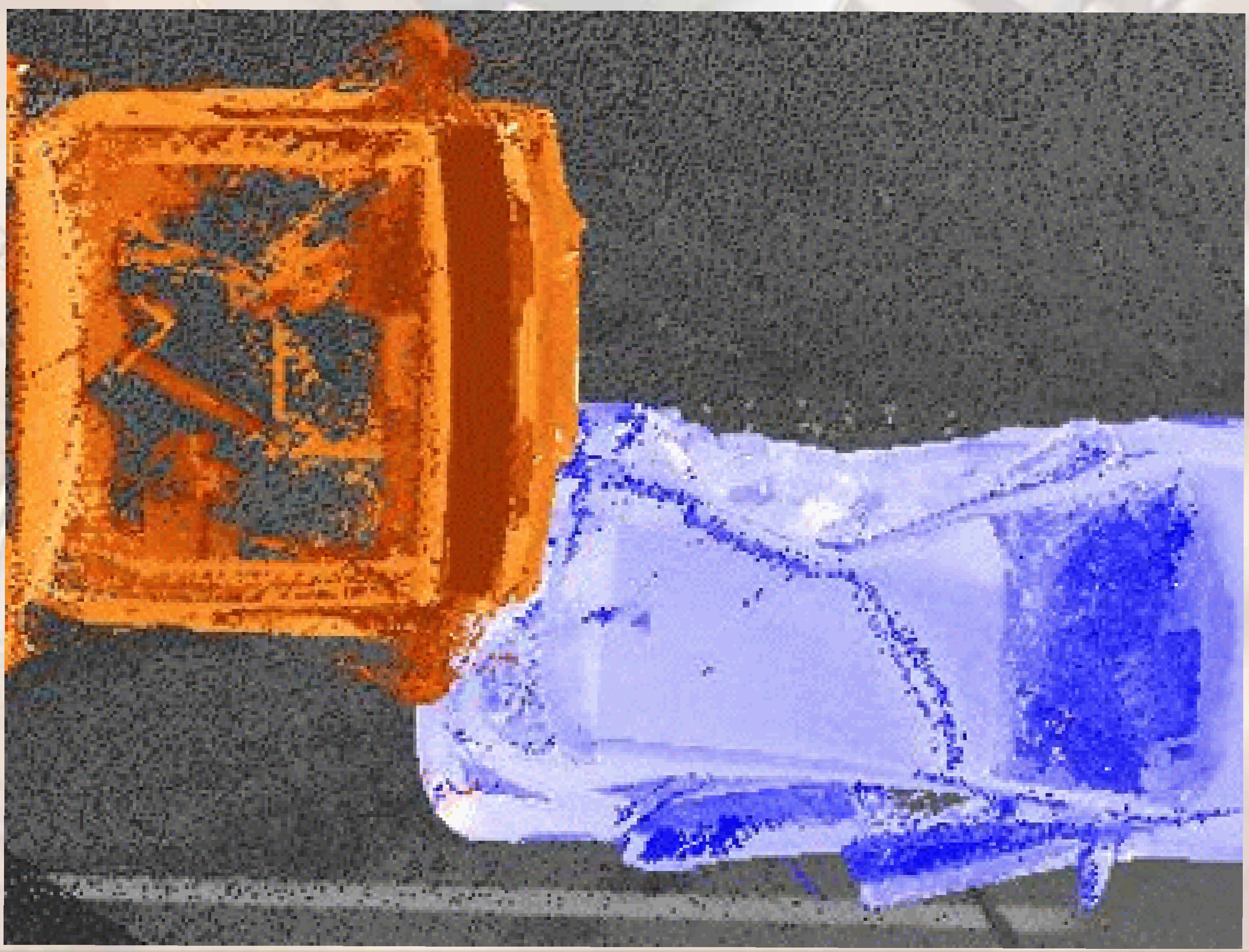
Vehicle Crush Stiffness Values
Case Example 1 - Illustration of Problems



<- Isuzu mirrored to correlate damage outline

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems



Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

From the scans of the Isuzu and Hyundai which were put together to show alignment, I was able to scale off some additional crush measurements for both vehicles.

2015 HYUNDAI ELANTRA GT

Curb Weight (pounds): 2954
Occupant + Cargo Weight (pounds): 306
Total Weight (pounds): 3260
Angle Coll Force to Normal (degrees): 0
No Damage Speed (mph): 2
Energy Crush Depth (inches): 14.45
Auto-Calculate Energy Crush Depth ☑
Damage Length (inches): 39.8
Crush Profile Measurements: 5
Crush Spacing: ○ Equal ◉ Non-Equal

PDOF
Lever Arm Distance (inches): 0
Yaw Moment of Inertia (lb-ft-sec²): 2151.80
Auto-Calculate Yaw Moment ☑

Impact Location: ○ Front ○ Side ◉ Rear ○ Other

Vehicle 1 Crush Measurements

	A (lb/in.)	B (lb/in.²)
Average	263.6	85.4
Minimum	155.7	31.0
Maximum	440.3	191.5
Std. Devation	73.1	42.3

C1 (in.)	0.00
C2 (in.)	14.9
C3 (in.)	14.9
C4 (in.)	15.4
C5 (in.)	15.4
C6 (in.)	
C7 (in.)	
C8 (in.)	
C9 (in.)	
C10 (in.)	

Spacing	Zone Area	Zone Depth(x) (inches)	Area Depth(x) (inches³)	Zone Depth(y) (inches)	Area Depth(y) (inches³)
4.00	29.80	4.97	148.01	2.67	79.47
3.50	52.15	7.45	388.52	5.25	273.79
17.40	263.61	7.58	1997.03	43.55	11479.65
14.90	229.46	7.70	1766.84	52.15	11966.34

Average Crush (inches): 14.45

2013 ISUZU FRR600

Curb Weight (pounds): 23259
Occupant + Cargo Weight (pounds): 190
Total Weight (pounds): 23449
Angle Coll Force to Normal (degrees): 0
No Damage Speed (mph): 10
Energy Crush Depth (inches): 6.87
Auto-Calculate Energy Crush Depth ☑
Damage Length (inches): 29.8
Crush Profile Measurements: 3
Crush Spacing: ○ Equal ◉ Non-Equal

PDOF
Lever Arm Distance (inches): 0
Yaw Moment of Inertia (lb-ft-sec²): 22809.47
Auto-Calculate Yaw Moment ☑

Impact Location: ◉ Front ○ Side ○ Rear ○ Other

C1 (in.)	0.00
C2 (in.)	7.5
C3 (in.)	7.5
C4 (in.)	
C5 (in.)	
C6 (in.)	
C7 (in.)	
C8 (in.)	
C9 (in.)	
C10 (in.)	

Spacing	Zone Area	Zone Depth(x) (inches)	Area Depth(x) (inches³)	Zone Depth(y) (inches)	Area Depth(y) (inches³)
5.00	18.75	2.50	46.88	3.33	62.50
24.80	186.00	3.75	697.50	37.20	6919.20

Average Crush (inches): 6.87

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

2015 HYUNDAI ELANTRA GT

Curb Weight (pounds):	2954
Occupant + Cargo Weight (pounds):	306
Total Weight (pounds):	3260
Angle Coll Force to Normal (degrees):	0
No Damage Speed (mph):	2
Energy Crush Depth (inches):	14.45

Damage Length (inches):	39.8
Crush Profile Measurements:	5

		Spacing	Zone Area	Depth(x) (inches)
C1 (in.)	0.00	4.00	29.80	4.97
C2 (in.)	14.9	3.50	52.15	7.45
C3 (in.)	14.9	17.40	263.61	7.58
C4 (in.)	15.4	14.90	229.46	7.70
C5 (in.)	15.4			
C6 (in.)				

2013 ISUZU FRR600

Curb Weight (pounds):	23259
Occupant + Cargo Weight (pounds):	190
Total Weight (pounds):	23449
Angle Coll Force to Normal (degrees):	0
No Damage Speed (mph):	10
Energy Crush Depth (inches):	6.87

Damage Length (inches):	29.8
Crush Profile Measurements:	3

		Spacing	Zone Area	Depth(x) (inches)
C1 (in.)	0.00	5.00	18.75	2.50
C2 (in.)	7.5	24.80	186.00	3.75
C3 (in.)	7.5			
C4 (in.)				
C5 (in.)				
C6 (in.)				

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

In the initial work up, the Reporting Officer used the CF=27 value and the 0.58 m of max crush to calculate the delta-v for the Hyundai. Armed with that delta-v, the Closing speed was then calculated using standard formula.

PROBLEMS -

- As we have already discussed, crush cannot calculate the delta-v directly.
- Using CF=21, or a test specific CF value based on the Damage Energy, a Damage Energy Speed can be calculated. From there, using additional calculations, a Closing Speed and delta-v could be calculated.
- The CF=27 is used to estimate the Bullet Vehicle Closing Speed based on Target Vehicle damage only. Using CF=27 in this instance and way is the wrong CF value to use.

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

When using CF=21 and -

- the reported Max Crush of ~0.58 m (~1.9 ft), a KEES of ~55.5 kph (~34.5 mph) is calculated
- when using the ~0.6 feet of max crush to the Isuzu scaled (conservatively) from the vehicle scan provided in combination with the ~1.9 feet of crush to the Hyundai, a KEES of ~ 38.8 mph (62.4 kph) is calculated
- when using only the ~1.3 feet of max crush for the Hyundai scaled (conservatively) from the vehicle scan provided, a KEES of ~ 28.6 mph (46.0 kph) is calculated

Remember that KEES can be calculated/estimated from Closing speed in a "vehicle" vs "vehicle" impact as follows:

$$KEES = SQR[(Wt_{Bullet} * Speed_{Bullet}\hat{}2) / (Wt_{Bullet} + Wt_{Target})]$$

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

By rearranging this formula, one can calculate/estimate a Closing Speed from the KEES:

$$KEES = SQR[(Wt_{Bullet} * Speed_{Bullet}\hat{}2) / (Wt_{Bullet} + Wt_{Target})]$$

Rearranged gives

$$Speed_{Bullet} = SQR[(KEES\hat{}2 * (Wt_{Bullet} + Wt_{Target}) / Wt_{Bullet})]$$

From this a closing speed for the Isuzu can be calculated of -

Crush = 1.9 ft then Closing Speed = 36.9 mph (59.3 kph)

Crush = 2.4 ft then Closing Speed = 41.5 mph (66.8 kph)

Crush = 1.3 ft then Closing Speed = 30.5 mph (49.1 kph)

All of these speeds are below the posted limit of 80 kph (50 mph). Thus, based on this information, overly excessive speed (at impact) on the part of the Isuzu was not an issue.

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

However .....

From the Defense Expert (DE)-

- The DE attempted to find test data for the I30, but was unable to do so.
- The DE was able to find Youtube videos of a number of different rear end tests. Of the available rear impact tests, two tests were used by the DE for his analysis. One of these was for a standard Jetta sedan (totally dissimilar to the subject vehicle body type), the other was for a Hyundai Accent sedan (again, dissimilar vehicle body type). The Contractor Reports for these two tests are attached to this presentation.

Reviewing these two reports, one finds -

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

For the Jetta -

- NO vehicle crush depths or Indentation Length
- NO barrier crush depths or Indentation Length
- NO post impact (departure) speed

For the Accent -

- NO barrier crush depths or Indentation Length
- A reported "average" crush depth of 666 mm (pg 2-1) which is in fact the maximum centerline crush depth (pg 3-8)
- NO post impact (departure) speed

In both cases the DE made (reasonable) estimates of the missing data to fill in the gaps. This author has no argument with that, you have to work with what you are given.

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

However, DE then went on to critique the CF value based upon its failure to correctly estimate the CHANGE IN VELOCITY, which is not what the CF value calculates. The DE also was critical that the CF value, which is an average of a large number of tests, did not "correctly" calculate the speed in two selected tests. Again, a failure to understand how the value was obtained and what it was calculating.

These problems were then further compounded by calculating a "proper" CF using the calculated delta-v from these two tests.

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

Jetta -

Closing Speed = 79 kph, Departure Speed = 36 kph, crush depth = 0.98 m, Δv_{Jetta} = 36 kph

Then using the metric form:

CF = (Δv_{Jetta}) ^2 / (254*0.98) = 36^2/ 248.92 = **5.2**

Accent -

Closing Speed = 79 kph, Departure Speed = 39 kph, crush depth = 0.666 m, Δv_{Accent} = 39 kph

Then using the metric form:

CF = (Δv_{Accent}) ^2 / (254*0.666) = 39^2 / 169.2 = **9.0**

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

The math is performed correctly for the numbers that are input into the formula, HOWEVER, when one uses the improper variables, the values obtained as answers are meaningless.

The difference in calculation, and values obtained, go as follows:

First realize that for the same vehicle (i.e. moving barrier) KEES = SQR (CS^2 - PIS^2)

Where CS = Closing Speed and PIS = Post Impact Speed

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

So -

Jetta -

Impact ~79 kph (49.1 mph), PIS ~ 36 kph (22.4 mph)

Crush depth 0.98 m (3.2 ft)

KEES = SQR (79^2 - 36^2) = 70.3 kph (not 36 kph)

This is the Kinetic Energy Equivalent Speed from the barrier that went into creating the damage to the Jetta (and the barrier).

CF = KEES ^2 / (254 * $\text{Crush}_{\text{(in meters)}}$)

CF = 70.3^2 / (254*0.98) = 4945 / 248.92 = **19.8** (not 5.2)

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

In the same way -

Accent -

Impact ~79 kph (49.1 mph), PIS ~ 39 kph (24.2 mph)

Crush depth 0.666 m (2.2 ft)

KEES = SQR (79^2 - 39^2) = 68.7 kph (not 39 kph)

This is the Kinetic Energy Equivalent Speed from the barrier that went into creating the damage to the Accent (and the barrier).

CF = KEES ^2 / (254 * Crush$_{\text{(in meters)}}$)

CF = 68.7^2 / (254*0.666) = 4719.69 / 169.16 = **27.9** (not 9.0)

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

As this presentation was being prepared, in the back of the author's mind the crowd could be heard muttering "Boy, this guy is REALLY defensive!"

However, it was not the author's intent to be defensive, rather the intent was to clearly show that if one starts with the wrong assumptions, the wrong answers are derived.

To carry this example through to the end of the matter, and to illustrate the problem further, lets look at our 5 CF values ....

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

DE obtained values -

$CF_{\Delta vJetta} = 5.2$

$CF_{\Delta vAccent} = 9.0$

And Energy obtained values-

$CF_{KEESJetta} = 19.8$

$CF_{KEESAutoStatsdefault} = 21$

$CF_{KEESAccent} = 27.9$

Lets now use the reported Hyundai maximum crush depth of 0.58 m (1.9 feet) to get the KEES speed for the Hyundai damage

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

The resulting calculated KEES speeds (keeping in mind that the first two are not really KEES speeds) after changing just one "leetle" variable (the CF value) are -

$CF_{\Delta vJetta} = 5.2$ - KEES = 27.7 kph - CS_{Isuzu}= 29.6 kph

$CF_{\Delta vAccent} = 9.0$ - KEES = 36.5 kph - CS_{Isuzu}= 38.9 kph

$CF_{KEESJetta} = 19.8$ - KEES = 54.1 kph - CS_{Isuzu}= 57.7 kph

$CF_{KEESAutoStatsdefault} = 21$ - KEES = 55.7 kph - CS_{Isuzu}= 59.4 kph

$CF_{KEESAccent} = 27.9$ - KEES = 64.2 kph - CS_{Isuzu}= 68.5 kph

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

The standard or typical +/- speed range to be expected when using the CF=21 value, as stated in Expert AutoStats is +/- 5 mph (8 kph).

- It can be seen that when the calculations are made with the proper data, the Jetta's test specific CF when applied to the subject collision is well within this range.
- While the Accent's test specific CF is ~1 kph outside of the standard +/- 8 kph range, it is still within acceptable (to this author) tolerances, especially when one considers that one is applying a "Sedan" body type to a flat "Hatchback" vehicle.

Also keep in mind that the CF = 21 is a "average" of the NHTSA Crash Test tests, and is applicable to finding the KEES speed for Front, Side, and Rear impacts when nothing else is "known" about the impacted vehicle.

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

For further in depth analysis work on the CF values as applied to Frontal tests as contained in the NHTSA database, please refer to "**CRUSH FACTOR: A VALIDITY ANALYSIS - PART 1 (FRONTAL)**" on the 4N6XPRT Systems web site -

https://www.4n6xprt.com/papers/

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

As a check on the Crush Factor analysis, a Force Balance analysis using traditional A-B-G values was also conducted within the 4N6XPRT StifCalcs program.

A “CLASS” vehicle was first created by looking for REAR tests on FLAT Rear Cars (i.e. - Hatchback & Station Wagon).

Although not included in this CLASS vehicle preparation, depending upon the crash to be evaluated, Van and Utility body styles might also be included as they also have relatively “flat” rear ends.

Tests where the “A” value exceeded a value of 500, or had a value of 0 or less were excluded. The Statistical Summary for the 47 tests found in the search is shown on the next slide.

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

4N6XPRT StifCalcs® Available Test Results Rear Impact Test Summary		|-----------Vehicle Width-----------| |-------Stiffness Values--------| A	B	G	Kv	Crush Factor
Average (AVG)		263.6	85.4	428.4	137.0	19.5
Minimum (MIN)		155.7	31.0	339.5	45.9	9.7
Maximum (MAX)		440.3	191.5	644.9	313.1	48.5
Standard Deviation (STDev-sample)		73.1	42.3	65.4	70.0	7.1
Number of Tests (n)	47					

Note the average CF value is 19.5. Not far from the 19.8 calculated for the Jetta Sedan, and as we have seen, the difference between CF~19 and CF 21 is minimal.

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

The Statistical Summary A-B values were imported to the Force Balance module, and the crush profiles for both the I30 and FRR were input based upon scaling off of the alignment scan.

Due to the damage to the I30 reportedly going over the bumper, a NO DAMAGE value of 2 mph was used for the I30. Per Wikipedia, the Elantra is a similar vehicle to the I30.

Due to the bumper affixed to the FRR appearing to be more substantial than a “normal” bumper, a NO DAMAGE value of 10 mph was used for the FRR

The data inputs can be seen on the next slide.

Vehicle Crush Stiffness Values

2015 HYUNDAI ELANTRA GT

Curb Weight (pounds): 2954
Occupant + Cargo Weight (pounds): 306
Total Weight (pounds): 3260
Angle Coll Force to Normal (degrees): 0
No Damage Speed (mph): 2
Energy Crush Depth (inches): 14.45
Auto-Calculate Energy Crush Depth ☑

PDOF
Lever Arm Distance (inches): 0
Yaw Moment of Inertia (lb-ft-sec^2): 2151.80
Auto-Calculate Yaw Moment ☑

Impact Location
○ Front ○ Side ◉ Rear ○ Other

Vehicle 1 Crush Measurements

	A (lb/in.)	B (lb/in.^{2})
Average	263.6	85.4
Minimum	155.7	31.0
Maximum	440.3	191.5
Std. Devation	73.1	42.3

Damage Length (inches): 39.8
Crush Profile Measurements: 5

Crush Spacing
○ Equal ◉ Non-Equal

		Spacing	Zone Area	Zone Depth(x) (inches)	Area Depth(x) (inches^2)	Zone Depth(y) (inches)	Area Depth(y) (inches^2)
C1 (in.)	0.00	4.00	29.80	4.97	148.01	2.67	79.47
C2 (in.)	14.9	3.50	52.15	7.45	388.52	5.25	273.79
C3 (in.)	14.9	17.40	263.61	7.58	1997.03	43.55	11479.65
C4 (in.)	15.4	14.90	229.46	7.70	1766.84	52.15	11966.34
C5 (in.)	15.4						
C6 (in.)							
C7 (in.)							
C8 (in.)							
C9 (in.)							
C10 (in.)							

Average Crush (inches): 14.45

2013 ISUZU FRR600

Curb Weight (pounds): 23259
Occupant + Cargo Weight (pounds): 190
Total Weight (pounds): 23449
Angle Coll Force to Normal (degrees): 0
No Damage Speed (mph): 10
Energy Crush Depth (inches): 6.87
Auto-Calculate Energy Crush Depth ☑

PDOF
Lever Arm Distance (inches): 0
Yaw Moment of Inertia (lb-ft-sec^2): 22809.47
Auto-Calculate Yaw Moment ☑

Impact Location
◉ Front ○ Side ○ Rear ○ Other

Damage Length (inches): 29.8
Crush Profile Measurements: 3

Crush Spacing
○ Equal ◉ Non-Equal

		Spacing	Zone Area	Zone Depth(x) (inches)	Area Depth(x) (inches^2)	Zone Depth(y) (inches)	Area Depth(y) (inches^2)
C1 (in.)	0.00	5.00	18.75	2.50	46.88	3.33	62.50
C2 (in.)	7.5	24.80	186.00	3.75	697.50	37.20	6919.20
C3 (in.)	7.5						
C4 (in.)							
C5 (in.)							
C6 (in.)							
C7 (in.)							
C8 (in.)							
C9 (in.)							
C10 (in.)							

Average Crush (inches): 6.87

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

The resulting speeds for this Force Balance analysis can be seen below and in the next slide. The calculated Closing Speed based on the CLASS average A-B values was 40.2 mph (64.7 kph), slightly higher than the Closing Speed calculated using the CF=21 value, but well within the +/- 8 kph target range.

2015 HYUNDAI ELANTRA GT

Curb Weight (pounds):	2954
Occupant + Cargo Weight (pounds):	306
Total Weight (pounds):	3260
Angle Coll Force to Normal (degrees):	0
No Damage Speed (mph):	2
Energy Crush Depth (inches):	14.45

PDOF

Lever Arm Distance (inches):	0
Yaw Moment of Inertia (lb-ft-sec^2):	2151.80
Auto-Calculate Yaw Moment	☑

Impact Location: ○ Front ○ Side ● Rear ○ Other

Results

	A (lb/in.)	B (lb/in.^{2})	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	Closing Speed (mph)
Minimum	155.7	31.0	12012.64	19869.98	13.5	30.0	34.2
Avg - 2 Std. Deviations	117.4	0.8	2566.30	34483.74	17.8	30.6	34.8
Avg - 1 Std. Deviations	190.5	43.1	16184.57	25974.19	15.5	31.4	35.7
Average	263.6	85.4	29802.84	44591.79	20.3	35.3	40.2
Avg + 1 Std. Deviatio...	336.7	127.7	43421.10	63379.34	24.2	38.8	44.2
Avg + 2 Std. Deviatio...	409.8	170.0	57039.37	82209.98	27.5	42.0	47.8
Maximum	440.3	191.5	63828.75	91418.40	29.0	43.4	49.5

Damage Centroid Depth (x) (inches):	7.48
Damage Centroid Depth (y) (inches):	41.39
Area of Damage (inches^2):	575.11
k^2	3060.57
Eff. Mass Ratio (gamma)	1.00

2013 ISUZU FRR600

Curb Weight (pounds):	23259
Occupant + Cargo Weight (pounds):	190
Total Weight (pounds):	23449
Angle Coll Force to Normal (degrees):	0
No Damage Speed (mph):	10
Energy Crush Depth (inches):	6.87

PDOF

Lever Arm Distance (inches):	0
Yaw Moment of Inertia (lb-ft-sec^2):	22809.47
Auto-Calculate Yaw Moment	☑

Impact Location: ● Front ○ Side ○ Rear ○ Other

Results

	A (lb/in.)	B (lb/in.^{2})	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	bSub1
Minimum	745.7	8.8	12012.64	91674.84	10.8	4.2	2.1
Avg - 2 Std. Deviations	169.1	0.5	2566.30	81319.75	10.2	4.2	0.5
Avg - 1 Std. Deviations	981.4	15.3	16184.57	96095.96	11.1	4.4	2.7
Average	1689.6	45.2	29802.84	110035.87	11.9	4.9	4.7
Avg + 1 Std. Deviatio...	2325.7	85.7	43421.10	123396.80	12.6	5.4	6.5
Avg + 2 Std. Deviatio...	2908.1	133.9	57039.37	136326.15	13.2	5.8	8.1
Maximum	3182.1	160.4	63828.75	142641.38	13.5	6.0	8.9

Damage Centroid Depth (x) (inches):	3.64
Damage Centroid Depth (y) (inches):	34.10
Area of Damage (inches^2):	204.73
k^2	4510.34
Eff. Mass Ratio (gamma)	1.00

Vehicle Crush Stiffness Values

Case Example 1 - Illustration of Problems

2015 HYUNDAI ELANTRA GT

Curb Weight (pounds): 2954
Occupant + Cargo Weight (pounds): 306
Total Weight (pounds): 3260
Angle Coll Force to Normal (degrees): 0
No Damage Speed (mph): 2
Energy Crush Depth (inches): 14.45

PDOF
Lever Arm Distance (inches): 0
Yaw Moment of Inertia (lb-ft-sec²): 2151.80
Auto-Calculate Yaw Moment ☑

Impact Location
○ Front ○ Side ● Rear ○ Other

Results

	A (lb/in.)	B (lb/in.²)	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	Closing Speed (mph)
Minimum	155.7	31.0	12012.64	19869.98	13.5	30.0	34.2
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Maximum	440.3	191.5	63828.75	91418.40	29.0	43.4	49.5

Damage Centroid Depth (x) (inches): 7.48
Damage Centroid Depth (y) (inches): 41.39
Area of Damage (inches²): 575.11
k²: 3060.57
Eff. Mass Ratio (gamma): 1.00

2013 ISUZU FRR600

Curb Weight (pounds): 23259
Occupant + Cargo Weight (pounds): 190
Total Weight (pounds): 23449
Angle Coll Force to Normal (degrees): 0
No Damage Speed (mph): 10
Energy Crush Depth (inches): 6.87

PDOF
Lever Arm Distance (inches): 0
Yaw Moment of Inertia (lb-ft-sec²): 22809.47
Auto-Calculate Yaw Moment ☑

Impact Location
● Front ○ Side ○ Rear ○ Other

Results

	A (lb/in.)	B (lb/in.²)	Average Force (poundsf)	Damage Energy (ft*lbs)	KE Speed (mph)	Delta V (mph)	bSub1
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Damage Centroid Depth (x) (inches): 3.64
Damage Centroid Depth (y) (inches): 34.10
Area of Damage (inches²): 204.73
k²: 4510.34
Eff. Mass Ratio (gamma): 1.00

Vehicle Crush Stiffness Values

We have CDR/EDR - Case Example 2

So Why ???

Do We Need Crush?

So Why ???

Do We Need "Old Fashioned" Techniques?

Vehicle Crush Stiffness Values

Case Example 2 - Why Do We Need Crush?

A comment I have heard somewhat frequently lately is "Why do I need crush? I get my data from the CDR download."

As we have seen in the previous example, for a variety of reasons, a download is not always available.

Worse yet, at least in my mind, even when available a download is not done, even in criminal cases where a search warrant should be able to be easily obtained, and even when no warrant is needed because the vehicle is owned by the government entity.

This first example is from Florida.

Vehicle Crush Stiffness Values

Case Example 2 - Why Do We Need Crush?

Collision is between a 2016 GMC C1500 Pickup driven by a Florida DLE officer on a throughway, and a 2004 Ford F150 Pickup towing a trailer coming off of an offramp.

Issues/Questions are -

- Was the FDLE officer exceeding the posted speed limit of 45 mph such that the driver on the exit ramp thought they had sufficient time to clear the "intersection"?
- Did the driver on the exit ramp come to a stop prior to entering the "intersection"?

Vehicle Crush Stiffness Values

Case Example 2 - Why Do We Need Crush?

Driver of the Ford was cited for failure to stop and failure to yield. To the authors thinking, a search warrant for a download to support the charge should be easily obtainable.

Since FDLE owns the GMC, no search warrant should be necessary. Additionally, FDLE should be doing the download as a preventative matter just to be able to show excessive speed was not an issue in the case.

More than a year after the incident, during mediation, FDLE's defense for not doing the download was "We don't think they can be."

Guess what .... they can be ... both of them.

Both vehicles are supported.

Vehicle Crush Stiffness Values

Case Example 2 - Why Do We Need Crush?

Bosch Support

CDR® Vehicle List

CDR Software 23.2

Module Abbreviations: ACM: Airbag Control Module, ADS: Advanced Driver System ASCM: Active Safety Control Module, FCM: Forward Camera Module, PCM: Powertrain Control Module, PPM: Pedestrian Protection Module, ROS: Rollover Sensor,

Year	Make	Model	Module Supported	Important Coverage Notes	Market
2016	GMC	Canyon	ACM		NAFTA
2016	GMC	Savana	ACM		NAFTA
2016	GMC	Sierra	ACM		NAFTA
2016	GMC	Terrain	ACM		NAFTA
2016	GMC	Yukon	ACM		NAFTA
2004	Ford	Explorer	PCM		US, Canada
2004	Ford	F-150 (except Heritage)	PCM		US, Canada
2004	Ford	F-150 (Heritage)	ACM		US, Canada
2004	Ford	F-250, F-350, F-450, F-550 Super Duty	ACM		US, Canada

Vehicle Crush Stiffness Values

Case Example 2 - Why Do We Need Crush?

In addition to no downloads ....

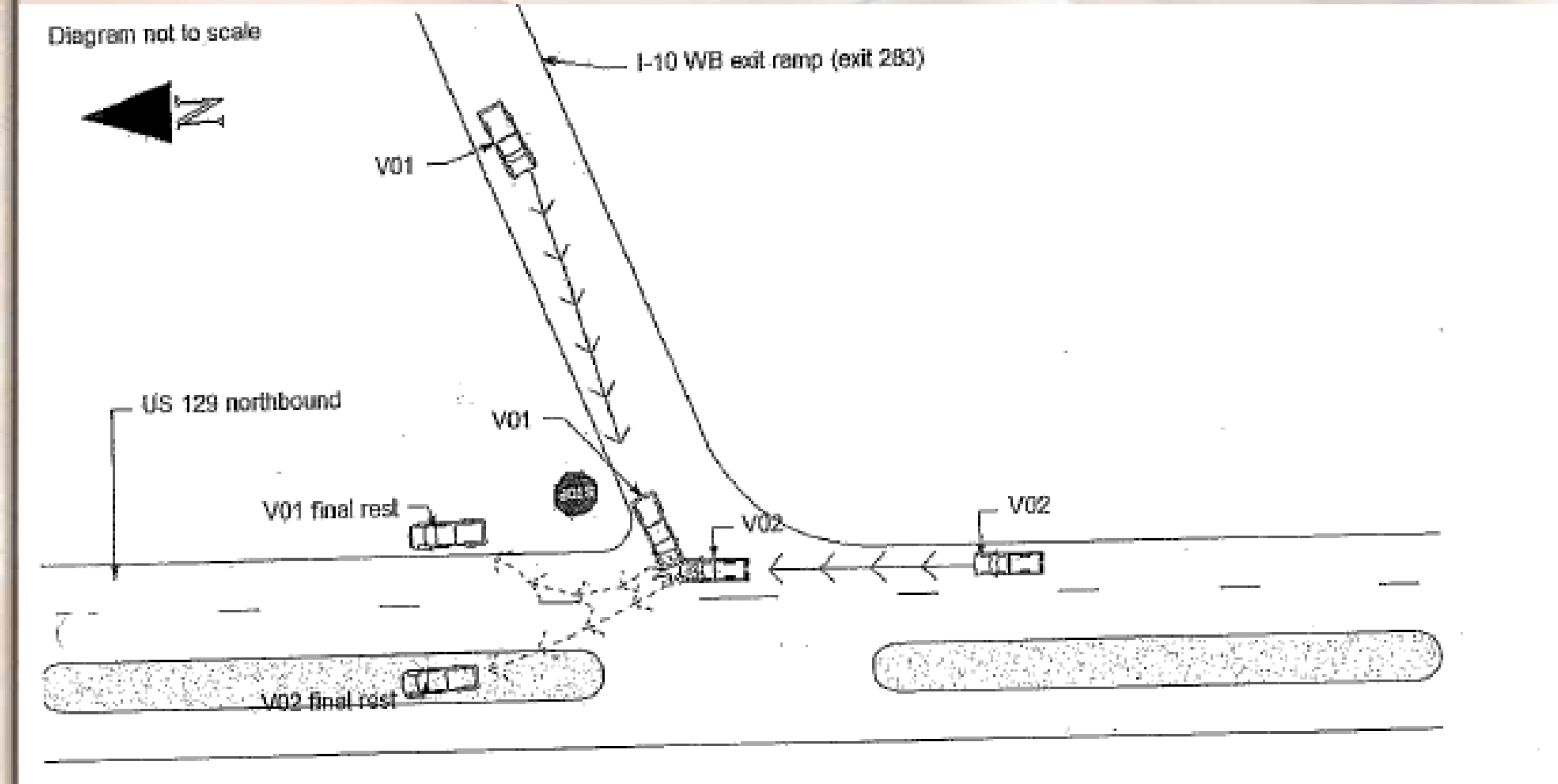
- No scene measurements
- VERY few scene photographs
- No Post collision documentation of damage to either vehicle other than the photographs at the scene
- Only a few additional photographs of the Ford taken by the owners in a storage yard - No additional measurements - No download - No scans

Both occupants of the Ford were "Life Flighted" to the hospital - thus, serious, possible life threatening injuries.

Vehicle Crush Stiffness Values

Case Example 2 - Why Do We Need Crush?

Scene Diagram - Note POR positions



Vehicle Crush Stiffness Values

Case Example 2 - Why Do We Need Crush?

Scene overhead view

Vehicle Crush Stiffness Values

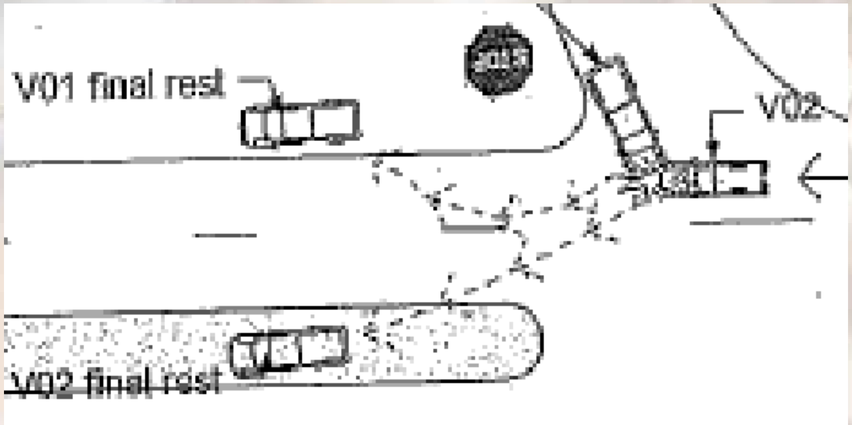
Case Example 2 - Why Do We Need Crush?

Scene overhead view

Vehicle Crush Stiffness Values

Case Example 2 - Why Do We Need Crush?

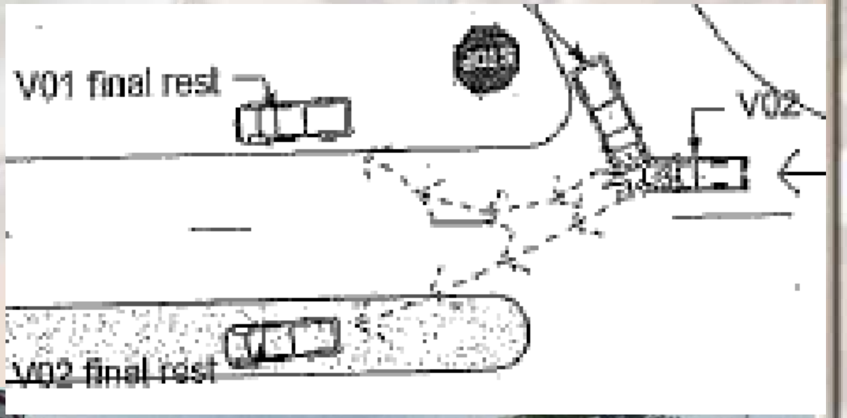
Scene street view - Does this match diagram?



Vehicle Crush Stiffness Values

Case Example 2 - Why Do We Need Crush?

Scene street view - Does this match diagram?



Vehicle Crush Stiffness Values

Case Example 2 - Why Do We Need Crush?

Crush - F150 - ~19 inches

Vehicle Crush Stiffness Values

Case Example 2 - Why Do We Need Crush?

Crush - GMC 1500 - RF Tire displacement ~10 inches

Vehicle Crush Stiffness Values

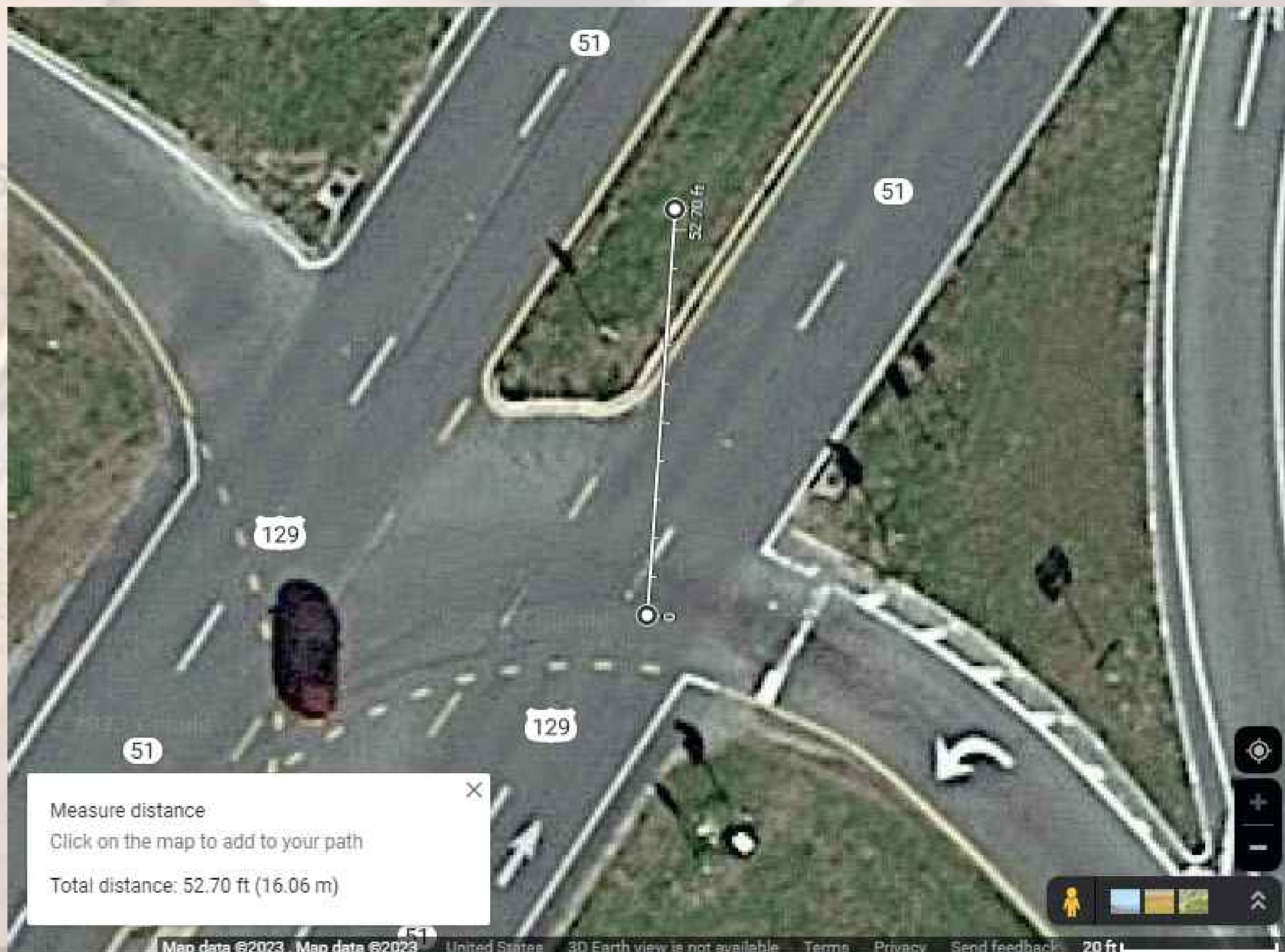
Case Example 2 - Why Do We Need Crush?

Ford AOI-POR Travel Distance

Vehicle Crush Stiffness Values

Case Example 2 - Why Do We Need Crush?

GMC AOI-POR Travel Distance



Vehicle Crush Stiffness Values

Case Example 2 - Why Do We Need Crush?

Calculations

Based on the scene photographs and the aerial photos from Google

- Preliminary Post Impact travel distance for the FDLE GMC was determined to be ~53 feet.
- Preliminary Post Impact travel distance for the F150 was determined to be ~52 feet.

Post Impact Travel Speed (pits) = SQR(30 * distance in feet * friction)

- FDLE GMC = SQR (30 * 53 * 0.7) = SQR (1113) = 33.4 mph
- F150 = SQR (30 * 52 * 0.7) = SQR (1092) = 33.0 mph

Vehicle Crush Stiffness Values

Case Example 2 - Why Do We Need Crush?

Calculations

Based upon the photographs of the F150 and the FDLE GMC vehicles

- Preliminary maximum crush measurements for the F150 of 19 inches was determined.

- Preliminary maximum crush measurement for the GMC FDLE vehicle of 10 inches was determined.

Speed from Crush (sfc) = SQR (30 * max crush distance in feet * Crush Factor)

- FDLE GMC = SQR (30 * 10/12 * 21) = SQR (525) = 22.9 mph

- F150 = SQR (20 * 19/12 * 21) = SQR(997.5) = 31.6 mph

Vehicle Crush Stiffness Values

Case Example 2 - Why Do We Need Crush?

Calculations

Since all of the energy losses expressed as speed in the northeastward direction came from the FDLE vehicle, and all of the crush energy losses expressed as a speed came from the FDLE vehicle, an impact speed for the FDLE vehicle can be calculated by combining the above 4 speeds.

Vehicle Crush Stiffness Values

Case Example 2 - Why Do We Need Crush?

Calculations

FDLE Impact speed = SQR ($FDLE_{pits}$^2 + $F150_{pits}$^2 + $FDLE_{sfc}$^2 + $F150_{sfc}$^2)

FDLE Impact speed = SQR (33.4^2 + 33.0^2 +22.9^2 + 31.6^2)

FDLE Impact speed = SQR (1113 + 1092 + 525 + 997.5)

FDLE Impact speed = SQR (3727.5)

FDLE Impact speed = 61.0 mph

Vehicle Crush Stiffness Values

Case Example 2 - Why Do We Need Crush? Summary

Is this an optimistic calculation for the F150 side?

- YES

However, it DOES show the need for Crush and “Old Fashioned” Techniques, and it does illustrate how these techniques can be used under less than ideal circumstances when they need to be.

- Additionally, take this to heart ....

IF documentable evidence is NOT obtained, especially when its obtainable by YOU ....

Don't “whine” when the other side takes that “optimistic” stance. You could-a should-a .... but didnt .... so .... look in the mirror.

Vehicle Crush Stiffness Values

Case Example 2 - Why Do We Need Crush?

Summary

In Florida, "spoliation of evidence" refers to the intentional or negligent destruction, alteration, or hiding of evidence relevant to a pending or reasonably foreseeable lawsuit, which can result in court sanctions against the spoliator.

Here's a more detailed explanation:

Definition:

Spoliation is defined as the "intentional destruction of evidence or the significant and meaningful alteration of a document or instrument" and "the intentional concealment of evidence".

Duty to Preserve:

A party to litigation, or even a non-party, has a duty to preserve evidence that is relevant to a pending or reasonably foreseeable lawsuit. This duty can arise from a contract, statute, or discovery requests.

Elements of a Spoliation Claim:

To establish a claim for spoliation, a plaintiff must prove:

- Existence of a potential civil action.
- A legal or contractual duty to preserve evidence.
- Destruction of that evidence.
- Significant impairment in the ability to prove the lawsuit.
- A connection between the evidence destruction and the inability to prove the lawsuit.
- Damages.

Further, consider that "Spoliation" of evidence is NOT just its destruction.

It is also a failure to preserve (or hiding) evidence relevant to a reasonably foreseeable lawsuit.

Vehicle Crush Stiffness Values

Case Example 2 - Why Do We Need Crush?

Summary

Scene overhead view. One last point - Line of Sight

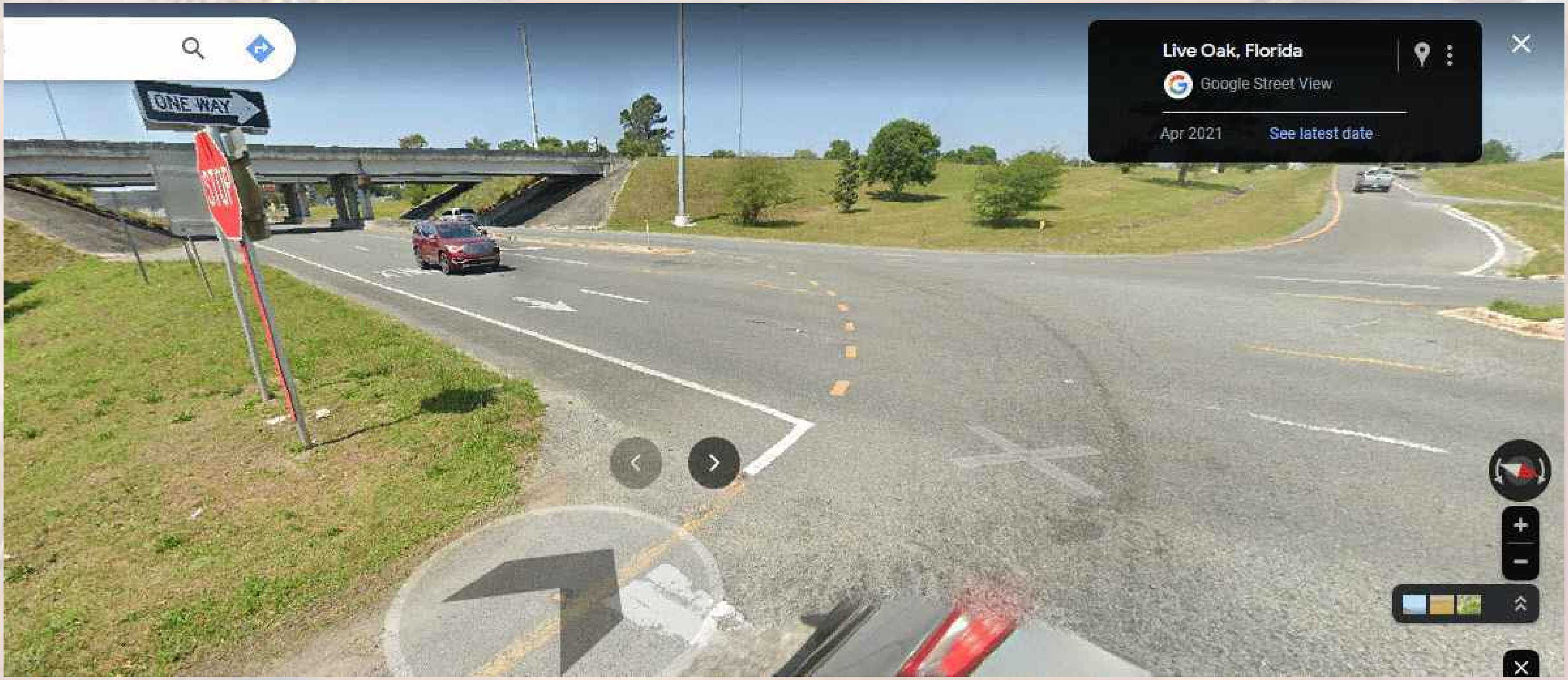
IPTM Symposium 2025

Vehicle Crush Stiffness Values

Case Example 2 - Why Do We Need Crush?

Summary

One last point - Line of Sight - this is why the speed evaluation is important in this case.



Vehicle Crush Stiffness Values

We have CDR/EDR - Case Example 3

So Why ???

Do We Need Crush?

So Why ???

Do We Need
"Old Fashioned" Techniques?

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

This last case comes out of California.

Unfortunately, it is NOT a case where crush could be used .... because it was never measured .... or scanned .... or photographed .... which would have been helpful. However, other techniques could be, and were, used by the author.

Again, CDR/EDR was available on both involved vehicles, a 2020 Nissan 370Z and a 2020 Ford Fusion, but neither was downloaded.

CRUSH could answer, or aide in answering, the question of speed on the part of the through vehicle (370Z).

CDR/EDR could have answered questions of speed on the part of the through vehicle (370Z), and “Did they stop?” as well as for how long, on the part of the left turning vehicle (Fusion).

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

DRE tidbit -

Alcohol is involved, and will be discussed. However, Driver 1 was not fighting the alcohol portion, just the increased penalties due to "excessive speed" ....

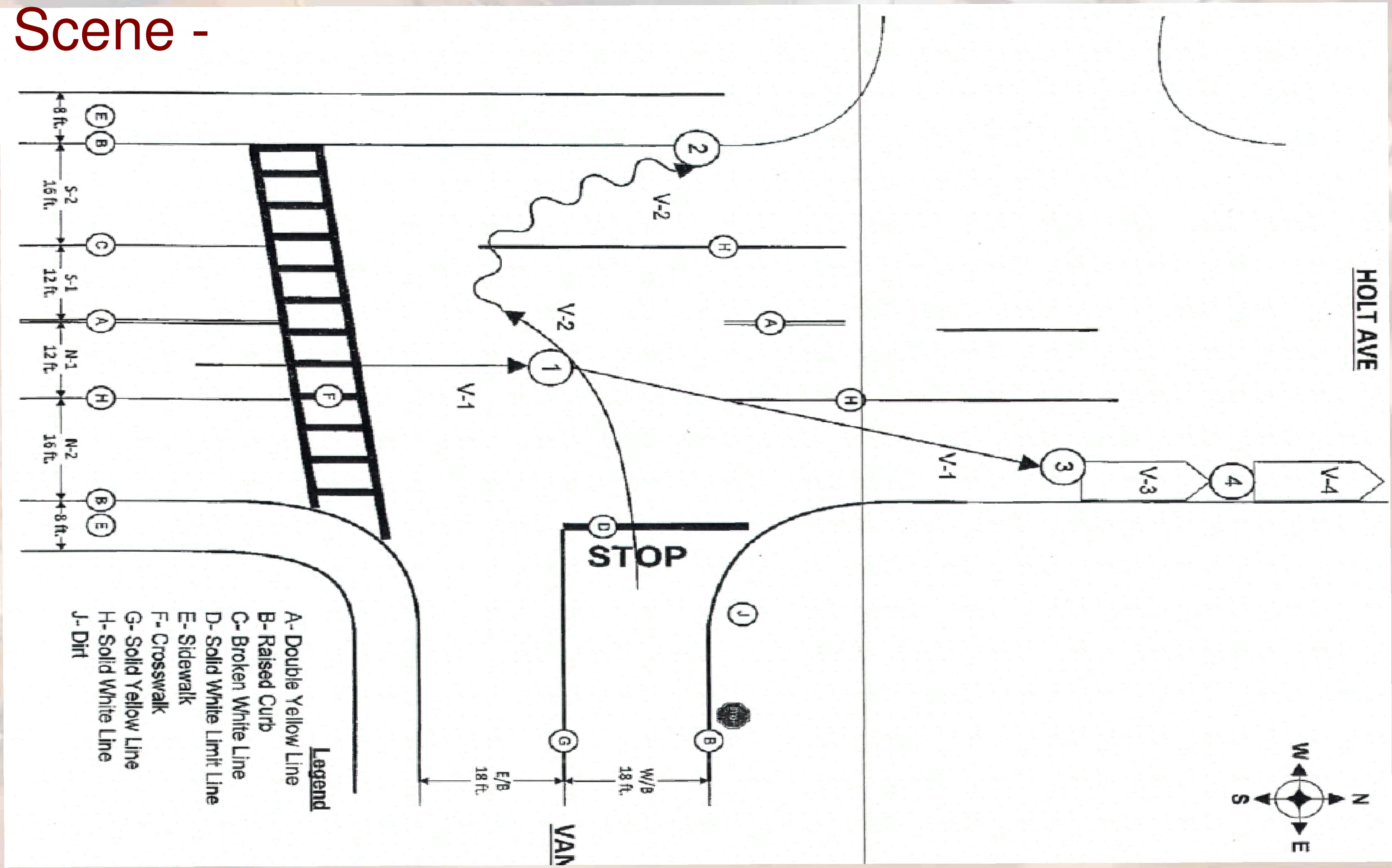
Speed note -

NO work was provided documenting ANY kind of speed analysis. It was just labeled "excessive" and the Prosecutor ran with it.

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

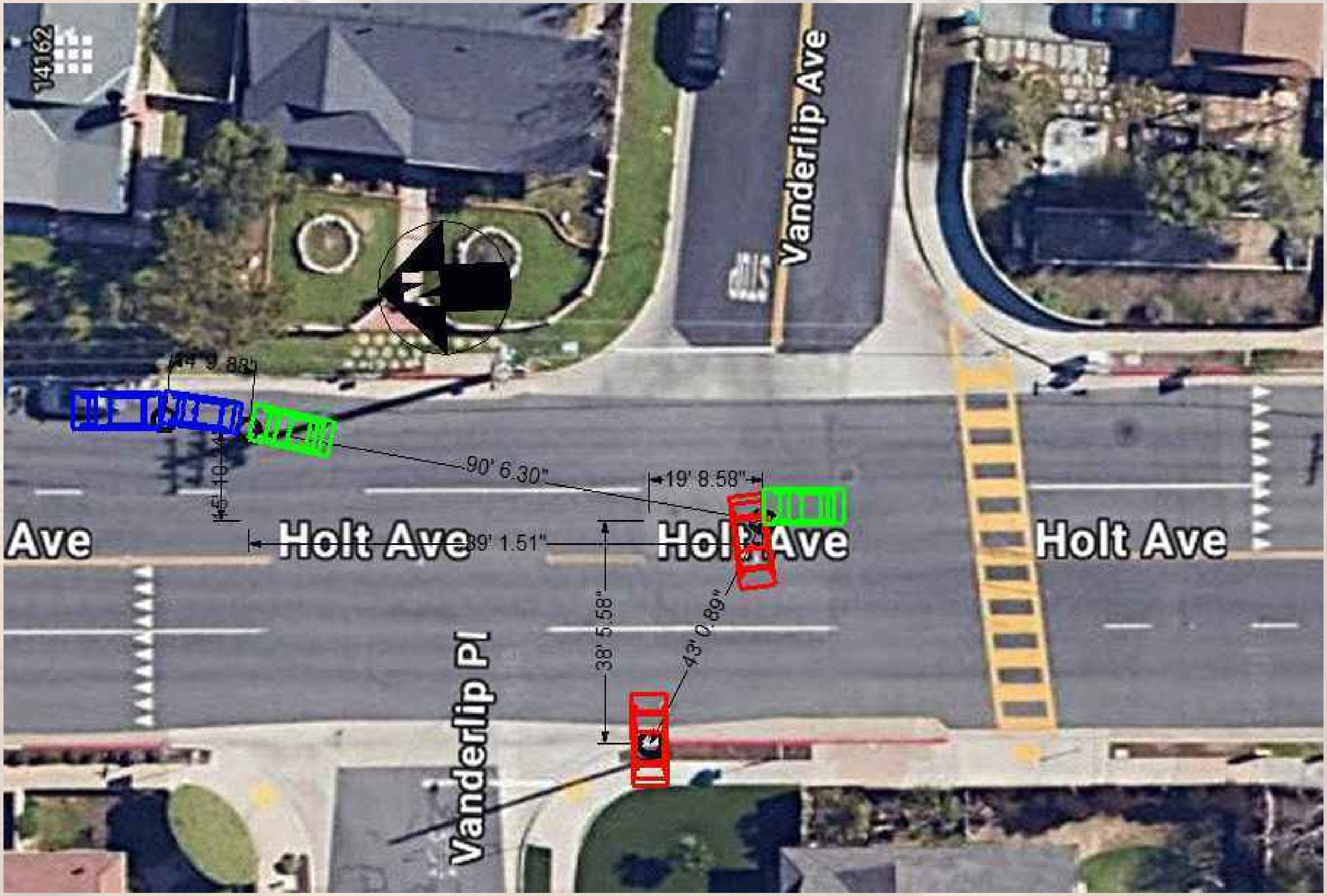
Scene -



Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Scene



Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Vehicle 1 - 2020 Nissan 370Z

40 mph Speed Limit (play fore shadowing music)

PARTY 1	DRIVER'S LICENSE NUMBER	STATE	CLASS	AIR BAG	SAFETY EQUIP.	VEH. YEAR	MAKE/MODEL/COLOR	LICENSE NUMBER	STATE
		CA	C	L	G	2020	NISS 370Z WHI		CA

DRIVER [X] — NAME (FIRST, MIDDLE, LAST)

OWNER'S NAME [X] SAME AS DRIVER

PEDESTRIAN [ ] — STREET ADDRESS

OWNER'S ADDRESS [X] SAME AS DRIVER

PARKED VEHICLE [ ] — CITY/STATE/ZIP: ORANGE CA 92866

DISPOSITION OF VEHICLE ON ORDERS OF: [X] OFFICER [ ] DRIVER [ ] OTHER

BICYCLIST [ ]	SEX	HAIR	EYES	HEIGHT	WEIGHT	BIRTHDATE Mo. Day Year	RACE
	M	BLK	BRN	5' 5"	145	08/11/1994	H

PRIOR MECHANICAL DEFECTS: [X] NONE APPARENT [ ] REFER TO NARRATIVE

OTHER [ ] — HOME PHONE — BUSINESS PHONE: NONE

VEHICLE IDENTIFICATION NUMBER

OPERATOR [ ] — INSURANCE CARRIER: AAA — POLICY NUMBER

VEHICLE TYPE: 01

DESCRIBE VEHICLE DAMAGE: [ ] UNK. [ ] NONE [ ] MINOR [ ] MOD. [X] MAJOR [ ] ROLL-OVER

SHADE IN DAMAGED AREA — TOP VIEW

DIR OF TRAVEL	ON STREET OR HIGHWAY	LANE	THRU LANES	TOTAL LANES	SPEED LIMIT
N	HOLT AVE	1	4	4	40

CA ______ DOT ______

CAL-T ______ TCP/PSC ______ MC/MX ______

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Later in the report ....

SCENE DESCRIPTION:

and sidewalk. The roadway is bordered to the east by a raised concrete curb. Holt Avenue is controlled by a posted speed limit of 45 miles per hour.

So, what is the speed limit? Is it 40 mph, or is it 45 mph?

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Vehicle 2 - 2020 Ford Fusion

PARTY	DRIVER'S LICENSE NUMBER	STATE	CLASS	AIR BAG	SAFETY EQUIP.
2		CA	C	L	G

DRIVER [X] — NAME (FIRST, MIDDLE, LAST):

PEDESTRIAN [ ] — STREET ADDRESS:

PARKED VEHICLE [ ] — CITY/STATE/ZIP: LAGUNA NIGUEL CA 92677

SEX	HAIR	EYES	HEIGHT	WEIGHT	BIRTHDATE Mo. Day Year	RACE
F	GRY	BLU	5' 0"	167	07/23/1938	W

BICYCLIST [ ]

OTHER [ ] — HOME PHONE: — BUSINESS PHONE: NONE

OPERATOR [ ] — INSURANCE CARRIER: NONE — POLICY NUMBER: REFER TO NARRATIVE

DIR OF TRAVEL	ON STREET OR HIGHWAY	LANE	THRU LANES	TOTAL LANES	SPEED LIMIT
W	VANDERLIP AVENUE	W/B	1	2	25

VEH. YEAR	MAKE/MODEL/COLOR	LICENSE NUMBER	STATE
2020	FORD FUSION BLK		CA

OWNER'S NAME [X] SAME AS DRIVER

OWNER'S ADDRESS [X] SAME AS DRIVER

DISPOSITION OF VEHICLE ON ORDERS OF: [X] OFFICER [ ] DRIVER [ ] OTHER

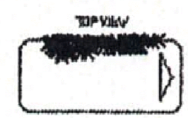
PRIOR MECHANICAL DEFECTS: [X] NONE APPARENT [ ] REFER TO NARRATIVE

VEHICLE IDENTIFICATION NUMBER:

VEHICLE TYPE: 01

DESCRIBE VEHICLE DAMAGE: [ ] UNK. [ ] NONE [ ] MINOR [ ] MOD. [X] MAJOR [ ] ROLL-OVER

SHADE IN DAMAGED AREA



CA ______ DOT ______

CAL-T ______ TCP/PSC ______ MC/MX ______

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Damage Description -

Vehicle #1 (Nissan) was located on its wheels, facing in an easterly direction, blocking the #1 and #2 lane of Holt Avenue northbound. Vehicle #1 sustained major damage as a result of the crash including, but not limited to, the following:

- Crushed front bumper
- Crushed grille
- Buckled hood
- Crushed left front fender
- Crushed right front fender
- Crushed engine compartment
- The airbags were deployed

A visible check of the safety restraint system revealed it was functioning properly. No prior damage or mechanical defects were noted or claimed.

Vehicle #2 (Ford) was located on its wheels, facing in an easterly direction, on the westside sidewalk of Holt Avenue. Vehicle #2 sustained major damage as a result of the crash including, but not limited to, the following:

- Crushed left rear passenger door
- Crushed left driver door
- Crushed left rear fender
- Crushed windshield
- The airbags were deployed

A visible check of the safety restraint system revealed it was functioning properly. No prior damage or mechanical defects were noted or claimed.

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Driver 2 Injuries

WITNESS ONLY	PASSENGER ONLY	AGE	SEX	EXTENT OF INJURY ("X" ONE)				INJURED WAS ("X" ONE)						PARTY NUMBER	SEAT POS.	AIR BAG	SAFETY EQUIP.	EJECTED
				FATAL INJURY	SUSPECTED SERIOUS INJURY	SUSPECTED MINOR INJURY	POSSIBLE INJURY	DRIVER	PASS.	PED.	BICYCLIST	OTHER	OPER.					
☐ #	☐	83	F	☐	X	☐	☐	X	☐	☐	☐	☐	☐	2	1	L	G	0

NAME / D.O.B. / ADDRESS

TELEPHONE

(INJURED ONLY) TRANSPORTED BY:
CARE AMBULANCE

EMS RUN NUMBER

TAKEN TO:

DESCRIBE INJURIES

COMPOUND FRACTURE TO RIGHT LEG, SEAT BELT ABRASION

☐ VICTIM OF VIOLENT CRIME NOTIFIED

Supplemental

On 2/27/23, I spoke with Victim on the telephone about the injuries she sustained as a result of this collision. related that she would be send me an email describing the injuries. She sent me copies of her hospital billings and described the following care required:

Injuries
Crushed right ankle
Fibula Fracture
Pelvic Fracture

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Statements of what happened attributed to the parties involved.

STATEMENTS:

Party #1 (   ) was contacted seated on the east curb on Holt Avenue, north of Vanderlip Avenue. Party #1 was identified by his California driver license as   Party #1 related to me the following: He was driving Vehicle #1 (Nissan) on Holt Avenue southbound, north of Vanderlip Avenue, in the #2 lane at approximately 45 miles per hour. A moment later he felt an impact to the front of his vehicle. After the crash, Party #1 exited Vehicle #1 and awaited assistance.

Party #2 (   ) was contacted by Officer C   , at the crash scene, and later at   Medical Center, and related the following, in essence: She was driving Vehicle #2 (Ford) on Vanderlip Avenue westbound, east of Holt Avenue. Party #2 was stopped at the intersection of Holt Avenue and Vanderlip Avenue, getting ready to make the left turn to go southbound on Holt Avenue. Party #2 looked both ways, did not see another vehicle approaching, Party #2 made the left turn. As Party #2 was entering southbound Holt Avenue, she felt an impact to the left side of her vehicle. After the crash, Party #2 remained trapped inside Vehicle #2 and had to be assisted out of the vehicle.

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Summary

<u>SUMMARY:</u>

This crash occurred within the intersection of Holt Avenue at Vanderlip Avenue. Party #1 was driving Vehicle #1 on Holt Avenue northbound, south of Vanderlip Avenue, in the #1 lane, at a speed greater than 65 miles per hour, approaching Vehicle #2 from the south, while under the influence of an alcoholic beverage. Party #2 was driving Vehicle #2 on Vanderlip Avenue westbound, east of Holt Avenue, and was at a complete stop, at the limit line, preparing to make a left turn onto Holt Avenue southbound. Vehicle #3 was parked along the easterly road edge of Holt Avenue, north of Vanderlip Avenue, north of Vehicle #1 and Vehicle #2. Vehicle #4 was parked along the easterly road edge of Holt Avenue, north of Vanderlip Avenue, directly in front of Vehicle #3.

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Summary (cont)

Party #2 entered into the intersection and began making a left turn toward Holt Avenue southbound. Prior to turning, Party #2 had yielded the right-of-way to all vehicles which were approaching so closely as to constitute an immediate hazard; however, due to Party #1's unsafe speed, Party #1 had closed the distance between Vehicle #1 and Vehicle #2 faster than what a reasonable person should expect. Due to Party #1's level of intoxication, combined with his unsafe speed, Party #1 allowed the front of Vehicle #1 to collide with the left side of Vehicle #2. The force of the impact spun Vehicle #2 in a northwesterly direction, causing Vehicle #2 to collide with the concrete curb on the westside of Holt Avenue. After the impact with Vehicle #2, Vehicle #1 veered in a northeasterly direction and the front of Vehicle #1 collided with the rear of Vehicle #3 (Toyota). The force of this impact caused Vehicle #3 to be pushed forward, and the front of Vehicle #3 collided with the rear of Vehicle #4 (Jaguar).

No POR's Identified in Report

After the crash, Vehicle #1 came to rest on its wheels, facing in an easterly direction, blocking the #1 and #2 lane of Holt Avenue northbound, Vehicle #2 came to rest on its wheels, facing in an easterly direction, on the southwest sidewalk corner of Holt Avenue and Vanderlip Place, and Vehicle #3 and Vehicle #4 came to rest on their wheels, facing in a northerly direction, along the east road edge of Holt Avenue northbound.

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Causation -

"No person shall drive a vehicle upon a highway at a speed greater than is reasonable or prudent having due regard for weather, visibility, the traffic on, and the surface and width of, the highway, and in no event at a speed which endangers the safety of persons or property."

Due to Party #1's level of intoxication and unsafe speed, it is unreasonable for Party #2 to expect Vehicle #1 to be traveling at a high rate of speed and to be able to avoid Vehicle #1 prior to the crash. As a result, the above crash occurred

Yet, statements as to the speed of the Nissan are made with NO documentation, calculation, or work conducted to establish that speed!!

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Speed "Calculations" -

- No EDR/CDR downloads
- No damage measurements
- No photographs of the damage, post collision vehicle positions, or any other physical evidence
- No POR position measurements for any of the vehicles

For the moment, lets take the Alcohol issue out of the equation. For the LE's in the audience, lets say you have to review this for another agency as an officer involved collision, with no lights or sirens.

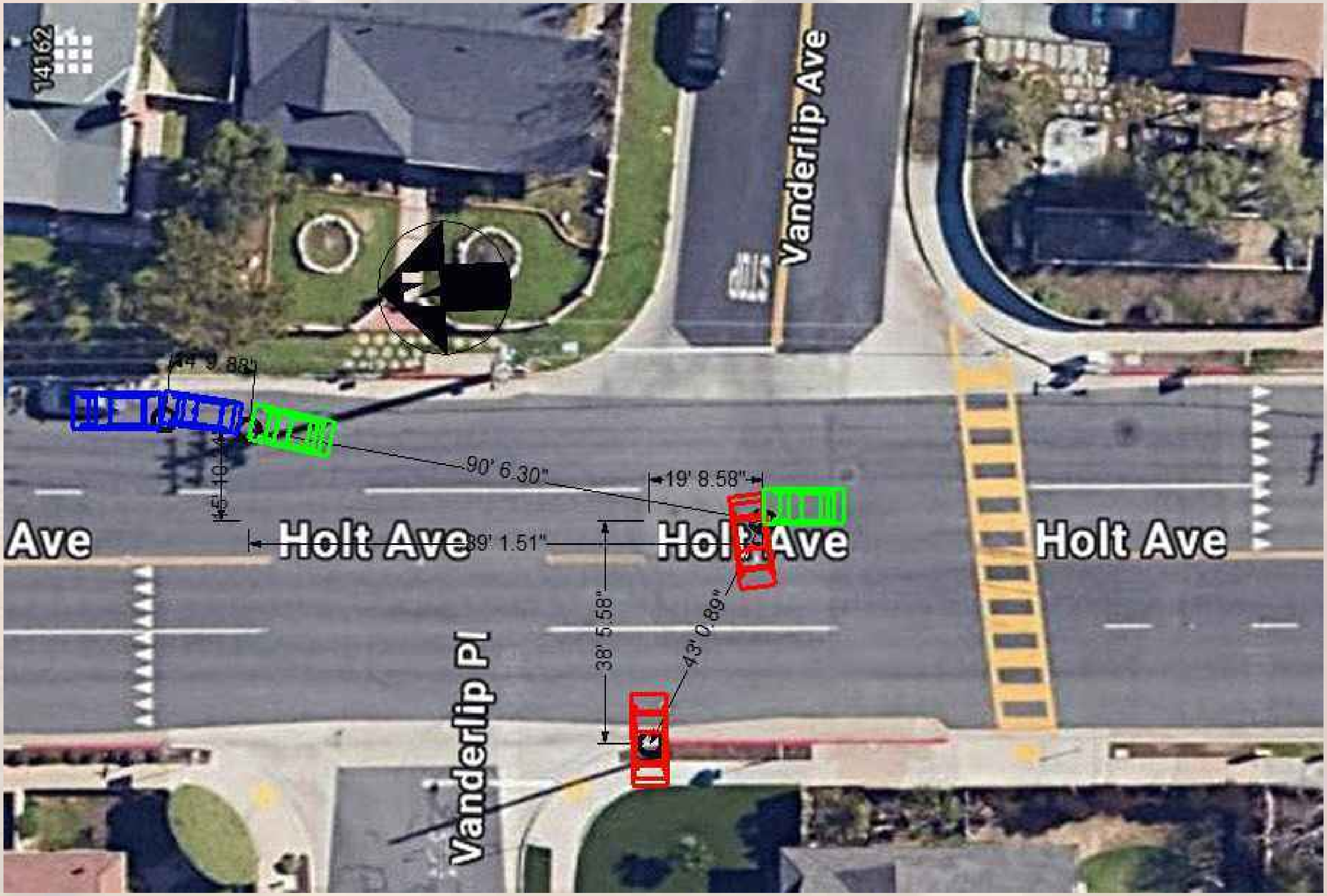
So, what can we do?? Can we do ANY calculations to establish a speed at impact?

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Scene

AOI's were reported in the Traffic Collision Report



Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Speed Calculations (cont)

As can be seen, the Nissan's heading is to the RIGHT post Impact 1, which is opposite of what it should be in order to use traditional 360 degree momentum calculations.

However, we can still do some Inline Momentum calculations.

So lets start "walking" our way backwards ....

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Speed Calculations (cont)

AOI 4 is between the front of a Toyota Tercel and the rear of a Jaguar F-Pace, with minimal damage to either of them.

Assuming a 1 foot Post Impact Travel distance, for both vehicles we get a speed at impact between the Toyota and the Jaguar of ~6-10 mph, depending upon if you assume that the Toyota hit the Jaguar alone, or if you had the Nissan pushing the Toyota into the Jaguar.

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Speed Calculations (cont)

For AOI 3, the Nissan into the Toyota, we get an impact speed of ~9 mph for the Nissan, consistent with the described damage to the Toyota of a "dented bumper", but no other described damage.

AOI 2 is between the Fusion and the West curb.

For AOI 1 to AOI 2 -

ALL of the energy in the Northbound direction comes from the Nissan. ALL of the energy in the Westbound direction comes from the Fusion. SO ....

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Speed Calculations (cont)

For AOI 1 to AOI 2 (cont) -

The calculated speed for the Fusion based on the westward movement is ~ 26 mph and is attributed to the Fusion at impact.

The calculated speed for the Fusion based on the northward movement is ~ 19 mph and is attributed to the Nissan at impact.

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Speed Calculations (cont)

For the Nissan’s travel from AOI 1 to AOI 3, a range of speeds from ~14-39 mph is calculated based upon the amount of braking assigned to the Nissan.

Braking efficiencies of 10%, 25%, 50%, 75%, and 100% were evaluated.

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Speed Calculations (cont)

Combining the Energy losses expressed as speeds in the northbound direction, we get a speed at AOI 1 for the Nissan of ~ 25-50 mph. The “correct” speed is depending on the amount of braking from AOI 1 to AOI 3 by the Nissan.

The most likely “braking efficiencies” under these conditions would be expected to be 50%-75% which would result in an expected impact speed of ~38-44 mph.

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

But WAIT .... THERE's MORE!!!!

The house on the Northeast corner had a "ring" camera, which shows the impact ......

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

But WAIT .... THERE’s MORE!!!! (cont)

- In the video, Nissan has both headlights functional
- Fusion does not, in the author’s opinion, come to a “full and complete” stop
- Fusion definitely is not at a stop for sufficient time for the driver to look carefully in both directions before commencing it’s left turn
- Significant rotation post impact on the part of the Fusion consistent with an impact at or behind the Rear axle

.... Did the Reporting Officer even review the video??

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Alcohol -

* Asked prior to FSTs

INVESTIGATION INTERVIEW

DO YOU KNOW OF ANYTHING MECHANICALLY WRONG WITH YOUR VEHICLE ? DESCRIBE. ☐ YES ☒ NO	ARE YOU SICK OR INJURED? DESCRIBE. ☐ YES ☒ NO	
ARE YOU DIABETIC OR EPILEPTIC? ☐ YES ☒ NO	DO YOU TAKE INSULIN? (Pills/Injection) ☐ YES ☒ NO	DO YOU HAVE ANY PHYSICAL IMPAIRMENTS? DESCRIBE. (Feet, Legs, Ankles, or Hips) ☐ YES ☒ NO

WHEN DID YOU LAST SLEEP? LAST NIGHT	HOW LONG? 8 HRS	WHEN DID YOU LAST EAT? 12:00 P.M.	DESCRIBE CHICKEN SANDWICH
WERE YOU DRIVING THE VEHICLE? ☒ YES ☐ NO ☐ N/A	IF NO, WHO?	WHERE DID YOU START DRIVING? TUSTIN	WHERE WERE YOU GOING? HOME

WHERE WERE YOU STOPPED? ORANGE	WHAT HAVE YOU BEEN DRINKING? L.A. WATER	HOW MUCH? 1 DRINK	TIME STARTED? 10:30 P.M.	TIME STOPPED? 11:00 P.M.
LOCATION WHERE YOU WERE DRINKING? CHA-CHA	NAME/ADDRESS	DO YOU FEEL THE EFFECTS OF THE DRINKS? DESCRIBE. ON SCALE OF 0-10, A 7		☒ YES ☐ NO
DID YOU BUMP YOUR HEAD? ☐ YES ☒ NO ☐ N/A	HAVE YOU BEEN DRINKING SINCE THE ACCIDENT? ☐ YES ☒ NO ☐ N/A	IF YES, WHAT?		HOW MUCH?
ARE YOU UNDER CARE OF A DOCTOR/DENTIST? ☐ YES ☒ NO	IF YES, NAME/ADDRESS			RECENT SURGERY PERFORMED? ☐ YES ☒ NO *(Explain in Narrative)
HAVE YOU TAKEN ANY MEDICINE OR DRUGS? ☐ YES ☒ NO	IF YES, WHAT?	HOW MUCH?	TIME OF LAST DOSAGE?	

DO YOU FEEL THE EFFECTS OF THE MEDICINE/DRUGS? DESCRIBE. ☐ YES ☐ NO
N/A

OBJECTIVE SIGNS/APPEARANCE/FIELD SOBRIETY TEST LOCATION

THE SUBJECT WAS ADVISED OF THE ABOVE STAT...

☐ NOT ADVISED ☒ ARRESTING OFFICER ☐ OR ID: TIME: 2328

PAS SERIAL NUMBER	TEMPERATURE	ZEROED	RESULTS NO. 1	TIME 1	RESULTS NO. 2	TIME 2	RESULTS NO. 3 (if needed)	TIME 3
17120013	23.3	☒ YES ☐ NO	☐ Refused .200	2330	.221	2333		

LOCATION OF TEST	BREATH SAMPLE	OFFICER ADMINISTERING PAS TEST	ID NUMBER	AREA
☒ At scene	☒ Automatic ☐ Manual	☒ ARRESTING OFFICER ☐ OR	21914	9675

CHEMICAL TEST INFORMATION

☒ Implied Consent Admonishment, Section 23612 CVC ☐ Refused Test(s) (Complete DS 367)	DRUG ADMONISHMENT ☐ N/A ☐ Yes ☐ Refused (Complete DS 367)	ATTACHMENTS ☐ CHP 202 DRE ☐ OTHER

TYPE OF TEST	TIME	ID OF SAMPLE(S)	RESULTS, IF AVAILABLE	DISPOSITION OF SAMPLE(S)
1 ☐ Breath				
2 ☒ Blood	0025	699932	PENDING	WITH CFP
3 ☐ Urine				

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Alcohol -

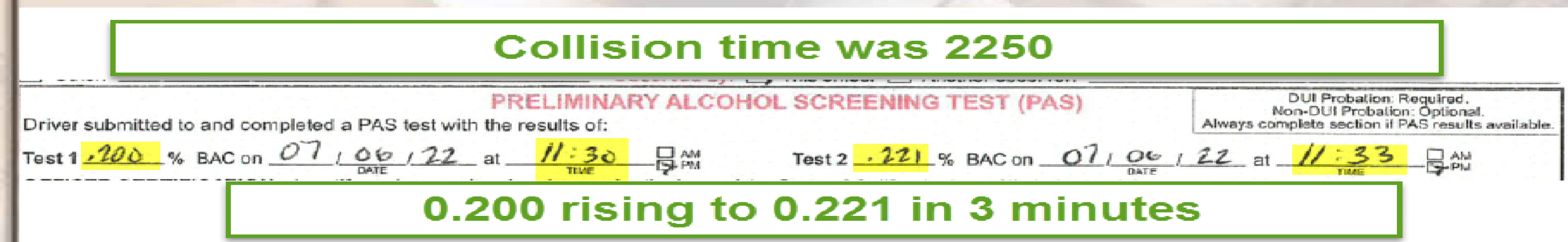
- Started drinking at 10:30p, ended at 11:00p. Okay, since the collision reportedly occurred at 10:50p (or 10:53p per the video), we know that the end time is not correct, BUT, this does indicate that the end of drinking was shortly before the collision. Also, when asked the time at 10:50, many/most people will reply with “11".
- “Did you Bump Your Head? - NO” ... come on, Really? Airbags went off. Supposedly impact speed 65 mph or greater. Yet the driver didnt “bump” his head in an unexpected collision?
- **PAS - Test 1 at 2330 = 0.200, Test 2 at 2333 = 0.221**

STRONGLY indicative that alcohol absorption is still occurring post collision.

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Alcohol -


Collision time was 2250

PRELIMINARY ALCOHOL SCREENING TEST (PAS)

Driver submitted to and completed a PAS test with the results of:

DUI Probation: Required.
Non-DUI Probation: Optional.
Always complete section if PAS results available.

Test 1 .200 % BAC on 07 / 06 / 22 at 11:30 AM PM

Test 2 .221 % BAC on 07 / 06 / 22 at 11:33 AM PM

0.200 rising to 0.221 in 3 minutes

- Per the PAS tests, 0.021 rise in alcohol in 3 minutes.

Collision occurred at 2250, first PAS test at 2330, so lets do the standard criminalist calculation ...

2330 - 2250 = 40 minutes. Divide that by 3, and you get 13+ increments.

13*0.021 = ~0.27+ absorption from 2250 to 2330. This is MORE THAN the amount of alcohol in the system of the driver at the time of test per the PAS device.

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!

Alcohol -

Blood test draw at 0025 = 0.24.

Blood is ~0.02-0.04 higher than at PAS testing.

This is again indicative of rising level, not falling, between collision and the time of the blood draw.

Interesting to the author on a “curiosity level” is that the blood tests were conducted by 2 different analysts.

LABORATORY ANALYTICAL RESULTS AND INTERPRETATIONS - (See below for final result)

Analyst	Analysis Date (ID)	Method	Ethanol Result (% W/V)	Volatiles Detected
M. N		GC/FID/MS	0.246 ± 0.013	
M. H		GC/FID/MS	0.242 ± 0.013	

Collision 2250, PAS 2330, Blood 0025

Vehicle Crush Stiffness Values

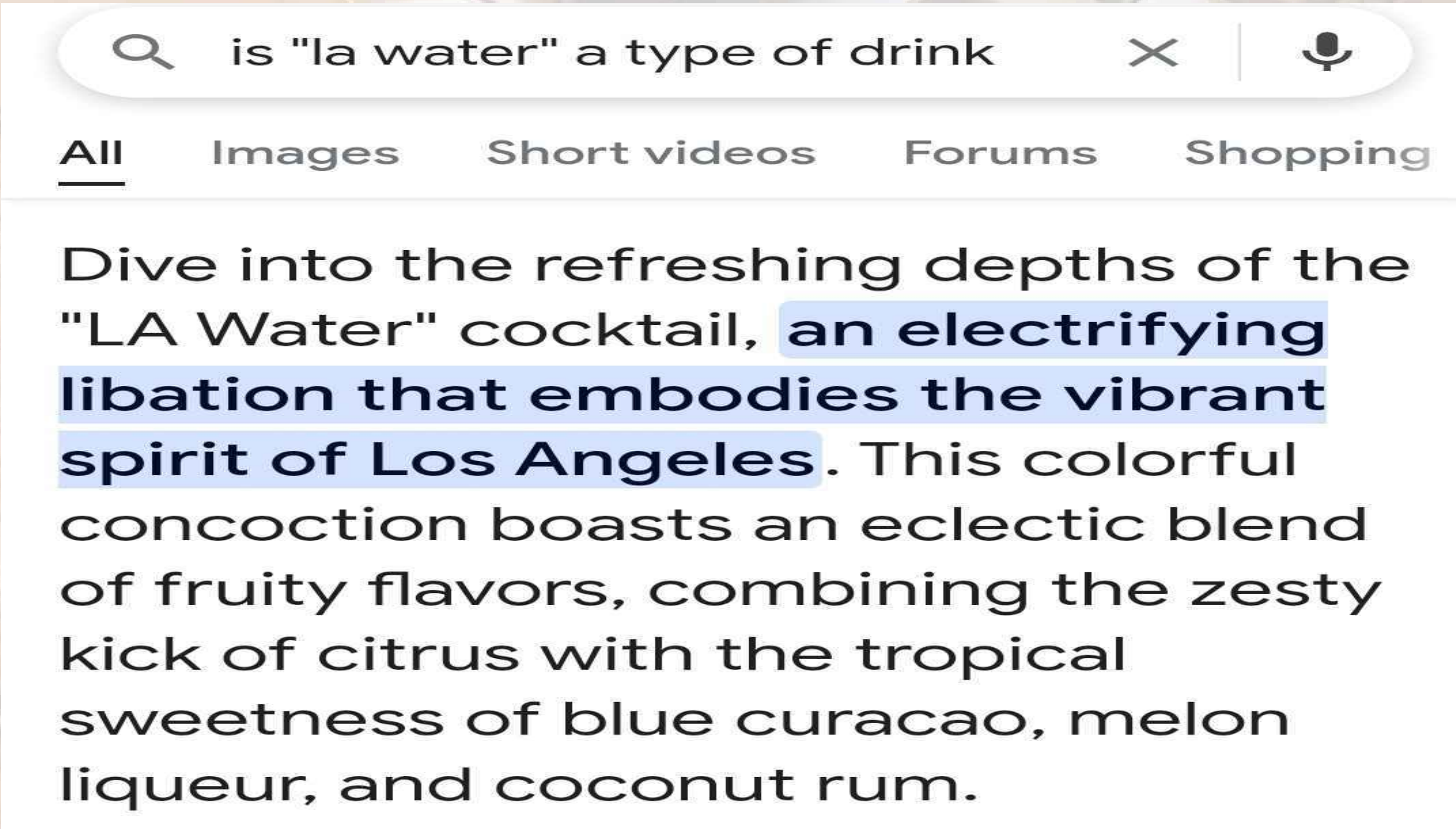
Crash Test Data, Data Problems, and Common Misconceptions
Case Example 3 - We have EDR !!!

- **PAS - Test 1 at 2330 = 0.200**
- **PAS - Test 2 at 2333 = 0.221**
- **Blood at 0025 = 0.246 / 0.242**

Yet, only 1 drink? .... wait ... **LA Water** ... was the driver not being sarcastic???

Vehicle Crush Stiffness Values

Crash Test Data, Data Problems, and Common Misconceptions
Case Example 3 - We have EDR !!!



Vehicle Crush Stiffness Values

Crash Test Data, Data Problems, and Common Misconceptions
Case Example 3 - We have EDR !!!

INGREDIENTS

	My Bar
1 oz **vodka**	✗
1 oz **pineapple juice** (buy)	✗
1 oz **coconut rum**	✗
1 oz **blue curacao**	✗
1 oz **midori**	✗
1 oz **sweet and sour mix** (buy)	✗

DIRECTIONS

1. In a shaker with ice, add vodka, blue curacao, melon liqueur, coconut rum, sweet and sour mix, and pineapple juice.
2. Shake the mixture vigorously for about 10-15 seconds to blend the flavors and chill the ingredients.
3. Strain the mixture into a highball glass filled with ice and garnish the LA Water cocktail with a slice of orange for a citrusy and visually appealing touch(optional).

Vehicle Crush Stiffness Values

Crash Test Data, Data Problems, and Common Misconceptions
Case Example 3 - We have EDR !!!

So no, the driver was NOT being sarcastic or flippant.

At a weight of 145 pounds, with 4 drinks in him .... especially if the pour was heavy, makes total sense that he got up to 0.24(??) Off of “1 drink”.

But enough about the alcohol issues, lets wrap up the “high” (or is it low??) Points of the Recon/speed determination in this example ....

Vehicle Crush Stiffness Values

Case Example 3 - We have EDR !!!
Summary

Irregardless of the alcohol issues -

- Even when the reconstructionist is dealt a less than perfect hand, much can be done with the traditional methods of accident reconstruction. These skills are STILL needed and important.
- If crush had been documented, that would provide a method of solidifying and narrowing the speeds determined through the inline momentum method presented.
- If the EDR/CDR had been downloaded, a number of issues would probably have been resolved.
- Proper documentation saves EVERYONE time and effort.
- If you aren't going to document or analyze it .... should you be "talking" about it?

Vehicle Crush Stiffness Values

Crash Test Data, Data Problems, and Common Misconceptions SUMMARY

- There are a number of "problems" within the NHTSA Crash Test database. While there is little that can be done about the problems, we need to be aware they exist and how to work around them.
- Crush calculations are ENERGY calculations, not Δv calculations. You cannot mix the two and get proper answers. You can convert back and forth, but not mix.
- Δv should not be used in calculating stiffness values. Again, it is a different speed than a crush speed. Also, if a Δv is used to calculate stiffness in frontal tests, you are violating laws of physics.

Vehicle Crush Stiffness Values

Crash Test Data, Data Problems, and Common Misconceptions SUMMARY

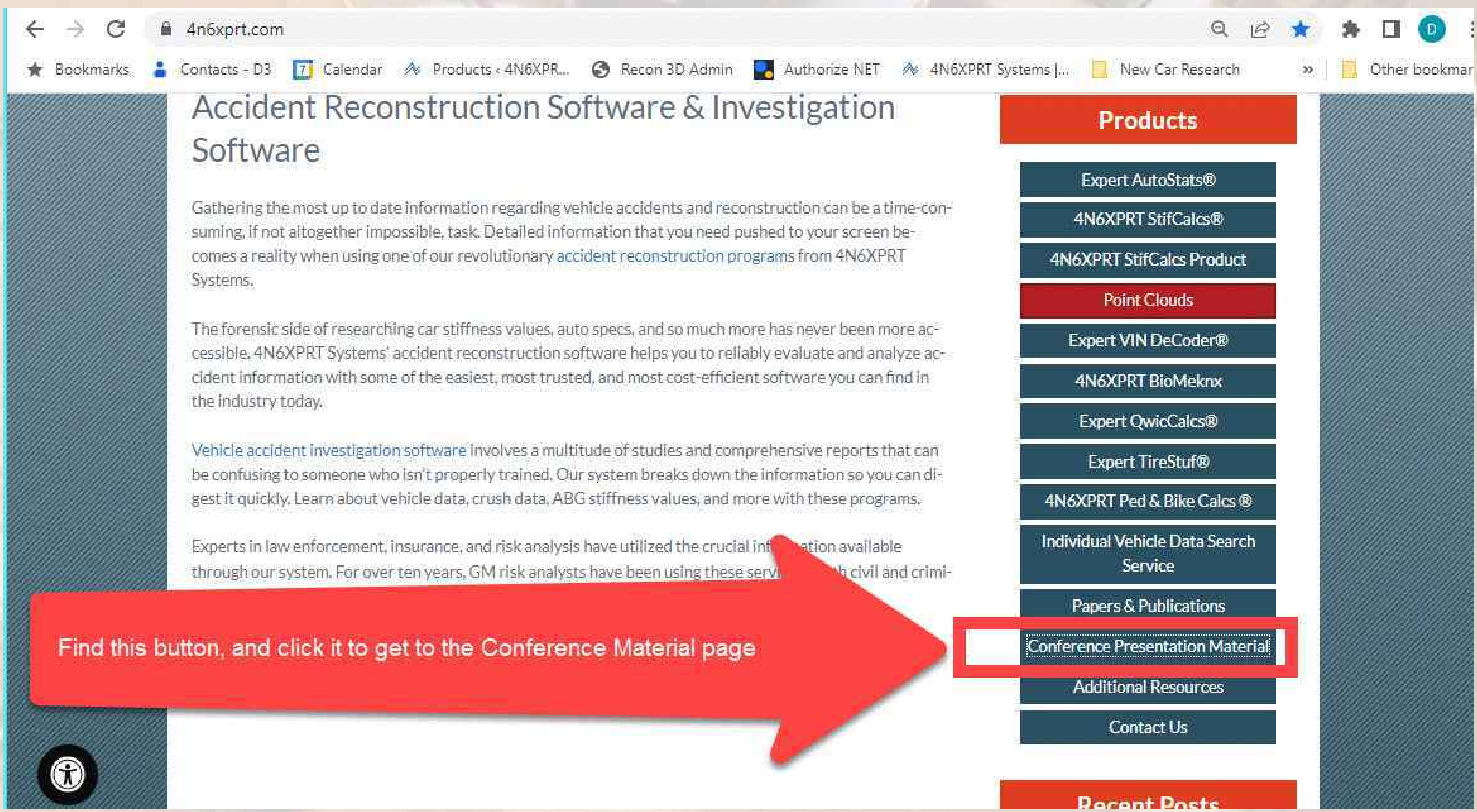
- Speed from Crush calculations provide valid speed estimates when they are conducted properly.
- There are more than just A-B-G stiffness values out “in the world”, and when used appropriately, they will provide useful and reliable answers to vehicle speeds.

Vehicle Crush Stiffness Values

Presentation available for Download from **www.4N6XPRT.com**

Vehicle Crush Stiffness Values

Presentation available for Download from **www.4N6XPRT.com**



Vehicle Crush Stiffness Values

Presentation available for Download from **www.4N6XPRT.com**

and
Presentations

Conference	Conference Material Page	Material on Page
Illinois Association of Technical Accident Investigators - September 2022	IATAI-2022	Speed from Crush Considerations
Midw	MATAI-2022	Conference Video Force-Balance Analysis of Crush 4N6XPRT Systems Vehicle Data
Sout	SCARS-2023	Recon-3D and Cloud Compare Speed from Crush Considerations
	IPTM-2024	Conference Video 4N6XPRT Systems vehicle Data
	SATAI_2024	Recon-3D and Cloud Compare Speed from Crush Considerations
NAPARS Online Trasining - March 2025	NAPARS 2025	Research and Calculation of Stiffness Values Manually
SATAI Conference Crash Testing - March 2025	SATAI_March-2025	Conference Crash Test Videos Recon-3D Scene Scans 4N6XPRT Systems Vehicle Data
IPTM Symposium - May 2025	IPTM_2025	NHTSA Crash Test Data Problems and Misconceptions Conference Crash Test Videos 4N6XPRT Systems Vehicle Data

Go to this page to find the presentation, videos, and other conference material from 4N6XPRT Systems

Vehicle Crush Stiffness Values

Presentation available for Download from **www.4N6XPRT.com**

4n6xprt.com/IPTM-2025.htm

Bookmarks | Contacts - D3 | Calendar | Products ‹ 4N6XPR... | Recon 3D Admin | Authorize NET | 4N6XPRT Systems |... | New Car Research | NHTSA | TAX | » | Other bookmarks

Daniel W. Vomhof III

Presentation Materials And CRASH Videos for

IPTM Symposium - May 18-22, 2025

NHTSA Crash Test Data Problems and Common Misconceptions

The first part of this presentation deals with some common, but misunderstood, problems within the NHTSA Crash Test data. This is then followed by three recent case examples. The first case illustrates how some of the misconceptions and problems can lead to an error in calculating speeds in the subject collision. The second and third example show why the crash investigator/reconstructionist cannot rely upon having EDR/CDR information available, and how crush analysis and other traditional methods can still provide "workable" information.	Download Crash Test Data and Common Misconceptions Presentation - 1 Slide per page
Selected videos from the 2023 Pennsylvania State Patrol conference that help to illustrate some of the issues and problems discussed in the first part of the presentation.	Videos from the 2023 PSP conference that help to illustrate the problems reference first part of the presentation.

Definition of Terms Used by this Author

^2 - Square the value immediately in front of the carrot (^) .

A - B - G - Stiffness Values used to evaluate crush within the CRASH III program

AOI - Area of Impact

Bullet - The incoming vehicle or object imparting damage to a “Target”

CDR - Crash Data Retrieval, also referred to as an “Airbag Module”

Closing Speed or Impact Speed - For the purposes of crash testing the terms are used interchangeably. Typically the Closing speed is obtained by a time trap spatially placed immediately prior to the impact point.

CF - Crush Factor - A unitless calculated stiffness value to be used in calculating speed from crush, similar to a drag factor or coefficient of friction.

CLASS vehicle - a representative vehicle or group of vehicles based upon one or more vehicle characteristics to be used in place of the subject vehicle due to a lack of crash data for the subject vehicle.

CRASH III - **C**alspan **R**econstruction of **A**ccident **S**peeds on the **H**ighway. - CRASH III is the third iteration of the software program

Crush Factor - A unitless calculated stiffness value to be used in calculating speed from crush, similar to a drag factor or coefficient of friction.

CS - Closing Speed - Pre Impact Speed.

CT - Crash Test

DamageSpeed - Speed determined from damage - KEES.

DPD - Damage Profile Dimension - a crush depth measurement

Δv - delta-v

delta-v - Change in Speed or direction or both. However, it is commonly used without reference to direction within the collision investigation/reconstruction industry. Commonly used Speed units may be fps, mps, mph, or kph.

DepartureSpeed - Speed departing from an event - Sf - PostImpactSpeed.

EDR - Event Data Recorder, also referred to as a “Airbag Module”

ft or f - Feet.

fps or ft/sec - Feet per second.

ImpactSpeed - Speed at Impact - Si - PreImpactSpeed - Closing Speed.

IW - Impactor Weight - Moving Barrier Weight - Bullet Vehicle Weight.

KE - Kinetic Energy

KEES - Kinetic Energy Equivalent Speed, otherwise stated as Kinetic Energy EXPRESSED as a Speed.

kph or km/h - Kilometers per hour.

m - Meter or mass, depending on context.

MaxCrushinFeet - The maximum crush depth in units of feet

mm - Millimeter.

MPH or mph - Miles per Hour.

mps or m/sec - Meters per second.

NHTSA - National Highway Traffic Safety Administration

PDOF - Principle Direction of Force

PreImpactSpeed - Pre Impact Speed - Si - Closing Speed - Impact Speed

PIS - Post Impact Speed

pits - Post Impact Travel Speed

POR - Point of Rest

PostImpactSpeed - Post Impact Speed - Sf. - DepartureSpeed

S = Speed

Si - Initial speed - the speed of an object entering an event to be evaluated - PreImpactSpeed

Sf - Final Speed - the speed of an object departing an event to be evaluated - PostImpactSpeed

sfc - Speed from Crush

SqRoot( ) - Square Root of the value calculated within the parenthesis.

SQR( ) - Square Root of the value calculated within the parenthesis.

Target - The vehicle or object which receives damage from the “Bullet”

v - Velocity, standard units are fps or mps.

VDI - Vehicle Damage Index

VW - Weight of the Target Vehicle - Weight of the object for which the KEES is being determined.

W - Weight

Wt - Weight

Speaker C.V.

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(619) 464-3477

Daniel William Vomhof III, E.I.T.
Certified Accident Reconstruction Specialist

EDUCATION:

B. S. Engineering	October 1994
A. S. Engineering	June 1992
A. S. Surveying	August 1986

ACCIDENT SPECIFIC EDUCATION (3,640+ Hrs)

PROFESSIONAL CERTIFICATION:

- Engineering E.I.T. Registration #XE088556, 1993
- Accredited Traffic Accident Reconstructionist, The Accreditation Commission for Traffic Accident Reconstruction, Registration #484, 1993-2028
- Certified Accident Reconstruction Specialist - Institute of Police Traffic Management, 1983

EXPERIENCE:

Expert Witness Services, Inc.

(1992-present) - Accident Reconstructionist.
(1984-1992) - Accident Reconstruction Assoc.
(1981-1984) - Accident Reconstructionist.
(1976-1981) - Technician.

Primary responsibilities include:

- Evaluation of traffic signal timing related to vehicle, pedestrian, and motorcycle accidents
- Reconstruction of vehicle, pedestrian, and motorcycle accidents
- Evaluation of Pedestrian/Facility/Walking Surface interactions
- Measurement and evaluation of lighting as it affects perception of hazards
- Measurement and evaluation of sound levels
- Documentation of vehicle evidence and scene conditions through photography and measurements
- Preparation of scale scene diagrams and other exhibits for use in depositions, arbitration hearings, and trial.

4N6XPRT Systems

(1992-present) - General Manager/Technical Support/Programmer

Primary responsibilities include:

- Maintain data and Software Programs available for sale
- Provide Technical Support to program owners
- Provide data to Accident Investigators throughout North America when requested via email, phone, or fax

City of La Mesa - Traffic Engineering
(1988-1992) - Engineering Technician I.

Primary responsibilities in the field included preparation, review, and inspection of traffic control plans; preparation of striping, signing, and traffic signal plans and layouts for the field crews; traffic signal system coordination; field changes to traffic signal timing plans; and determination of proper sign type and placement to remedy existing traffic problems.

Primary responsibilities in the office included monthly review of accident reports for possible conditions contributing to the accidents which would be correctable by engineering projects; preparation of individual and system traffic signal timing plans; preparation of staff reports and exhibits for public hearings; and presentation of staff reports at public hearings.

Acted as Primary Interface between Traffic Engineering and Police Department in issues of Traffic Signal timing and downloads

SWORN TESTIMONY:

Qualified in San Diego and San Bernardino Superior Court on:
* Traffic Signal timing sequence and "who had the green" issues

Qualified in San Diego, El Cajon, Vista, San Bernardino, Pasadena, Solano, and Wisconsin Superior Courts on one or more of these issues:
*Time-Speed-Distance-Force calculations
*Speed survey design, conduction, & data analysis
*Preparation of scale diagrams of roadways
*Lighting considerations
*Vehicle and pedestrian paths of travel
*"Normal" vehicle speeds for an area
*Human factors - Perception, Reaction, Line-of-Sight
*Vehicle and Occupant movements
*Speed from Damage

Computer Software Programs Developed and Maintained:

D.W. Vomhof III, D. W. Vomhof, and S. Young, 4N6XPRT StifCalcs, 4N6XPRT SYSTEMS, La Mesa, CA (2007-2023)
D.W. Vomhof III and D. W. Vomhof, Expert AutoStats, 4N6XPRT SYSTEMS, La Mesa, CA (1993-2024)
D.W. Vomhof, D. W. Vomhof III, and S. Young, Expert VIN DeCoder, 4N6XPRT SYSTEMS, La Mesa, CA (2007-2023)
D.W. Vomhof III, D. W. Vomhof, and B. Cunningham, 4N6XPRT StifCalcs, 4N6XPRT SYSTEMS, La Mesa, CA (2003-2006)
D.W. Vomhof and D. W. Vomhof III, 4N6XPRT Ped & Bike Calcs, 4N6XPRT SYSTEMS, La Mesa, CA (1996)

Publications:

A-B-G Stiffness Values ... How to Research .... and Calculate .... Step-by-Step, Published by IPTM Press, Copyright 2014

Kinetic Energy Equivalent Speed:

What Is It?
Why Calcualte It?
How to Calculate It

Kinetic Energy Equivalent Speed:

What is it? Why Calculate it? How to Calculate it?

Kinetic Energy Equivalent Speed (KEES) - What is it?

One of the tools of the accident reconstructionist is a Kinetic Energy (K.E.) analysis. In this type of analysis the K.E. transfers, or "losses," are summed for each of the vehicles in order to determine the beginning speeds/velocities of the vehicles. One of these K.E. "losses" occurs in "crushing" a vehicle during impact.

At its most basic, the K.E. Equivalent Speed is the speed equivalent of the K.E. loss. Two common K.E. losses are from damage and from sliding across a surface. The Speed Equivalent of the K.E. loss is calculated with the following equation[1]:

Equation #1:

$$Speed(mph)=\sqrt{\frac{30*(EnergyLoss)}{(ObjectWeight)}}$$

When calculating a speed from damage, historically the most common "crash test" is a frontal impact into a fixed, non-deformable barrier. In this type of test, the weight of the vehicle is known, the damage is to the test vehicle only, the crush distance can be measured, the pre-impact speed is known, and the post-impact speed is known (assumed) to be zero. In this type of collision, because everything is known, the Energy loss can be easily calculated. Once the Energy loss has been calculated the energy equivalent speed can be calculated. Now, armed with a speed and a crush depth, stiffness values can be calculated. These stiffness values can be the A-B-G values used for a Crash III analysis, the Crush Factor values published in the Expert AutoStats® program, or some other stiffness value, possibly a modification/refinement of the Emori equation[2] for a specific type of collision.

A short digression is now called for. The term "Kinetic Energy Equivalent Speed" to the best of the author's knowledge was first used and published by Daniel W. Vomhof III and Daniel W. Vomhof, Ph.D. in the Expert AutoStats® program in 1991. In most collisions no fixed, non-deformable barrier is involved. Thus the creation of this term, which they believe is a better descriptor of what is being dealt with in the context of vehicle collisions than the more commonly used term "*Equivalent Barrier Speed*," or any other term[3] using the word "*Barrier*." There have been some stated objections to using the term "Kinetic Energy" when discussing this speed, since a spring formula is being used (in the case of the Crash III model's A-B-G values), and a spring model calculates Potential Energy. The creators of the term disagree with this objection for the following three reasons:

1) Potential Energy is stored energy. In the aftermath of a collision, the Potential Energy of the undamaged vehicle has been changed to Kinetic Energy in the crushing of the vehicle,
2) Not all formulas for calculating "Speed from Crush" are based on a spring model, and

3) In most cases, while a Potential Energy model may be the mathematical model, the model is being used to calculate a Kinetic Energy loss, which is what is important to the accident investigator and reconstructionist.

Finally, there has been some objection to the term "Kinetic Energy" because other forms of energy are released in a collision - primarily heat, sound, and light. While these energies are acknowledged, they have not been generally measured, and they are not of (primary) concern to the accident investigator/reconstructionist. Further, these are the energies that the Kinetic Energy is being "changed" into, and thus, the flip side of the energy "coin."

Kinetic Energy Equivalent Speed (KEES) - Why calculate it??

The calculations of the stiffness values become somewhat more complicated when a side impact or rear impact test is conducted, or when a frontal impact test is conducted with a moving "barrier."

Before going further, think about two commercials commonly seen on television in the United States. The first commercial is for a Mercedes. This commercial shows the vehicle approaching a barrier, crushing, and coming to a stop right there at the barrier. This illustrates your common frontal barrier test. The second commercial is for a Saturn. This commercial shows an oncoming barrier approaching the driver's door. At the last moment the camera angle changes to an overhead view and shows the barrier impacting the vehicle and then barrier and vehicle continue out of camera view. This illustrates the problem with the side and rear impact tests. Not ALL of the energy of the moving barrier is used in crushing the vehicle. Only a portion of that energy is transferred or "lost" in damaging the target vehicle.

This is a VERY important and often overlooked point when attempting to calculate vehicle stiffness values based upon crash test data. When the full closing speed is used to calculate stiffness values, erroneously high values are the result. In order to calculate "correct" stiffness values, the speed equivalent to the energy that went into damaging the vehicle MUST be calculated.

Kinetic Energy Equivalent Speed (KEES) - How to calculate it??

One method of calculating the KEES of the lost energy is through the following equation:

Equation #2:

$$KEES = \sqrt{30 * \frac{\frac{0.5}{32.2} * \left[IW * \left(\frac{I_{IS} * 5280}{3600} \right)^2 - (IW) * \left(\frac{I_{PIS} * 5280}{3600} \right)^2 - (VW) * \left(\frac{V_{PIS} * 5280}{3600} \right)^2 \right]}{IW}}$$

IW = *Impactor Weight*, I_{IS} = *Impactor Impact Speed*, I_{PIS} = *Impactor Post Impact Speed*
VW = *Vehicle Weight*, V_{PIS} = *Vehicle Post Impact Speed*

In this formula the object weight used as the divisor in calculating the KEES, is the moving impactor barrier weight because that is the object imparting the damage. The more commonly used object weight in the divisor is that of the vehicle being impacted. Which weight to use, and why, will be resolved later in this paper.

In addition to the divisor weight question, there is another problem that needs to be dealt with before this formula can be used. The NHTSA Crash Test database does not currently report the Post Impact Speeds for any of their tests. This is most particularly of concern for any of the NON-FRONTAL (side and rear) impact tests, as well as the frontal impact tests involving a moving impact "barrier." Since this important item of data is not reported, one or more assumptions must be made. The first assumption is that the Impactor and Vehicle reach a common post impact velocity. To help the non-reconstructionist visualize this, it is further assumed that the impactor and vehicle "stick" together post impact, thus illustrating the two vehicles reaching and maintaining a common post impact speed. Finally, it is assumed that there is no rotational energy involved post impact.

With these assumptions, Equation #2 may be simplified to:

Equation #3:

$$KEES = \sqrt{30 * \frac{\frac{0.5}{32.2} * \left[IW * \left(\frac{I_{IS} * 5280}{3600} \right)^2 - (IW + VW) * \left(\frac{PIS * 5280}{3600} \right)^2 \right]}{IW}}$$

$$IW = Impactor\ Weight,\ I_{IS} = Impactor\ Impact\ Speed$$
$$VW = Vehicle\ Weight,\ PIS = Post\ Impact\ Speed$$

Using the same assumptions, the calculations may be further simplified through the principle of reduced mass. One important aspect of the principle of reduced mass is the idea of frame of reference. If one views the collision from the frame of reference of the impacting barrier, the barrier approaches the vehicle, impacts the vehicle, and then has continuing post impact movement in the direction of its original path of travel. If one views the collision from the frame of reference of the vehicle, the vehicle approaches the barrier,[4] impacts the barrier, and then "rebounds" from the barrier. The rebounding movement has been traditionally ignored in the calculation of stiffness values. The principle of reduced mass, allows for the calculation of the energy loss in the barrier impact[5]. The expanded reduced mass formula is:

Equation #4:

$$Energy_{MaximumDamage} = \frac{0.5 * Mass_{Vehicle_1} * Mass_{Vehicle_2} * V_{Closing}^2}{Mass_{Vehicle_1} + Mass_{Vehicle_2}}$$

$$V_{Closing} = Closing\ Velocity\ (Speed)\ in\ feet\ per\ second$$

Substituting in the NHTSA specific terms for the general terms the formula becomes:

Equation #5:

$$Energy_{MaximumDamage} = \frac{0.5 * Mass_{Impactor} * Mass_{Vehicle} * V^2_{Closing}}{Mass_{Impactor} + Mass_{Vehicle}}$$

$$V_{Closing} = Closing\ Velocity\ (Speed)\ in\ feet\ per\ second$$

When the speed is reported in miles per hour and the weights are in pounds, this formula becomes:

Equation #6:

$$Energy_{MaximumDamage} = \frac{0.5 * \frac{Weight_{Impactor}}{32.2} * \frac{Weight_{Vehicle}}{32.2} * \left(Speed_{Clo}sing * \frac{5280}{3600}\right)^2}{\frac{Weight_{Impactor}}{32.2} + \frac{Weight_{Vehicle}}{32.2}}$$

Simplified the equation reads as:

Equation #7:

$$Energy_{MaximumDamage} = \frac{1089}{65205} * \frac{Weight_{Impactor} * Weight_{Vehicle} * (Speed_{Closing})^2}{Weight_{Impactor} + Weight_{Vehicle}}$$

The KEES is now calculated as:

Equation #8:

$$Speed_{(mph)} = \sqrt{\frac{30 * Energy_{MaximumDamage}}{(ObjectWeight_{(pounds)})}}$$

Using the same reasoning process as before, that the object imparting the damage should be in the divisor, the Object weight to be used is the Vehicle Weight rather than the Impactor Weight (remember, we are assuming the Vehicle hits the barrier). The resulting “final” equation is therefore:

Equation #9:

$$Speed_{(mph)} = \sqrt{\frac{30 * Energy_{MaximumDamage}}{(Vehicle\ \ Weight_{(pounds)})}}$$

We have now seen a logical, rational, explanation where either the Impactor Weight or the Vehicle Weight is the proper weight to use in the divisor. But which is correct??!!??

Kinetic Energy Equivalent Speed (KEES) - Cautions to be aware of:

First caution - again, why calculate the KEES speed?

To illustrate the effect of using the reported impact speed vs. the KEES speed, consider the NHTSA Rear Impact test for a 1988 Chevrolet Cavalier (# 1279). The pertinent data is as follows:

Impactor Weight = 4000 pounds
Vehicle test weight = 3989 pounds
Closing speed = 29.4 mph
average crush depth = 13.1 inches
a "No damage" value of 5 mph
crush width = vehicle width = 65.5 inches.

When one calculates the A-B-G values based upon the closing speed of 29.4 mph, the results are:
A = 457.1, B = 170.7, G = 612.0

Using the same data, the KEES speed = 20.8 mph, and the A-B-G values based on this speed are:
A = 295.3, B = 71.3, G = 612.0

It can be seen that there is a significant difference between the two A-B stiffness results. To get the proper visualization of what is being calculated in the first set of stiffness values, picture a vehicle with steel rods securing the vehicle to the ground at each of the four tires. The Impactor barrier hits the vehicle, and ALL of the impact energy of the impactor barrier goes into the resultant crush of the vehicle. When using these stiffness results for a reconstruction of a rear-ender collision involving a similar Chevrolet Cavalier, a higher than actual speed calculation will be the likely result.

Second caution - which "vehicle" weight should be used in the divisor for the KEES speed calculation?

Again using the data from NHTSA test #1279, what is the difference on the KEES speed between using the Impactor Weight and the Vehicle Weight in the divisor? If the calculated Energy loss = 57663.798, then the KEES speed calculated using the Impactor Weight =20.796 mph, and the KEES speed using the Vehicle Weight = 20.825 mph, a difference of only 0.029 mph. A difference which is not enough to be concerned about, and is in fact practically an invisible difference . . . when the weights are close.

However, let us now apply a principle of ESP[6] (Exaggeration of System Parameters) and substitute your "typical" tractor (also called a "semi-tractor" or "over-the-road tractor") for the impacting barrier, which is the nearest thing the author can think of to a "non-deformable" impactor barrier in a "real" collision. While the vehicle weight remains at 3,989 pounds, the barrier weight now becomes 13,500 pounds which results in a calculated Energy loss of 88900.553. When the ***vehicle weight*** is the divisor the resulting KEES speed is 25.857 mph, and when the ***impactor weight*** is the divisor the KEES speed is 14.056 mph. While both speeds are mathematically correct and valid, this, most would agree, is a SIGNIFICANT difference in speeds.

Which speed is “truly correct”? What is the point? If both speeds are “valid,” what does this illustrate?

This example illustrates the point that when calculating the KEES speed, use the divisor weight of the “vehicle” for which the stiffness values are to be calculated.[7] [8] This is the weight to use, NOT because we are pretending it is the object imparting the damage, but because IT is the vehicle upon which the energy loss is acting.

Summation and Conclusions

The concept of a KEES speed, by whatever name it is called, is important. Its calculation is simplified when the collision is into a fixed barrier, much as the speed change from skid is simplified when the ending speed is zero. However, just as when the ending speed is not zero, the speed change from skidding becomes more complicated, so does the calculation of the KEES speed become more complicated when the barrier is not fixed. In order to obtain a correct initial speed when the ending speed from skid is not zero it is important to go through extra calculations. Likewise, if one is going to calculate stiffness values from vehicles in test crashes to be applied to a vehicle involved in a side or rear impact collision, it is just as important to go through the extra calculations to obtain the KEES speed.

The calculations demonstrated have often times either not been made or made incorrectly. In fact this paper came about due to questions arising regarding calculation errors in A-B-G stiffness values in NHTSA test # 1279. As also demonstrated, an incorrect test speed WILL lead to incorrect stiffness values, and thus an incorrect speed calculation in the subject collision.

Finally, it must be remembered that while the NHTSA crash data is usually the best data available, several critical assumptions MUST be made in order to calculate stiffness values for the side and rear of test vehicles. These assumptions may, or may not, be valid. Therefore, the reliance upon the speed calculations made based upon the calculated stiffness values must always be examined carefully by the accident reconstructionist.

1. Throughout this paper, if no units are stated, weights are in pounds and speeds are in miles per hour.

2. "The Investigation of Automobile Collisions with Wooden Utility Poles and Trees" as presented by Joseph Cofone at the S.A.T.A.I. Spring Conference, 3/9-10/2001.

3. For a variety of terms, the reader is referred to DOT/HS 800 624 and the following SAE papers - 680016, 740565, 850256, 850437, 930899, 940914, 2000-01-0462, 2001-01-0499, and 2001-01-0500.

4. Again, refer to the Saturn commercial. As one views the approaching barrier, the viewer does not know if the barrier is approaching the vehicle or if the vehicle is approaching the barrier. We only "know" that the barrier is approaching the vehicle due to our having knowledge not immediately present in the camera shot.

5. The reduced mass principle can be stated as [m1*m2/(m1+m2)]. Mr. Bonnett has further refined this for his applications of determining CEEBS (Crush Energy Equivalent Barrier Speed). Mr. Bonnett discusses this further in an as yet unpublished paper "**Stiffness Coefficients - Energy and Damage"** © George M. Bonnett, JD 2001 All Rights Reserved. It is also discussed in SAE papers 850437, 930899, 2000-01-0462, 2001-01-0499, and 2001-01-0500.

6. I first saw a reference to this term in the book ***Star Driver***, ©1980 by Lee S. Corey. In applying this principle you make some part of what you are working on very big, very small, very fast, very slow, etc. blowing that part totally out of proportion to the rest of what you are working on. This then helps to see problems where they might otherwise not be detected, as in the case of which object weight to use. When both objects are nearly the same weight and the numerical display is only to one decimal place, the difference in speeds are not detected, in both cases for test 1279 "the calculated speed" is 20.8 mph.

7. As a result of work on this paper, the formula used at 4N6XPRT Systems for calculating the KEES speed from the NHTSA crash test data has been modified to:

$$KEES_{MPH}=\sqrt{30*\frac{\frac{0.5}{32.2}*\left[IW*\left(\frac{I_{IS}*5280}{3600}\right)^2-(IW+VW)*\left(\frac{PIS*5280}{3600}\right)^2\right]}{VW}}$$

$$IW = Impactor\ Weight\ (pounds),\ I_{IS} = Impactor\ Impact\ Speed\ (MPH),$$
$$VW = Vehicle\ Weight\ (pounds),\ PIS = Post\ Impact\ Speed\ (MPH)$$

8. Further condensation of Equations 7 & 9 results in the following "simplified" equation:

$$KEES_{MPH} = \sqrt{\frac{484}{483} * \frac{ImpactorWeight_{(pounds)} * ClosingSpeed^2_{(MPH)}}{ImpactorWeight_{(pounds)} + VehicleWeight_{(pounds)}}}$$

Crush Factor: A Validity Analysis (Frontal)

ACCIDENT RECONSTRUCTION JOURNAL

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Modeling the Speed, Acceleration and Deceleration of Bicyclists
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Crush Factor: A Validity Analysis
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ACCIDENT RECONSTRUCTION JOURNAL

VOLUME TWENTY NINE, NUMBER ONE **JANUARY/FEBRUARY, 2019**

FEDERAL SHUTDOWN SLOWS PROBES OF TRANSPORTATION DEATHS

Because of the partial federal government shutdown, 10 new crashes in which 22 people died have not been investigated by the National Transportation Safety Board.

The nation's top transportation oversight investigative agency has been unable to study the circumstances of seven plane crashes in which 13 people were killed, two fatal railroad crashes, a highway crash in which seven people died and an incident in which a school bus collided with a tractor-trailer, injuring 15.

The NTSB also was unable to gather enough information to determine whether to send investigators to three other crashes — two on roadways and one on rails — that killed eight people.

"The National Transportation Safety Board's mission to promote safety in transportation has come to almost a complete halt because of this absurd government shutdown," said Rep. Peter A. DeFazio (D-Ore.), the new chairman of the House Transportation Committee. "This means dozens of ongoing investigations are sitting idle, and that numerous accidents that have occurred since the shutdown are not getting investigated.

"When NTSB employees cannot determine what caused an accident, we can't establish how to prevent similar accidents from happening," DeFazio said. "For the safety of all those who travel within our country, we must reopen the government."

Dolline Hatchett, acting director of the NTSB's Office of Safety Recommendations and Communications, said the agency's investigators have been furloughed and it is unable to go to "major accidents, as well as other accidents where specific risks to transportation safety exist."

NTSB investigators routinely are sent when planes and trains are involved in fatal crashes, and they often are dispatched to look at vehicle crashes such as the October limousine crash in Upstate New York that killed the driver, his 17 passengers — including four sisters and three of their husbands — plus two pedestrians.

Since the shutdown began, the agency has been unable to send teams to fatal small-plane crashes in Georgia, Florida, South Dakota, Tennessee and California. Two fatal rail crashes in New York have not been scrutinized by the agency. Neither has a Jan. 3 highway collision involving two tractor-trailers in a crash with a 15-passenger van that resulted in seven deaths. *- Washington Post*

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VICTOR CRAIG - EDITOR

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CRUSH FACTOR: A VALIDITY ANALYSIS - PART I (FRONTAL)

by Daniel W. Vomhof III and Daniel W. Vomhof, PhD

Background

4N6XPRT Systems began selling the Expert AutoStats® program in December 1991. As part of that program a set of "Crush Factor" values was published. These values were the summary of data analysis performed by the authors independently and jointly. None of the in-depth background analysis used to arrive at the Crush Factor values was published at that time or subsequently. However, a brief discussion of the authors' efforts was presented at the "Crash 98" conference.

The approach of calculating speed from crush using the speed from skid formula:

$$S = \sqrt{30*d*f}$$

Where: S = Speed in miles per hour,
f = drag factor
d = distance in feet

was originally 'suggested' to the authors in the "Traffic Accident Investigation Manual" by J. Stannard Baker. [Ref. 1] One of the tables on page 245 in that First Edition was titled "Typical Values of Acceleration and Deceleration for Motor Vehicles on Level Surfaces". Two lines were found at the bottom of that table are presented here in Table 1.

No discussion as to how these factors were arrived at was presented in the manual. The authors found that the value of -5 for a vehicle-to-vehicle impact was much lower than was practical based on vehicle reconstructions when they used this approach. However, in many of the reconstructions where they had other independent ways of calculating vehicle speeds other than using the crush, such as momentum, the values obtained using the -20 value seemed to be in reasonable agreement with the other methods. The authors found that depending upon both the physical evidence and the "fact" situation, a Crush Factor of between 15-22 to calculate a speed from crush matched well with other speed estimates in nearly every situation.

The Crush Factor is obtained/calculated in the same manner as a drag factor:

$$CF = \frac{S * S}{MID*30}$$

Where: S = Speed in miles per hour,
CF = Crush Factor,
MID = Maximum Indentation Depth (in feet)

The NHTSA Crash tests, as published in the *Accident Reconstruction Journal* [Ref. 2-6] as well as crash test data published by Engineering Dynamics Corp, [Ref. 7] were analyzed to find an independent Crush Factor Value based on crash tests as opposed to a value which was to a certain extent "force fit" into a crash reconstruction. Much of the data published by Engineering Dynamics was for vehicles older than the vehicles contained in the NHTSA crash test database, [Ref. 8] which is important for reconstructionists who work in areas outside of the snow/rust belt of the United States where vehicles are on the road for 10, 20, 30, and more (sometimes MANY more) years after they were originally sold.

Since the value in question was being used to evaluate Speed from Crush, the authors retitled the value "Crush Factor" in order to separate it from a speed from skid (and because it avoided the question of what was dragging across what).

The analysis of the various crash test data previouslyreferred to found that the tests tended to group about a Crush Factor of 21. Using a Crush Factor value of 21 in a back calculation of speed in each of the tests resulted in a calculated speed within +/- 5 mph of the recorded test closing speeds for the vast majority of the tests. The round number of CF=21 for frontal damage was used, in part, because:

- it was based upon known crash tests,
- it could be easily checked by others in the accident reconstruction community,
- it was usable in a commonly recognized formula,
- it was EASY to use...ESPECIALLY while on the witness stand or in a deposition,
- a whole number, as opposed to a number with decimals attached, was easy to remember,
- it was felt it would be of benefit to others in the accident reconstruction community, and
- it was independent of make, model, year, or body style of vehicle where the GVWR was under 10,000 pounds

TABLE 1. Typical Values of Deceleration for Motor Vehicles on Level Surfaces [Ref. 1]			
Deceleration Type	**Drag Factor**	**Meters/sec/sec**	**Feet/sec/sec**
Car Crash into Standing Car	5.00	49.01	161.0
Car Crash into Solid Fixed Object	20.00	196.0	644.0

Since originallypublishing the Crush Factor values there has been some resistance in certain quarters to using the approach, for one or more of the following reasons:

- it's too simple,
- one stiffness value cannot possibly be valid for all vehicles,
- the approach becomes erratic when minimal crush is present.

Thus, it was felt that it was time to re-evaluate the Crush Factor value both to give more background to the value AND to see if it had changed significantly since the original work was completed 33 years ago.

Analysis Process and Assumptions

In order to generate the initial data groups the 4N6XPRT StifCalcs® program was used to search the NHTSA Crash Test database (as downloaded on May 12, 2017) for all frontal crash tests in the database. One data set was developed based on the calculated AVERAGE crush, the other based on the MAXIMUM crush. Figure 1 and Figure 2 show the Average Crush data summaries.

It can be seen that the total number of frontal impact tests available where average crush can be calculated is 3045 tests.

The speed used for the stiffness calculation is the Kinetic Energy Equivalent Speed (KEES) rather than the Closing Speed. In the event that the vehicle is moving and strikes a fixed barrier, KEES = Closing Speed. However, when a barrier is moving and impacts the vehicle, the KEES needs to be used instead of the Closing Speed, as the Closing Speed will be erroneously high. The authors define the Kinetic Energy Equivalent Speed as the Kinetic Energy required to create the damage expressed as a speed.

The data was then imported into an Excel spreadsheet for further analysis and filtering.

The 4N6XPRT StifCalcs® program provides test summaries with the statistical measurements of the data set of: Number of tests, Average, Minimum, Maximum, and Standard Deviation (Sample). The Average value output by the program is the Arithmetic Mean value of the data. By using the Excel program the analysis can add the additional AVERAGE measurement methods of MEDIAN - the central value of the data set, MODE

- the most commonly occurring value in the data set, and QUARTILE 2 - the 50% value of the data set, which is also the MEAN. Further use of the Excel spreadsheet allows display of Quartiles 0-4 from which we can quickly see the values within the data set of various data points at the minimum (Q0), 1/4 point (Q1), ½ point (Q2), 3/4 point (Q3) and the maximum (Q4). Finallywe can easily displaythe Standard Deviation value spread from the AVERAGE (Mean) value rather than having the reader do the calculations in their head. In each case the Standard Deviation value used for this display is the SAMPLE Standard Deviation. Where the "A" stiffness value was negative, the A-B-G stiffness values were deleted but the test as a whole was retained as the data for a Crush Factor was still available. Where the Kv stiffness values were negative those values were also deleted.

When the analysis of the Crush Factor is broken down by body style, an additional filter of an upper threshold value for the "A" stiffness value is applied. The values applied are based on the calculation of A-B-G stiffness values and application of those values to vehicles involved in crash tests for hundreds of vehicles.

The A value is commonly defined as ***"A = Maximum force per inch of damage without permanent damage"***. This can be confirmed through unit analysis. Restated, when the Force per inch of crush length exceeds that shown in the A value, you will have permanent crush, when the Force is less than that shown in the A value, you will see no damage post impact. Values above the filter thresholds applied are usually indicative of measurement errors and/or "air gap" issues within the data.

Additional discussion of the A value filter and why the particular values were chosen is present in the discussion of each body type data set.

To help the reader quickly see various items, the Crash III "A" value column and the Crush Factor column have been highlighted with color. Additionally, selected values have been boxed as they are important and will be discussed in the analysis.

Part of the maximum crush Crush Factor analysis also includes a "back calculation" of the KEES speed based on the reported maximum crush and an evaluation of the calculated speed as compared to the reported speed.

For the purposes of this analysis, it is assumed that:

- the data contained in the NHTSA database is correct, which based on our analysis of the database, for the majority of the data is a valid assumption,
- the data is assumed to have a normal distribution

Maximum Crush vs. Average Crush

It should be noted that the calculation of the Crush Factor as published in the Expert AutoStats® program, and thus the speed from crush in a subject accident, was based on the "maximum crush", not the average crush as was, and is today, more common. This was intentionally done for several reasons, including:

- ease of calculation using one point instead of multiple points,
- reduced measurement, and calculation time,
- relative ease of spotting the measurement point in the field, and
- in general represents the point of maximum work/energy exchange

Since the original work was completed, it has been found that using the maximum crush has the added benefit of having a "data normalization" effect which is important for offset and pole tests. Additionally, a review of the statistical summary of the data shows increased "scatter" in the results when the average crush is used for the crush depth. (See Figures 1 & 2) Figure 1 is a summary of the entire NHTSA database as of May 12, 2017 with calculations based on the Average Crush Depth, and Figure 2 is the same database filtered with the following restrictions: the Crush Factor Value is in the range of 0<CF<100 and the Average Crush Depth, in inches, is within the range of 0<Crush<60. A quick review of these tables will begin to indicate to the reader why the original analysis was based on the maximum crush. No further work beyond these two tables will be shown in this discussion.

Maximum Crush - All Tests - No Filter

Figure 3 shows the data summary for all Frontal Tests where stiffness can be calculated based upon MAXIMUM crush. It should be noted that there are a total of 3056 tests available for use using maximum crush where as noted previously there are only3045 tests with the availability of AVERAGE crush.

The first thing to note in this table

Year	Make	Model	Body Style	No Damage Speed (mph)	Average Crush (inch)	KEES	A	B	G	Kv	Crush Factor	b_sub_1	Crush Length	Vehicle Weight (pounds)
Number of Tests (n)				3045	3045	3045	3045	3045	3045	3045	3045	3045	3045	3045
Average (AVG)				5	13.2	32.3	13088.4	28423375.0	223.1	46947549.1	883.1	1166.2	69.6	3811.6
Minimum (MIN)				5	0.0	4.7	-96379.3	-42739.8	-123367.6	-61951.7	5.2	-8.8	-0.4	1829.5
Maximum (MAX)				5	69.5	61.6	6764107.2	44862276416.6	6455.8	75593115214.7	374924.0	583651.4	229.7	17756.8
Standard Deviation (STDev-sample)				0	6.8	6.3	170957.8	880045294.6	5690.1	1477205730.8	10018.1	14581.8	7.4	954.7
Standard Deviation (STDev-population)				0	6.8	6.3	170929.7	879900776.1	5689.1	1476963148.3	10016.4	14579.4	7.4	954.5
Median				5	14.2	34.9	433.3	163.2	531.3	231.7	29.2	33.5	70.0	3709.6
Mode				5	0.1	35.0	301.0	114.2	566.7	91.3	25.1	34.1	66.5	2999.9
Quartile 0				5	0.0	4.7	-96379.3	-42739.8	-123367.6	-61951.7	5.2	-8.8	-0.4	1829.5
Quartile 1 - 25%				5	8.9	29.5	333.9	107.8	469.1	151.8	24.2	28.1	66.7	3152.0
Quartile 2 - 50%				5	14.2	34.9	433.3	163.2	531.3	231.7	29.2	33.5	70.0	3709.6
Quartile 3 - 75%				5	17.7	35.1	625.9	324.5	603.6	477.1	41.1	47.7	72.9	4366.5
Quartile 4				5	69.5	61.6	6764107.2	44862276416.6	6455.8	75593115214.7	374924.0	583651.4	229.7	17756.8
	-2 Std Dev						-328827.2	-1731667214.2	-11157.1	-2907463912.4	-19153.1			
	-1 Std Dev						-157869.4	-851621919.6	-5467.0	-1430258181.7	-9135.0			
	Average						**13088.4**	**28423375.0**	**223.1**	**46947549.1**	**883.1**			
	+1 Std Dev						184046.2	908468669.6	5913.1	1524153279.9	10901.1			
	+2 Std Dev						355004.1	1788513964.2	11603.2	3001359010.6	20919.2			

5 - 2017 Front AVG Summary / 0<CF<100 Cr<60 / CAR 0<A<500 / Pickup 0<A<650 / VAN 0<A<700 / Utility 0

Figure 1

is that while the average Crush Factor value is 24.9, the Median/Q2 value (the central value) is 21.3. It can also be seen that the back calculation of speed based on the Max Crush depth and a CF=21 value calculates the speed from crush for at least 75% of the tests within a +/- 5 mph range.

The lack of filtering of the data set leads to some very wide data scatter as can be seen from the Standard Deviation values for the various calculated stiffness values (A-B-G-Kv-CF).

Maximum Crush - All Tests - Filters = 0<CF<100 and 0<Crush<60

Figure 4 is the summary of the data after the most extreme outliers are eliminated. The tests where the Crush Factor was not positive (equal or less than 0) or greater than 100 were deleted, as were the tests where the reported maximum crush was not positive or was greater than 60 inches. This filtering resulted in the elimination of 57 tests, bringing the total number of tests evaluated down to 2999. The Average (MEAN) CF value of all the tests has dropped to 22.1 and the Median/Q2 value (the central value) is still at 21.3.

The Standard Deviation values for the A-B-G stiffness values are still running more than 100, which is a good indication that this data set still has some significant scatter. However, even with this scatter more than 75% of the tests are within +/- 5 mph of the KEES.

At this point, it has been shown that, based on the current NHTSA Crash Test database, speed from crush for frontal impacts accurate to within +/- 5 mph can be obtained 75+% of the time using a Crush Factor of 21 for all vehicles.

It will now be explored whether this holds true when specific body types are ex-

Test Number	Year	Make	Model	Body Style	No Damage Speed (mph)	Average Crush (inch)	KEES	A	B	G	Kv	Crush Factor	b_sub_1	Crush Length	Vehicle Weight (pounds)
	Number of Tests (n)				2695	2695	2695	2695	2695	2695	2695	2695	2695	2695	2695
	Average (AVG)				5	14.7	31.9	299.6	180.2	304.4	286.3	31.9	37.1	69.9	3859.9
	Minimum (MIN)				5	0.2	4.7	-78725.7	-25164.3	-123367.6	-36538.8	3.7	-8.8	-0.4	1829.5
	Maximum (MAX)				5	48.0	60.0	4507.8	3348.7	6455.8	28195.7	99.1	156.8	229.7	17756.8
	Standard Deviation (STDev-sample)				0	5.5	5.7	3209.4	1094.2	4917.9	1761.4	14.9	17.4	7.3	961.7
	Standard Deviation (STDev-population)				0	5.5	5.7	3208.8	1094.0	4917.0	1761.1	14.9	17.4	7.3	961.6
	Median				5	15.1	34.9	408.2	146.8	535.8	208.2	28.0	32.0	70.1	3755.9
	Mode				5	15.3	35.0	294.3	92.4	566.7	91.3	25.1	34.1	66.5	2999.9
	Quartile 0				5	0.2	4.7	-78725.7	-25164.3	-123367.6	-36538.8	3.7	-8.8	-0.4	1829.5
	Quartile 1 - 25%				5	11.4	29.5	321.8	103.0	473.1	145.3	23.6	27.4	66.8	3177.3
	Quartile 2 - 50%				5	15.1	34.9	408.2	146.8	535.8	208.2	28.0	32.0	70.1	3755.9
	Quartile 3 - 75%				5	18.2	35.1	527.4	233.6	610.7	335.4	34.8	40.1	73.1	4432.6
	Quartile 4				5	48.0	60.0	4507.8	3348.7	6455.8	28195.7	99.1	156.8	229.7	17756.8
		-2 Std Dev						-6119.2	-2008.2	-9531.5	-3236.6	2.0			
		-1 Std Dev						-2909.8	-914.0	-4613.6	-1475.2	17.0			
		Average						299.6	180.2	304.4	286.3	31.9			
		+1 Std Dev						3509.0	1274.3	5222.3	2047.7	46.9			
		+2 Std Dev						6718.4	2368.5	10140.2	3809.1	61.8			

0<CF<100 Cr<60 | CAR 0<A<500 | Pickup 0<A<650 | VAN 0<A<700 | Utility 0<A<650

Figure 2

13	Year	Make	Model	Body Style	No Damage Speed (mph)	Max Crush (inch)	KEES	A	B	G	Kv	Crush Factor	CF=21 Calc'd Speed	Speed Error Over	Speed Error Under	
3071																
3072			Number of Tests (n)		3056	3056	3056	3056	3056	3056	3056	3056	3056	1438	1618	Number of Tests (n)
3073			Average (AVG)		5	20.2	32.3	164.3	172.7	223.8	275.4	24.9	32.0	4.2	-4.2	Average (AVG)
3074			Minimum (MIN)		5	0.3	0.0	-66172.7	-20658.8	-123367.6	-30049.2	0.0	4.0	0.0	-47.0	Minimum (MIN)
3075			Maximum (MAX)		5	133.8	61.6	7937.4	56030.5	6455.8	80670.5	508.4	83.8	50.2	0.0	Maximum (MAX)
3076			Standard Deviation (STDev-sample)		0	7.7	6.4	3165.6	1930.0	5679.9	3127.1	28.2	6.0	5.2	5.9	Standard Deviation (STDev-sample)
3077			Standard Deviation (STDev-population)		0	7.7	6.4	3163.1	1929.7	5678.9	3126.6	28.2	6.0	5.2	5.9	Standard Deviation (STDev-populatic
3078																
3079	2006		Median		5	20.1	34.9	296.0	80.7	531.2	113.6	21.3	32.5	2.6	-2.6	Median
3080	2013		Mode		5	21.5	35.0	269.7	79.4	566.7	105.9	20.9	33.6	1.2	-1.4	Mode
3081																
3082														1079	1214	75% of Speed Sample
3083																
3084	1976		Quartile 0		5	0.3	0.0	-66172.7	-20658.8	-123367.6	-30049.2	0.0	4.0	0.0	-47.0	Quartile 0
3085	1995		Quartile 1 - 25%		5	16.5	29.5	240.4	59.2	469.1	83.5	18.1	29.4	1.1	-4.7	Quartile 1 - 25%
3086	2006		Quartile 2 - 50%		5	20.1	34.9	296.0	80.7	531.2	113.6	21.3	32.5	2.6	-2.6	Quartile 2 - 50%
3087	2012		Quartile 3 - 75%		5	23.4	35.1	364.7	112.6	603.3	158.8	24.9	35.0	4.9	-1.2	Quartile 3 - 75%
3088	2017		Quartile 4		5	133.8	61.6	7937.4	56030.5	6455.8	80670.5	508.4	83.8	50.2	0.0	Quartile 4
3089																
3090			-2 Std Dev			//	------------	-6162.9	-3687.4	-11135.9	-5978.7	-31.4				
3091			-1 Std Dev			/////	//---	-2999.3	-1757.3	-5456.1	-2851.7	-5.3				
3092			Average			95%	68%	164.3	172.7	223.8	275.4	24.9				
3093			+1 Std Dev			\\\\\	\\---	3327.8	2102.7	5903.6	3402.5	53.1				
3094			+2 Std Dev			\\	------------	6491.4	4032.7	11583.5	6529.5	81.3				
3095																

1965 - 2017 Front MAX Summary | 0<CF<100 Cr<60 | CARS A<500 | Pickups A<800 | VANS A<700 | Utility A-

Figure 3

amined, or do the large amount of CAR front ends "swamp out" differences in the smaller number of samples PICKUP, VAN, and UTILITY vehicle types.

Maximum Crush - All Tests -
Filters = CAR and "A"<500

Figure 5 shows the CAR type vehicles from the data set that resulted in Figure 4, with the application of an additional filter that eliminates tests where the "A" stiffness value is greater than 500. The CAR data set has a total of 1918 tests after this filtering is completed. The benefit of the additional filter based on the "A" stiffness value can be seen in that the Standard Deviation for the "A" value has dropped to ~77, and the "B" and "G" Standard Deviations have dropped to even lower values, which indicates a "tighter" data set.

The Average (MEAN) CF value of all the tests has dropped to 21.1 and the Median/ Q2 value (the central value) is at 20.9. Looking at the Quartile analysis, the 75% point in overestimating the speed is just above 5 mph higher (5.1 mph) than the KEES. On the underestimate side, the speed is only 4 mph less than the KEES. The authors are confident that an in-depth evaluation would show that a CF=21 value would still estimate more than 75% of the tests within +/- 5 mph. That analysis will be discussed in a subsequent paper.

Maximum Crush - All Tests -
Filters = PICKUP and "A"<800

Figure 6 shows the PICKUP type vehicles from the data set that resulted in Figure 4, with the application of an additional filter that eliminates tests where the "A" stiffness value is greater than 800. The PICKUP data set has a total of 287 tests after this filtering is completed. The filtering based on the "A" stiffness value of less than 800 only dropped the Standard Deviation for the "A" value to ~101. However, experience with the NHTSA database has shown that because some Heavy Duty Pickups with their sturdier frames are included in the database, a higher top threshold "A" value is appropriate.

13	Year	Make	Model	Body Style	No Damage Speed (mph)	Max Crush (inch)	KEES	A	B	G	Kv	Crush Factor	CF=21 Calc'd Speed	Speed Error Over	Speed Error Under	
3014																
3015			Number of Tests (n)		2999	2999	2999	2986	2986	2986	2989	2999	2999	1424	1575	Number of Tests (n)
3016			Average (AVG)		5	20.2	32.1	313.6	101.5	546.6	151.8	22.1	32.2	4.0	-3.5	Average (AVG)
3017			Minimum (MIN)		5	0.3	4.7	44.1	2.6	255.3	5.1	2.1	4.0	0.0	-31.5	Minimum (MIN)
3018			Maximum (MAX)		5	58.3	61.6	2334.7	3700.9	6455.8	12142.9	97.9	55.3	34.3	0.0	Maximum (MAX)
3019			Standard Deviation (STDev-sample)		0	6.2	5.8	132.5	132.1	153.5	322.8	8.8	5.1	4.4	3.8	Standard Deviation (STDev-sample)
3020			Standard Deviation (STDev-population)		0	6.1	5.8	132.4	132.1	153.5	322.8	8.8	5.1	4.4	3.8	Standard Deviation (STDev-population)
3021																
3022	1999		Median		5	20.2	34.8	295.6	80.6	532.4	113.2	21.3	32.6	2.6	-2.5	Median
3023	2001		Mode		5	21.5	35.0	269.7	79.4	566.7	105.9	20.9	33.6	1.2	-1.4	Mode
3024																
3025														1068	1181	75% of Speed Sample
3026																
3027	1972		Quartile 0		5	0.3	4.7	44.1	2.6	255.3	5.1	2.1	4.0	0.0	-31.5	Quartile 0
3028	1990		Quartile 1 - 25%		5	16.7	29.5	241.3	59.5	471.1	83.7	18.1	29.6	1.1	-4.4	Quartile 1 - 25%
3029	1999		Quartile 2 - 50%		5	20.2	34.8	295.6	80.6	532.4	113.2	21.3	32.6	2.6	-2.5	Quartile 2 - 50%
3030	2007		Quartile 3 - 75%		5	23.4	35.1	361.7	111.2	604.4	156.9	24.7	35.0	4.8	-1.2	Quartile 3 - 75%
3031	2017		Quartile 4		5	58.3	61.6	2334.7	3700.9	6455.8	12142.9	97.9	55.3	34.3	0.0	Quartile 4
3032																
3033			-2 Std Dev			//	--------	48.7	-162.7	239.6	-493.9	4.6				
3034			-1 Std Dev			/////	//---	181.1	-30.6	393.1	-171.0	13.4				
3035			**Average**			95%	68%	**313.6**	**101.5**	**546.6**	**151.8**	**22.1**				
3036			+1 Std Dev			\\\\\	\\---	446.0	233.6	700.1	474.7	30.9				
3037			+2 Std Dev			\\	--------	578.5	365.7	853.6	797.5	39.6				
3038																

0<CF<100 Cr<60 | CARS A<500 | Pickups A<800 | VANS A<700 | Utility A<800 | PU+Util A<800

Figure 4

13	Year	Make	Model	Body Style	No Damage Speed (mph)	Max Crush (inch)	KEES	A	B	G	KV	Crush Factor	CF=21 Calc'd Speed	Speed Error Over	Speed Error Under	
1933																
1934			Number of Tests (n)		1918	1918	1918	1909	1909	1909	1911	1918	1918	975	943	Number of Tests (n)
1935			Average (AVG)		5	20.7	32.0	270.6	78.6	495.7	121.4	21.1	32.6	4.3	-5.1	Average (AVG)
1936			Minimum (MIN)		5	0.3	4.7	44.1	2.6	287.3	5.1	2.1	4.0	0.0	-31.5	Minimum (MIN)
1937			Maximum (MAX)		5	58.3	61.6	498.5	311.5	857.9	12142.9	92.9	55.3	34.3	0.0	Maximum (MAX)
1938			Standard Deviation (STDev-sample)		0	6.2	6.0	77.0	40.2	74.1	305.9	7.0	5.0	4.7	3.3	Standard Deviation (STDev-sample)
1939			Standard Deviation (STDev-population)		0	6.2	6.0	77.0	40.2	74.1	305.8	7.0	5.0	4.7	3.3	Standard Deviation (STDev-population)
1940																
1941	1996		Median		5	20.5	34.8	266.1	72.2	497.8	101.2	20.9	32.8	2.7	-2.2	Median
1942	2001		Mode		5	20.9	35.0	269.7	79.4	441.4	91.5	20.7	33.1	1.0	-1.4	Mode
1943																
1944														731	707	75% of Speed Sample
1945																
1946	1972		Quartile 0		5	0.3	4.7	44.1	2.6	287.3	5.1	2.1	4.0	0.0	-31.5	Quartile 0
1947	1987		Quartile 1 - 25%		5	17.0	29.5	223.9	54.0	445.1	76.1	17.6	29.9	1.1	-4.0	Quartile 1 - 25%
1948	1996		Quartile 2 - 50%		5	20.5	34.8	266.1	72.2	497.8	101.2	20.9	32.8	2.7	-2.2	Quartile 2 - 50%
1949	2005		Quartile 3 - 75%		5	23.7	35.0	314.2	94.7	542.9	134.1	24.0	35.3	5.1	-1.1	Quartile 3 - 75%
1950	2017		Quartile 4		5	58.3	61.6	498.5	311.5	857.9	12142.9	92.9	55.3	34.3	0.0	Quartile 4
1951																
1952			-2 Std Dev			//	--------	116.6	-1.8	347.4	-490.3	7.1				
1953			-1 Std Dev			/////	//---	193.6	38.4	421.6	-184.5	14.1				
1954			**Average**			95%	68%	**270.6**	**78.6**	**495.7**	**121.4**	**21.1**				
1955			+1 Std Dev			\\\\\	\\---	347.5	118.8	569.8	427.3	28.0				
1956			+2 Std Dev			\\	--------	424.5	159.0	644.0	733.2	35.0				
1957																

0<CF<100 Cr<60 | **CARS A<500** | Pickups A<800 | VANS A<700 | Utility A<800 | PU+Util A<800

Figure 5

The Average (MEAN) CF value of all tests has dropped to 20.2 and the Median/Q2 value (the central value) is at 19.9. This is surprising as it is an indication that PICKUPs are actually somewhat softer than CAR front ends. Looking at the Quartile analysis, the 75% point in overestimating the speed is again just above 5 mph higher (5.1 mph) than the KEES. On the underestimate side, the speed is only~4 mph less than (3.9 mph) the KEES. The authors are again confident that an in depth evaluation would show that a CF=21 value would still estimate more than 75% of the tests within +/- 5 mph. That analysis will also be discussed in a subsequent paper.

Maximum Crush - All Tests - Filters = VAN and "A"<700

Figure 7 shows the VAN type vehicles from the data set that resulted in Figure 4, with the application of an additional filter that eliminates tests where the "A" stiffness value is greater than 700. The VAN data set has a total of 208 tests after this filtering is completed. The "A" stiffness value top threshold of 700 is based on the short front end of a number of the full size vans. It can be seen in that the Standard Deviation for the" A" value has dropped to ~81, and the "B" and "G" Standard Deviations have dropped to even lower values, which indicates a "tighter" data set.

The Average (MEAN) CF value of all tests has dropped to 21.2 and the Median/Q2 value (the central value) is at 21.3. The Quartile analysis indicates that a CF=21 value will quite comfortably estimate the speed of more than 75% of the tests within +/- 5 mph of the KEES.

Maximum Crush - All Tests - Filters = UTILITY and "A"<800

Figure 8 shows the UTILITY type vehicles from the data set that resulted in Figure 4, with the application of an additional filter that eliminates tests where the "A" stiffness value is greater than 800. The UTILITY data set has a total of 446 tests after this filtering is completed. The "A" stiffness value top threshold of 800 is based on the Utility Vehicles often being considered interchangeable with the pickups in regard to front end shape and

13	Year	Make	Model	Body Style	No Damage Speed (mph)	Max Crush (inch)	KEES	A	B	G	Kv	Crush Factor	CF=21 Calc'd Speed	Speed Error Over	Speed Error Under	
302																
303			Number of Tests (n)		287	287	287	287	287	287	287	287	287	170	117	Number of Tests (n)
304			Average (AVG)		5	21.3	32.0	337.8	93.9	641.0	132.4	20.2	33.1	3.9	-2.8	Average (AVG)
305			Minimum (MIN)		5	7.9	9.9	81.8	6.4	255.3	14.4	3.5	20.4	0.0	-9.4	Minimum (MIN)
306			Maximum (MAX)		5	50.1	40.2	784.0	382.6	979.0	598.0	39.5	51.3	21.7	0.0	Maximum (MAX)
307			Standard Deviation (STDev-sample)		0	5.8	5.1	101.1	49.5	118.0	68.7	5.5	4.5	3.8	2.1	Standard Deviation (STDev-sample)
308			Standard Deviation (STDev-population)		0	5.8	5.1	101.0	49.4	117.8	68.5	5.5	4.5	3.8	2.1	Standard Deviation (STDev-population)
309																
310	2001		Median		5	20.8	34.9	330.1	88.2	635.9	121.9	19.9	33.0	2.6	-2.4	Median
311	1999		Mode		5	18.5	35.0	287.9	51.8	524.5	108.0	18.3	31.2	4.5	-4.0	Mode
312																
313														128	88	75% of Speed Sample
314																
315	1978		Quartile 0		5	7.9	9.9	81.8	6.4	255.3	14.4	3.5	20.4	0.0	-9.4	Quartile 0
316	1992		Quartile 1 - 25%		5	17.6	29.6	275.6	64.3	547.3	89.4	17.0	30.4	1.4	-3.9	Quartile 1 - 25%
317	2001		Quartile 2 - 50%		5	20.8	34.9	330.1	88.2	635.9	121.9	19.9	33.0	2.6	-2.4	Quartile 2 - 50%
318	2008		Quartile 3 - 75%		5	24.6	35.1	386.9	109.9	716.1	153.6	23.3	35.9	5.1	-1.3	Quartile 3 - 75%
319	2017		Quartile 4		5	50.1	40.2	784.0	382.6	979.0	598.0	39.5	51.3	21.7	0.0	Quartile 4
320																
321			-2 Std Dev			//	----------	135.5	-5.1	405.0	-4.9	9.1				
322			-1 Std Dev			/////	//---	236.6	44.4	523.0	63.8	14.6				
323			**Average**			**95%**	**68%**	**337.8**	**93.9**	**641.0**	**132.4**	**20.2**				
324			+1 Std Dev			\\\\\	\\---	438.9	143.4	759.0	201.1	25.7				
325			+2 Std Dev			\\	----------	540.0	192.9	877.0	269.7	31.3				
326																

0<CF<100 Cr<60 | CARS A<500 | **Pickups A<800** | VANS A<700 | Utility A<800 | PU+Util A<800

Figure 6

13	Year	Make	Model	Body Style	No Damage Speed (mph)	Max Crush (inch)	KEES	A	B	G	Kv	Crush Factor	CF=21 Calc'd Speed	Speed Error Over	Speed Error Under	
223																
224			Number of Tests (n)		208	208	208	206	206	206	207	208	208	94	114	Number of Tests (n)
225			Average (AVG)		5	19.7	31.6	351.7	103.0	629.4	152.1	21.2	31.9	3.3	-2.3	Average (AVG)
226			Minimum (MIN)		5	1.0	4.8	104.9	9.1	456.4	25.6	3.5	7.2	0.0	-8.8	Minimum (MIN)
227			Maximum (MAX)		5	41.8	40.7	675.3	347.3	1085.3	1142.1	42.3	46.8	17.6	0.0	Maximum (MAX)
228			Standard Deviation (STDev-sample)		0	5.4	5.4	82.1	45.9	77.3	97.2	5.2	4.7	3.7	1.9	Standard Deviation (STDev-sample)
229			Standard Deviation (STDev-population)		0	5.3	5.4	81.9	45.8	77.1	97.0	5.2	4.7	3.7	1.8	Standard Deviation (STDev-population)
230																
231	1998		Median		5	20.2	34.8	352.8	98.7	616.4	136.0	21.3	32.6	2.1	-1.9	Median
232	2005		Mode		5	19.6	35.0	266.3	63.4	604.1	114.9	22.4	32.1	1.4	-1.9	Mode
233																
234														71	86	75% of Speed Sample
235																
236	1978		Quartile 0		5	1.0	4.8	104.9	9.1	456.4	25.6	3.5	7.2	0.0	-8.8	Quartile 0
237	1992		Quartile 1 - 25%		5	16.5	29.4	299.1	75.3	591.4	104.1	18.9	29.4	0.8	-3.3	Quartile 1 - 25%
238	1998		Quartile 2 - 50%		5	20.2	34.8	352.8	98.7	616.4	136.0	21.3	32.6	2.1	-1.9	Quartile 2 - 50%
239	2004		Quartile 3 - 75%		5	23.1	35.0	396.5	122.7	654.2	174.9	23.9	34.8	3.9	-0.9	Quartile 3 - 75%
240	2017		Quartile 4		5	41.8	40.7	675.3	347.3	1085.3	1142.1	42.3	46.8	17.6	0.0	Quartile 4
241																
242			-2 Std Dev			//	----------	187.4	11.2	474.8	-42.3	10.8				
243			-1 Std Dev			/////	//---	269.6	57.1	552.1	54.9	16.0				
244			**Average**			**95%**	**68%**	**351.7**	**103.0**	**629.4**	**152.1**	**21.2**				
245			+1 Std Dev			\\\\\	\\---	433.8	148.9	706.7	249.3	26.4				
246			+2 Std Dev			\\	----------	516.0	194.7	784.0	346.5	31.6				
247																

0<CF<100 Cr<60 | CARS A<500 | Pickups A<800 | **VANS A<700** | Utility A<800 | PU+Util A<800

Figure 7

stiffness. Therefore the same top end threshold was used for the UTILITY vehicles as was used for the Pickups. This can be seen in that the Standard Deviation for the "A" value has dropped to ~81, and the "B" and "G" Standard Deviations have dropped below 100 as well, which indicates a "tighter" data set than was present in the Figure 4 data set.

The Average (MEAN) CF value of all tests has dropped to 23.1 and the Median/Q2 value (the central value) is at 23.0. This is more along the lines of what was expected from the Pickups, a stiffer front end than is found in the CAR body style front end. However, the Quartile analysis indicates that a CF=21 value will quite comfortably estimate the speed of more than 75% of the tests within +/- 5 mph of the KEES. The author would not argue with someone who wishes to use a slightly stiffer CF value for Utility vehicles based on this analysis. At the same time, the author feels that the Quartile analysis indicates that the potential benefits in possible accuracy are outweighed by the loss of uniformity of using a "default" CF value other than 21.

Maximum Crush - All Tests - Filters = PICKUP+UTILITY and "A"<800

Figure 9 shows the PICKUP + UTILITY type vehicles from the data set that resulted in Figure 4, with the application of an additional filter that eliminates tests where the "A" stiffness value is greater than 800. The PICKUP + UTILITY data set has a total of 739 tests after this filtering is completed. This combining of the PICKUPS with the UTILITY vehicles was done to see if the front ends really are "interchangeable". It can be seen that the Standard Deviation for the "A" value has dropped to ~81, and the "B" and "G" Standard Deviations have dropped below 100 as well, which indicates a "tighter" data set than was present in the Figure 4 data set.

The Average (MEAN) CF value of all tests is at 22.0 and the Median/Q2 value (the central value) is at 21.9. The Quartile analysis indicates that a CF=21 value will quite comfortably estimate the speed of more than 75% of the tests within +/- 5 mph of the KEES. The effect of the UTILITY body type tests can be seen in the reduction of the A-B-G Standard Deviation values as well as the Q3 speed over-

13	Year	Make	Model	Body Style	No Damage Speed (mph)	Max Crush (inch)	KEES	A	B	G	Kv	Crush Factor	CF=21 Calc'd Speed	Speed Error Over	Speed Error Under	
461																
462			Number of Tests (n)		446	446	446	444	444	444	444	446	446	149	297	Number of Tests (n)
463			Average (AVG)		5	20.2	33.5	372.2	112.3	643.2	155.7	23.1	32.4	3.1	-3.3	Average (AVG)
464			Minimum (MIN)		5	6.7	15.0	143.1	21.7	411.2	34.0	6.2	18.8	0.1	-12.0	Minimum (MIN)
465			Maximum (MAX)		5	40.9	42.9	679.5	358.7	1081.0	516.9	43.3	46.3	14.8	0.0	Maximum (MAX)
466			Standard Deviation (STDev-sample)		0	4.4	4.0	80.9	47.3	90.8	65.5	5.5	3.6	2.9	2.3	Standard Deviation (STDev-sample)
467			Standard Deviation (STDev-population)		0	4.4	4.0	80.8	47.2	90.7	65.5	5.5	3.6	2.9	2.3	Standard Deviation (STDev-population)
468																
469	2005		Median		5	20.2	35.0	361.7	103.6	642.5	144.0	23.0	32.5	2.2	-3.0	Median
470	2002		Mode		5	21.3	35.0	376.2	97.1	566.7	117.8	22.8	33.4	1.0	-1.4	Mode
471																
472														112	223	75% of Speed Sample
473																
474	1978		Quartile 0		5	6.7	15.0	143.1	21.7	411.2	34.0	6.2	18.8	0.1	-12.0	Quartile 0
475	2001		Quartile 1 - 25%		5	17.5	34.7	318.0	82.3	574.4	114.9	19.8	30.3	1.0	-4.6	Quartile 1 - 25%
476	2005		Quartile 2 - 50%		5	20.2	35.0	361.7	103.6	642.5	144.0	23.0	32.5	2.2	-3.0	Quartile 2 - 50%
477	2011		Quartile 3 - 75%		5	22.6	35.1	412.4	129.7	696.2	179.6	26.3	34.4	4.1	-1.5	Quartile 3 - 75%
478	2017		Quartile 4		5	40.9	42.9	679.5	358.7	1081.0	516.9	43.3	46.3	14.8	0.0	Quartile 4
479																
480			-2 Std Dev			//	————	210.4	17.8	461.6	24.6	12.1				
481			-1 Std Dev			/////	//—	291.3	65.0	552.4	90.1	17.6				
482			**Average**			**95%**	**68%**	**372.2**	**112.3**	**643.2**	**155.7**	**23.1**				
483			+1 Std Dev			\\\\\	\\—	453.1	159.6	733.9	221.2	28.6				
484			+2 Std Dev			\\	————	534.0	206.8	824.7	286.8	34.1				
485																

0<CF<100 Cr<60 | CARS A<500 | Pickups A<800 | VANS A<700 | **Utility A<800** | PU+Uti A<800

Figure 8

13	Year	Make	Model	Body Style	No Damage Speed (mph)	Max Crush (inch)	KEES	A	B	G	Kv	Crush Factor	CF=21 Calc'd Speed	Speed Error Over	Speed Error Under	
748																
749			Number of Tests (n)		733	733	733	731	731	731	731	733	733	319	414	Number of Tests (n)
750			Average (AVG)		5	20.6	32.9	358.7	105.1	642.3	146.5	22.0	32.7	3.5	-3.1	Average (AVG)
751			Minimum (MIN)		5	6.7	9.9	81.8	6.4	255.3	14.4	3.5	18.8	0.0	-12.0	Minimum (MIN)
752			Maximum (MAX)		5	50.1	42.9	784.0	382.6	1081.0	598.0	43.3	51.3	21.7	0.0	Maximum (MAX)
753			Standard Deviation (STDev-sample)		0	5.0	4.5	90.9	49.0	102.3	67.7	5.7	3.9	3.4	2.2	Standard Deviation (STDev-sample)
754			Standard Deviation (STDev-population)		0	5.0	4.5	90.8	48.9	102.2	67.6	5.7	3.9	3.4	2.2	Standard Deviation (STDev-populat
755																
756	2004		Median		5	20.5	35.0	351.8	96.9	640.6	134.2	21.9	32.8	2.5	-2.8	Median
757	2011		Mode		5	18.5	35.0	376.2	117.0	524.5	108.0	21.2	31.2	0.7	-1.4	Mode
758																
759														239	311	75% of Speed Sample
760																
761	1978		Quartile 0		5	6.7	9.9	81.8	6.4	255.3	14.4	3.5	18.8	0.0	-12.0	Quartile 0
762	1998		Quartile 1 - 25%		5	17.6	30.1	304.8	75.0	565.4	105.8	18.6	30.4	1.1	-4.4	Quartile 1 - 25%
763	2004		Quartile 2 - 50%		5	20.5	35.0	351.8	96.9	640.6	134.2	21.9	32.8	2.5	-2.8	Quartile 2 - 50%
764	2011		Quartile 3 - 75%		5	23.4	35.1	403.3	122.8	699.3	170.7	25.5	35.0	4.5	-1.4	Quartile 3 - 75%
765	2017		Quartile 4		5	50.1	42.9	784.0	382.6	1081.0	598.0	43.3	51.3	21.7	0.0	Quartile 4
766																
767			-2 Std Dev			//	————	176.9	7.1	437.8	11.2	10.6				
768			-1 Std Dev			/////	//—	267.8	56.1	540.1	78.9	16.3				
769			**Average**			**95%**	**68%**	**358.7**	**105.1**	**642.3**	**146.5**	**22.0**				
770			+1 Std Dev			\\\\\	\\—	449.6	154.0	744.6	214.2	27.7				
771			+2 Std Dev			\\	————	540.5	203.0	846.8	281.9	33.3				
772																

0<CF<100 Cr<60 | CARS A<500 | Pickups A<800 | VANS A<700 | Utility A<800 | **PU+Uti A<800**

Figure 9

estimation speed error reduction, and the effect of PICKUP tests can be seen in the slight reduction of the CF average values from what we saw in Figure 8.

Summary

The analysis of the NHTSA Crash Test Database frontal tests using MAXIMUM crush has shown that:

1) It IS appropriate to use a Crush Factor value of 21 for CARs, PICKUPs, VANs, and UTILITY vehicle front ends and that a speed estimate within +/- 5 mph can be obtained 75% or more of the time.

2) This approach is less accurate when dealing with minimal crush. However, the author believes this to be true to most approaches to minimal crush. Additionally, while erratic from a statistical view point, the speed estimates still fall within the +/- 5 mph bracket in most cases, and when they don't, it is usually only slightly outside of that bracket.

It is stressed, however, that caution must still be used when applying any method to calculating speed from crush. Just because one has a formula, a stiffness value and some crush depths, it does not mean one should blindly apply the formula. Some thought still needs to be exercised.

This is the first of what is intended to be a series of articles. Future articles will deal with the side and rear tests and values derived there from.

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# # #

UTAH TO IMPLEMENT THE NATION'S STRICTEST DUI LIMIT, FIRST STATE TO GO TO .05

On New Year's Eve, as people across the country raise a glass or two to toast the end of one year and the beginning of another, residents of Utah probably will have to decline that last drink if they want to drive home afterward.

The state plans to impose the country's strictest limit for alcohol consumption before driving, making the new blood alcohol limit .05, down from the .08 standard nationwide. The measure — slated to take effect Dec. 30 — has prompted some criticism and spurred new training for law enforcement officials, but if it helps reduce drunken-driving deaths, other states could take notice.

"I don't anticipate other states immediately following," said Jonathan Adkins, executive director of the Governors Highway Safety Association. But, he said, "if it turns out this has been successful and is having an impact on drunk driving, it's certainly possible that other states will follow."

The shift in Utah — the first state to lower its limit below .08 — comes as deaths from drunken driving remain a serious danger nationwide. While down significantly during the past three decades amid aggressive enforcement of drunken-driving laws, alcohol-impaired drivers were involved in nearly one-third of all motor vehicle fatalities in 1997.

More than 37,000 people were killed in crashes in 2017, and more than 10,000 of them — about 29 percent — died in crashes involving drivers impaired by alcohol, defined as those with blood alcohol concentrations of .08 or higher, according to the National Highway Traffic Safety Administration. In Utah, about 19 percent of traffic deaths involved alcohol-impaired drivers, the lowest figure of any state.

Utah has long had restrictions on alcohol, including limits on how strong beer can be and prohibitions against bringing alcohol in from other states, but officials say drinking and driving remains an ongoing problem there.

"Despite decades of public campaigns and other efforts to discourage driving after drinking, survey and observational data show that many people continue to do so," the Utah Department of Public Safety said in a statement addressing the new law. "Over the last five years, there were 54,402 arrests for DUI in Utah, which represents an average of 29.8 per day."

The public safety department said that law enforcement agencies in the state had to undergo refresher training on field sobriety tests. The law taking effect this month states that a person cannot operate or be in physical control of a vehicle if a test shows that they have "a blood or breath alcohol concentration" of .05 or greater. It also states that a person who has that alcohol amount and "operates a motor vehicle in a negligent manner causing the death of another" will have committed an automobile homicide, a felony.

Utah Gov. Gary R. Herbert (R) signed the new law last year, noting that while he had some issues with the measure, it would "save lives, therefore it is good public policy."

The .08 standard nationwide was set in a bill signed by President Bill Clinton in 2000, though the exact laws and penalties often vary, according to the Governors Highway Safety Association. Most states and the District also have harsher penalties for drivers with particularly high blood alcohol measurements, although again, the specifics depend on the state. Federal authorities have long pushed for tougher drunken-driving laws than the .08 standard. The National Transportation Safety Board argued in 2013 for dropping that figure to .05, saying that research showed drivers above that level "are impaired and at a significantly greater risk of being involved in a crash where someone is killed or injured."

The American Beverage Institute — a restaurant trade association that lobbies for the industry and has opposed lowering the blood alcohol level — once called that 2013 proposal "terrible." It also decried the new Utah measure.

"I have no doubt that proponents of .05 laws are well-intentioned, but good intentions don't necessarily yield good public policy," Jackson Shedelbower, spokesman for the institute, said in a statement this week.

Shedelbower described the new measure as "targeting moderate and responsible drinkers" rather than people with much higher blood alcohol levels "and repeat drunk driving offenders responsible for the vast majority of alcohol-related traffic fatalities."

Federal statistics link deadly accidents with greater alcohol consumption. NHTSA has said that while .08 is considered impaired, "the large majority of drivers in fatal crashes with any measurable alcohol had levels far higher." Adkins, who said his group is monitoring the Utah law to see what impact it has, said that to combat drunken driving, "we need to reduce the high alcohol offenders."

The Centers for Disease Control and Prevention says a 160-pound man would reach a .05 blood alcohol concentration level — and have a reduced ability to track moving objects or steer — after having about three drinks in an hour. The CDC describes a standard drink as 12 ounces of beer, five ounces of wine or a shot of liquor, though it notes that a person's specific reaction to alcohol can vary depending on their age, physical condition, weight and other factors.

- Washington Post

The tables in the article are .... small .... through no fault of the Journal. The authors (primarily Daniel Vomhof III) assumes that responsibility as he could not figure out how to break them up into smaller chunks without losing meaning. In an effort to help lessen that effect, the tables are available on our web site in jpg format for easier viewing and printing in a larger size.

If you go to

http://www.4n6xprt.com/papers.htm#CF_Ft_21

and start scrolling down, you will quickly see where the figures are for this article.

Crash Test Report

CB5801
9859
2011 VW Jetta
Rear

REPORT NUMBER: 301-MGA-2011-002

SAFETY COMPLIANCE TESTING FOR FMVSS 301R
FUEL SYSTEM INTEGRITY – REAR IMPACT

VOLKSWAGEN DE MEXICO
2011 VOLKSWAGEN JETTA
NHTSA NUMBER: CB5801

PREPARED BY:
MGA RESEARCH CORPORATION
5000 WARREN ROAD
BURLINGTON, WI 53105

Test Date: May 26, 2011

Final Report Date: June 15, 2011

FINAL REPORT

PREPARED FOR:
U.S. DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
ENFORCEMENT
OFFICE OF VEHICLE SAFETY COMPLIANCE
1200 NEW JERSEY AVENUE, S.E., NVS-220
WASHINGTON, D.C. 20590

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Prepared by: Joe Fleck Date: 6/1/11
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FINAL REPORT ACCEPTED BY:

Edward E. Chan

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COTR, Rear Impact

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Technical Report Documentation Page

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16. Abstract

A rear impact was conducted on a 2011 Volkswagen Jetta at MGA Research Corporation on May 26, 2011. This test was conducted to obtain data indicant of FMVSS 301R. The impact velocity was 78.7 km/h. The ambient temperature at the time of impact was 12 degrees Celsius.

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SECTION 1

PURPOSE AND SUMMARY OF TEST

PURPOSE

This rear impact test is sponsored by the National Highway Traffic Safety Administration (NHTSA) under contract number DTNH22-06-C-00030. The purpose of this test is to reduce deaths and injuries occurring from fires that result from fuel spillage during and after motor vehicle crashes and resulting from ingestion of fuels during siphoning.

SUMMARY

A 2011 Volkswagen Jetta was impacted by a Moving Deformable Barrier (MDB) at a velocity of 78.7 km/h. The test was performed at MGA Research Corporation on May 26, 2011. Pre-and post-test photographs of the vehicle and dummies can be found in Appendix A.

One real-time camera and five high-speed cameras were used to document the impact event.

- Left Rear Half 1000 fps
- Right Rear Half 1000 fps
- Left Overall 1000 fps
- Overhead Overall 1000 fps
- Right Overall 1000 fps
- Real Time Pan 30 fps

Two ballast Part 572E, 50th percentile male anthropomorphic test devices (ATDs) were placed in the driver and right-front passenger seating positions according to dummy placement instructions specified in the Laboratory Indicant Test Procedure.

There was no Stoddard Solvent leakage after the event or during any phase of the static rollover.

The vehicle appeared to comply with all the requirements of FMVSS No. 301 “Fuel System Integrity.”

SECTION 2

DATA SHEETS

DATA SHEET NO. 1

TEST VEHICLE SPECIFICATIONS

Test Vehicle:	2011 Volkswagen Jetta	NHTSA No.:	CB5801
Test Program:	FMVSS 301 Fuel System Integrity	Test Date:	5/26/2011

TEST VEHICLE INFORMATION

Manufacturer	Volkswagen DE Mexico
Model	Jetta
Body Style	Passenger Car
Major Options	None
NHTSA No.	CB5801
VIN	3VW1K7AJ2BM056484
Color	Reflex Silver Metallic
Delivery Date	4/22/11
Odometer Reading (mile)	166
Dealer	ED Schmidt Auto Group
Transmission	Manual
Final Drive	Front Wheel Drive
Number of Cylinders	4
Engine Displacement (L)	2.0
Engine Placement	Lateral

DATA FROM VEHICLE'S CERTIFICATION LABEL

Manufactured By	Volkswagen DE Mexico
Date of Manufacture	01/11

GVWR (kg)	1820
GAWR Front (kg)	910
GAWR Rear (kg)	960

VEHICLE CAPACITY DATA

Measured Parameter	Front	Rear	Third	Total
Type of Seats	Bucket	Split Bench		
Number of Occupants	2	3		5
Capacity Wt. (VCW) (kg)				495
Number of Occupants x 68 kg.				340
Cargo Wt. (RCLW) (kg)				155

DATA SHEET NO. 1 (continued)

TEST VEHICLE SPECIFICATIONS

Test Vehicle:	2011 Volkswagen Jetta	NHTSA No.:	CB5801
Test Program:	FMVSS 301 Fuel System Integrity	Test Date:	5/26/2011

DATA FROM VEHICLE'S TIRE PLACARD

Measured Parameter	Front	Rear
Maximum Tire Pressure (kPa)	350	350
Cold Pressure (kPa)	220	220
Recommended Tire Size	P195/65R15	P195/65R15
Recommended Load Range	91H	91H
Tire Size on Vehicle	P195/65R15	P195/65R15
Tire Manufacturer	Continental	Continental
Location of Placard of Vehicle	Lower B-Pillar	
Type of Spare Tire (full size/space saver)	Full Size	

DATA SHEET NO. 2

PRE-TEST DATA

Test Vehicle:	2011 Volkswagen Jetta	NHTSA No.:	CB5801
Test Program:	FMVSS 301 Fuel System Integrity	Test Date:	5/26/2011

WEIGHT OF TEST VEHICLE

	Units	As Delivered (UVW) (Axle)			As Tested (ATW) (Axle)		
		Front	Rear	Total	Front	Rear	Total
Left	kg	374.2	273.1		423.2	374.2	
Right	kg	377.4	282.1		423.2	381.9	
Ratio	%	57.5	42.5		52.8	47.2	
Totals	kg	751.6	555.2	1306.8	846.4	756.1	1602.5

CALCULATION OF TARGET TEST WEIGHT (TTW)

Measured Parameter	Units	Value
Total Delivered Weight (UVW)	kg	1306.8
Rated Cargo/Luggage Weight (RCLW)	kg	155
Weight of 2 P572E ATDs	kg	148
Calculated Vehicle Target Weight (TVTW)	kg	1609.8

Vehicle Wheelbase	2651 mm
Vehicle Width	1782 mm
Weight of Ballast Secured in Rear Seat	153.8 kg
Method of Securing Ballast	Ratchet Straps
Vehicle Components Removed for Weight Reduction	None

VEHICLE ATTITUDES

	Units	LF	RF	LR	RR
As Delivered	mm	671	673	683	689
As Tested	mm	649	650	641	642

DATA SHEET NO. 2 (continued)

PRE-TEST DATA

Test Vehicle: 2011 Volkswagen Jetta NHTSA No.: CB5801
Test Program: FMVSS 301 Fuel System Integrity Test Date: 5/26/2011

FUEL SYSTEM DATA

	Units: Liters
Usable Capacity of "Standard Tank" (Owner's Manual)	55.0
Usable Capacity Figure Furnished by COTR	55.0
Usable Capacity of "Optional" Tank	
92-94% of Usable Capacity	50.6 to 51.7
Actual Test Volume (entire fuel system filled)	51.1

Test Fluid Type	Stoddard Solvent
Test Fluid Kinematic Viscosity (centistokes)	2.1 cSt @ 20° C
Test Fluid Color	Purple
Type of Vehicle Fuel Pump	Electrical
Activate Electric Fuel Pump Operation with Ignition Switch ON, but Engine OFF	Yes

Comments (noticeable attributes of fuel system components, capacity, etc.)	None

DATA SHEET NO. 3

MOVING BARRIER DATA

Test Vehicle:	2011 Volkswagen Jetta	NHTSA No.:	CB5801
Test Program:	FMVSS 301 Fuel System Integrity	Test Date:	5/26/2011

MOVING BARRIER'S TEST WEIGHT

	Units	Front	Rear	Total
Left	kg	374.2	308.8	
Right	kg	389.5	291.2	
Ratio	%	56.0	44.0	
Totals	kg	763.7	600.0	1363.7

Tires (Mfr, line, size)	Kumho
Tire Pressure (kPa)	207
Brake Abort System (Yes/No)?	Yes
Date of Last Calibration	8/6/2008

DATA SHEET NO. 4

POST-TEST DATA

Test Vehicle:	2011 Volkswagen Jetta	NHTSA No.:	CB5801
Test Program:	FMVSS 301 Fuel System Integrity	Test Date:	5/26/2011

IMPACT VELOCITY

	Units: km/h
Required Impact Velocity	80.0
Actual Impact Velocity (Trap No. 1)	78.7
Actual Impact Velocity (Trap No. 2)	78.7
Average Impact Speed	78.7

Temperature at Time of Impact (°C)	12
Test Time	1:18 pm

WELDING ROD IMPACT POINT

	Units: mm
Vertical distance from target center (+ above target / - below target)	12 up
Horizontal distance from target center (+ to the right / - to the left)	2 left

DATA SHEET NO. 5

STATIC ROLLOVER TEST DATA

Test Vehicle:	2011 Volkswagen Jetta	NHTSA No.:	CB5801
Test Program:	FMVSS 301 Fuel System Integrity	Test Date:	5/26/2011

STODDARD SOLVENT SPILLAGE MEASUREMENT

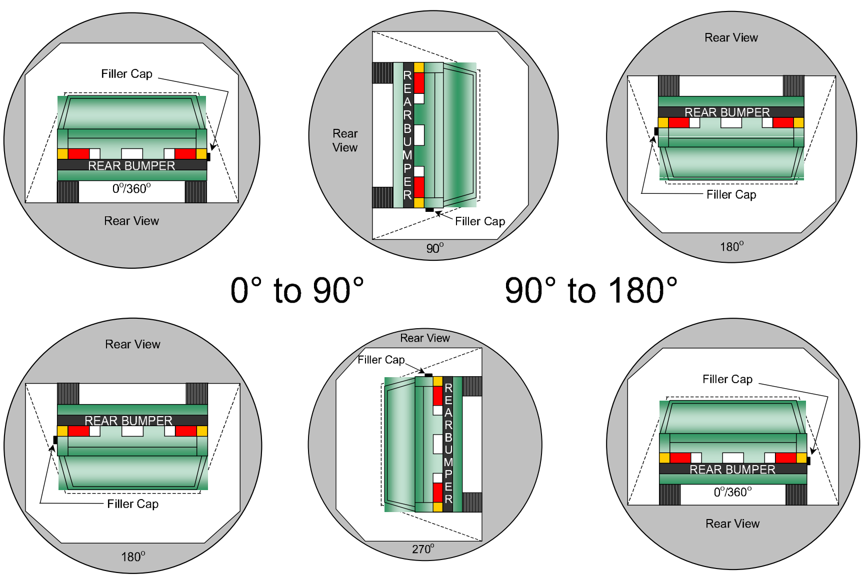
A. From impact until vehicle motion ceases: 0 g
(Maximum Allowable = 28 grams)

B. For the 5 minute period after motion ceases: 0 g
(Maximum Allowable = 28 grams)

C. For the following 25 minutes: 0 g
(Maximum Allowable = 28 grams/minute)

D. Spillage: **None**

FMVSS 301 STATIC ROLLOVER DATA



1. The specified fixture rollover rate for each 90° of rotation is 60 to 180 seconds.

2. The position hold time at each position is 300 seconds (minimum).

3. Details of Stoddard Solvent spillage locations: **Not Applicable**

DATA SHEET NO. 5 (continued)

STATIC ROLLOVER TEST DATA

Test Vehicle: 2011 Volkswagen Jetta NHTSA No.: CB5801
Test Program: FMVSS 301 Fuel System Integrity Test Date: 5/26/2011

STODDARD SOLVENT SPILLAGE MEASUREMENT
Hold Time = 5 minutes at all intervals

0° TO 90° Rotation Time (sec) = 118 sec

Test Phase	Spillage (g)	Spillage Details
First 5 minutes from onset of rotation	0	
Sixth minute from onset of rotation	0	
Seventh minute from onset of rotation	0	
Eight minute if required	N/A	

90° TO 180° Rotation Time (sec) = 109 sec

Test Phase	Spillage (g)	Spillage Details
First 5 minutes from onset of rotation	0	
Sixth minute from onset of rotation	0	
Seventh minute from onset of rotation	0	
Eight minute if required	N/A	

180° TO 270° Rotation Time (sec) = 105 sec

Test Phase	Spillage (g)	Spillage Details
First 5 minutes from onset of rotation	0	
Sixth minute from onset of rotation	0	
Seventh minute from onset of rotation	0	
Eight minute if required	N/A	

270° TO 360° Rotation Time (sec) = 118 sec

Test Phase	Spillage (g)	Spillage Details
First 5 minutes from onset of rotation	0	
Sixth minute from onset of rotation	0	
Seventh minute from onset of rotation	0	
Eight minute if required	N/A	

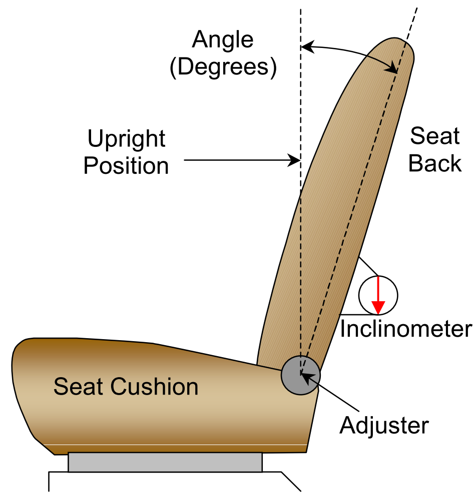
FORM 1

TEST VEHICLE INFORMATION

Test Vehicle:	2011 Volkswagen Jetta	NHTSA No.:	CB5801
Test Program:	FMVSS 301 Fuel System Integrity	Test Date:	5/26/2011

NORMAL DESIGN RIDING POSITION

With the seat in the mid fore-aft seat track position the angle of the driver's seat back when it is in the nominal riding position is set on seat back frame at 19.0 degrees. Front outboard passenger seat is set at 19.1 degrees.



FRONT SEAT ASSEMBLY

Driver Seat Back Angle	19.5° on seat back frame
Passenger Seat Back Angle	18.8° on seat back frame

SEAT FORE/AFT POSITIONING

	Total Fore/Aft Travel	Placed in Position #
Driver Seat	250 mm	125 mm
Passenger Seat	170 mm	90 mm

D-RING ADJUSTMENT

The driver and passenger D-rings were full up.

STEERING COLUMN ADJUSTMENT

The steering column was placed in the mid position.

APPENDIX A

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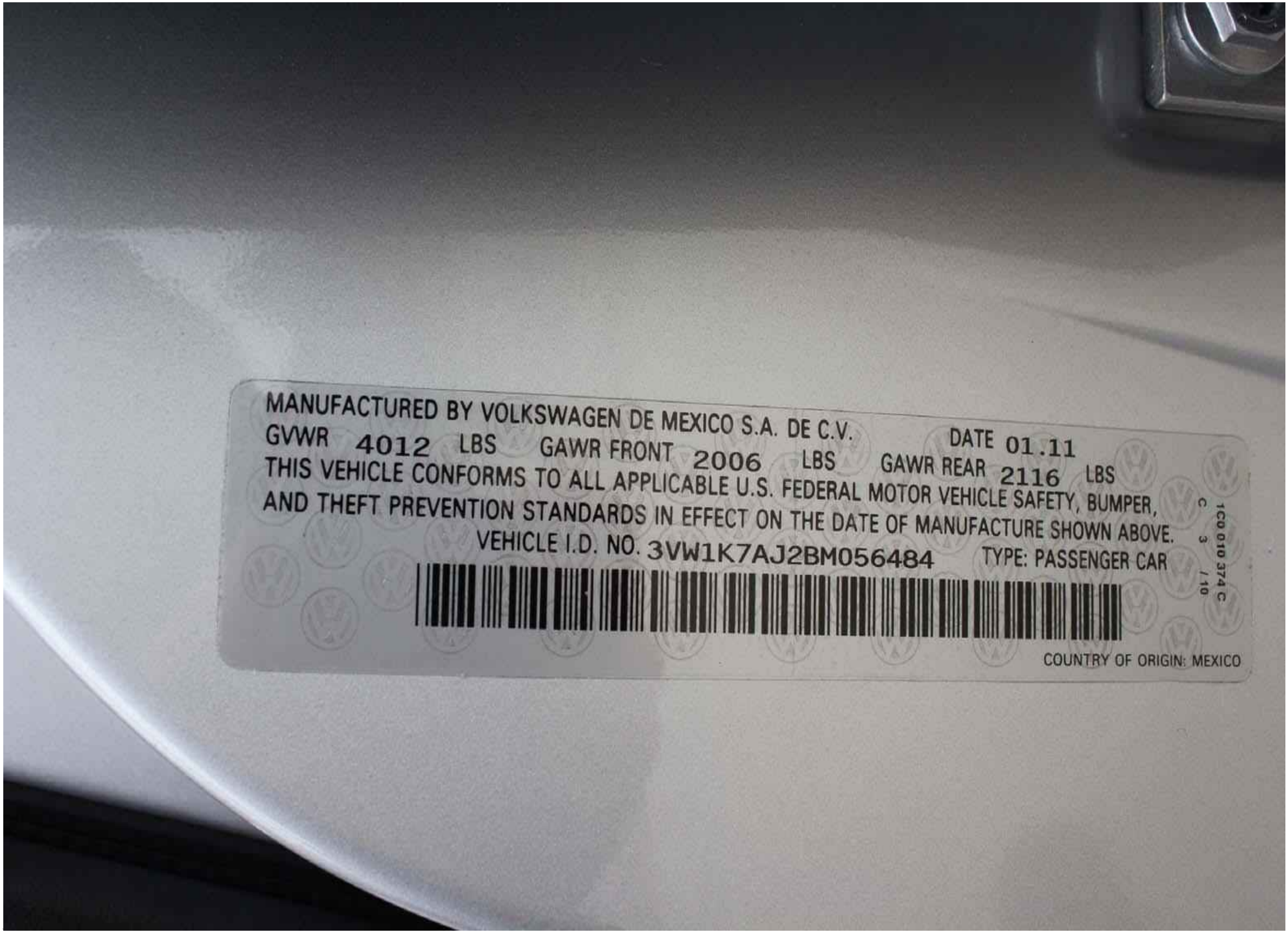
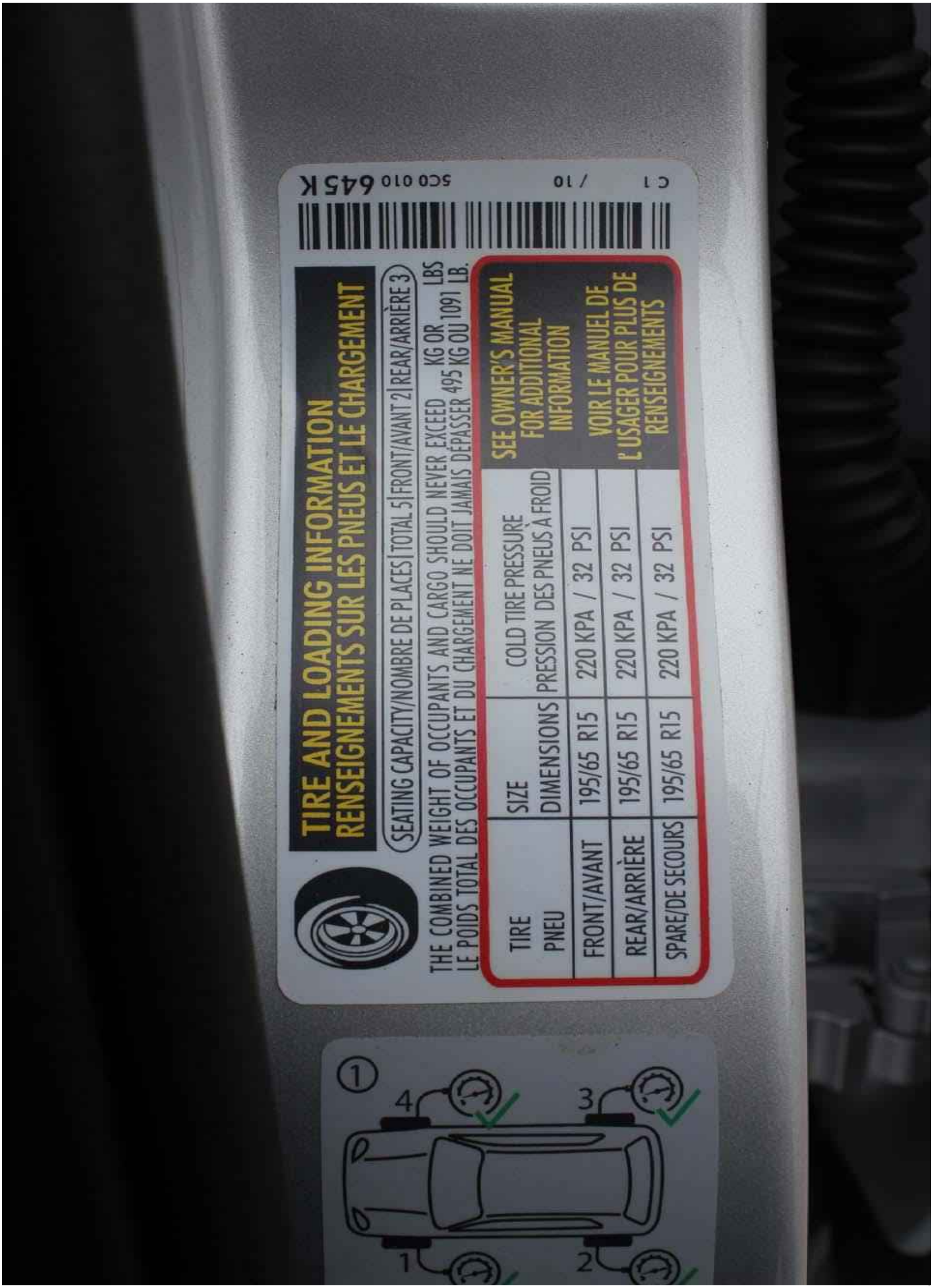


Vehicle's Certification Label



Vehicle's Tire Placard

Pre-Test Front View of Vehicle

Post-Test Front View of Vehicle

Pre-Test Left Side View of Vehicle

Post-Test Left Side View of Vehicle

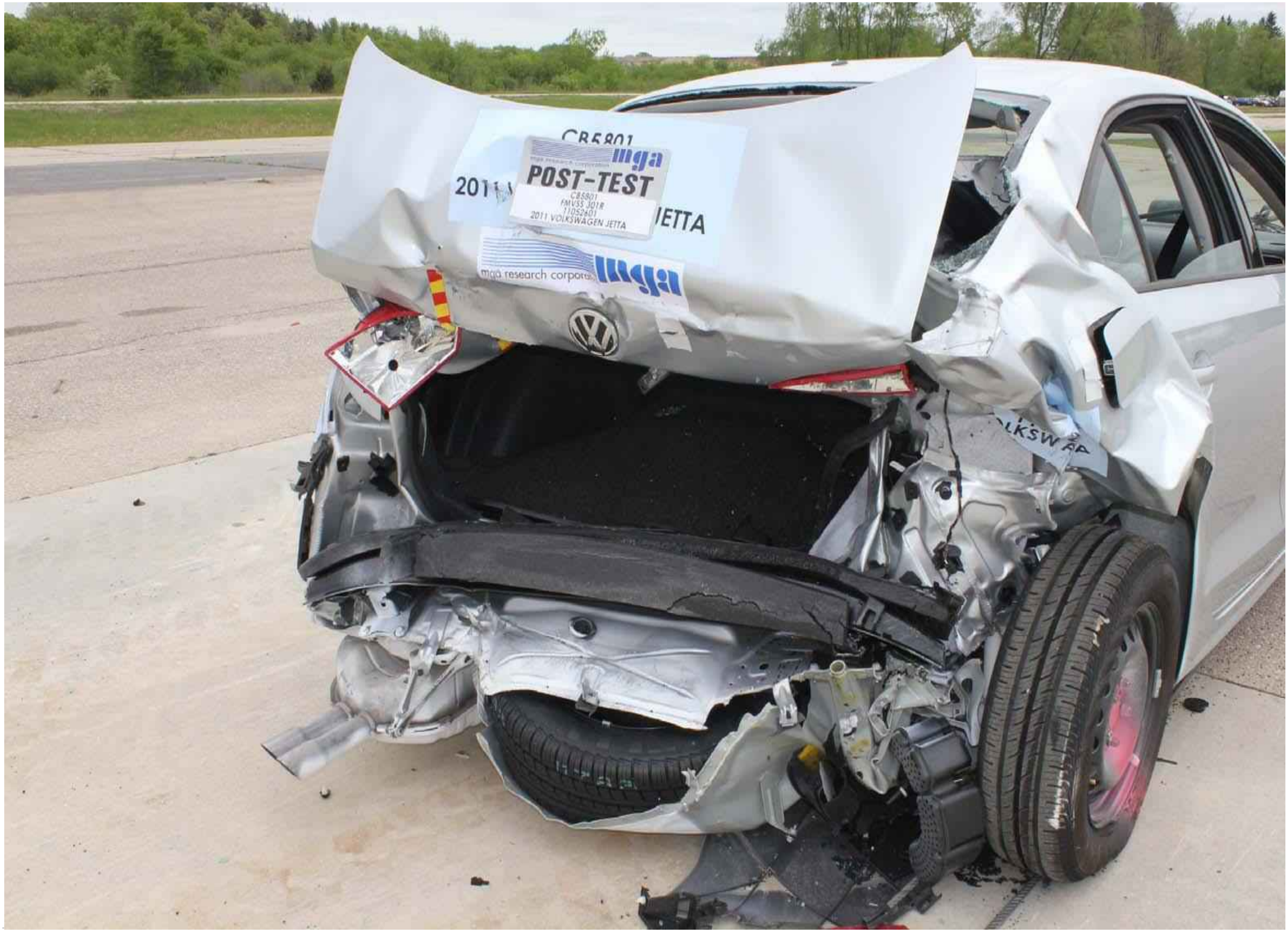
Pre-Test Left Rear Close-up View of Vehicle

Post-Test Left Rear Close-up View of Vehicle

Pre-Test Right Side View of Vehicle

Post-Test Right Side View of Vehicle

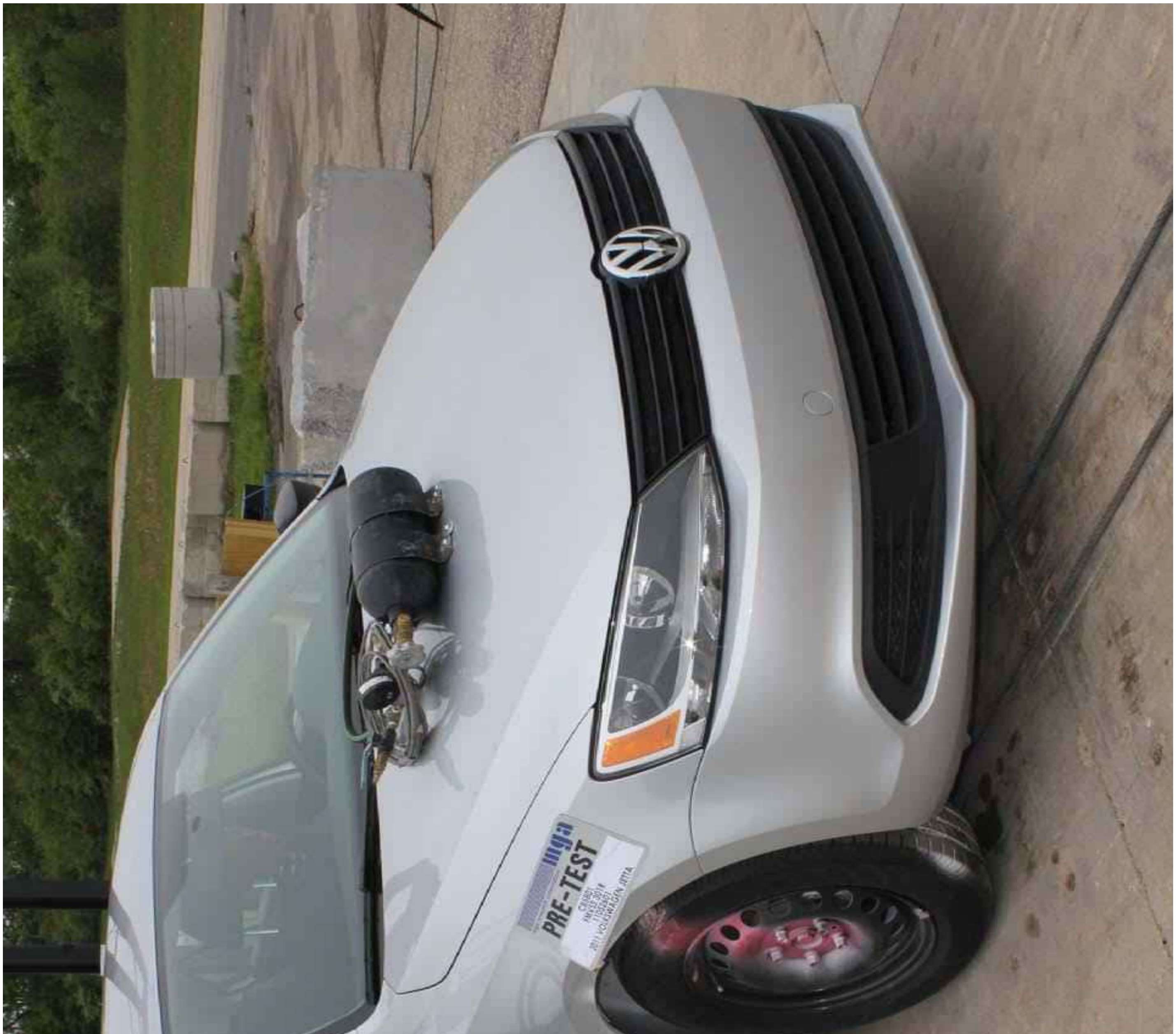
Pre-Test Right Rear Close-up View of Vehicle



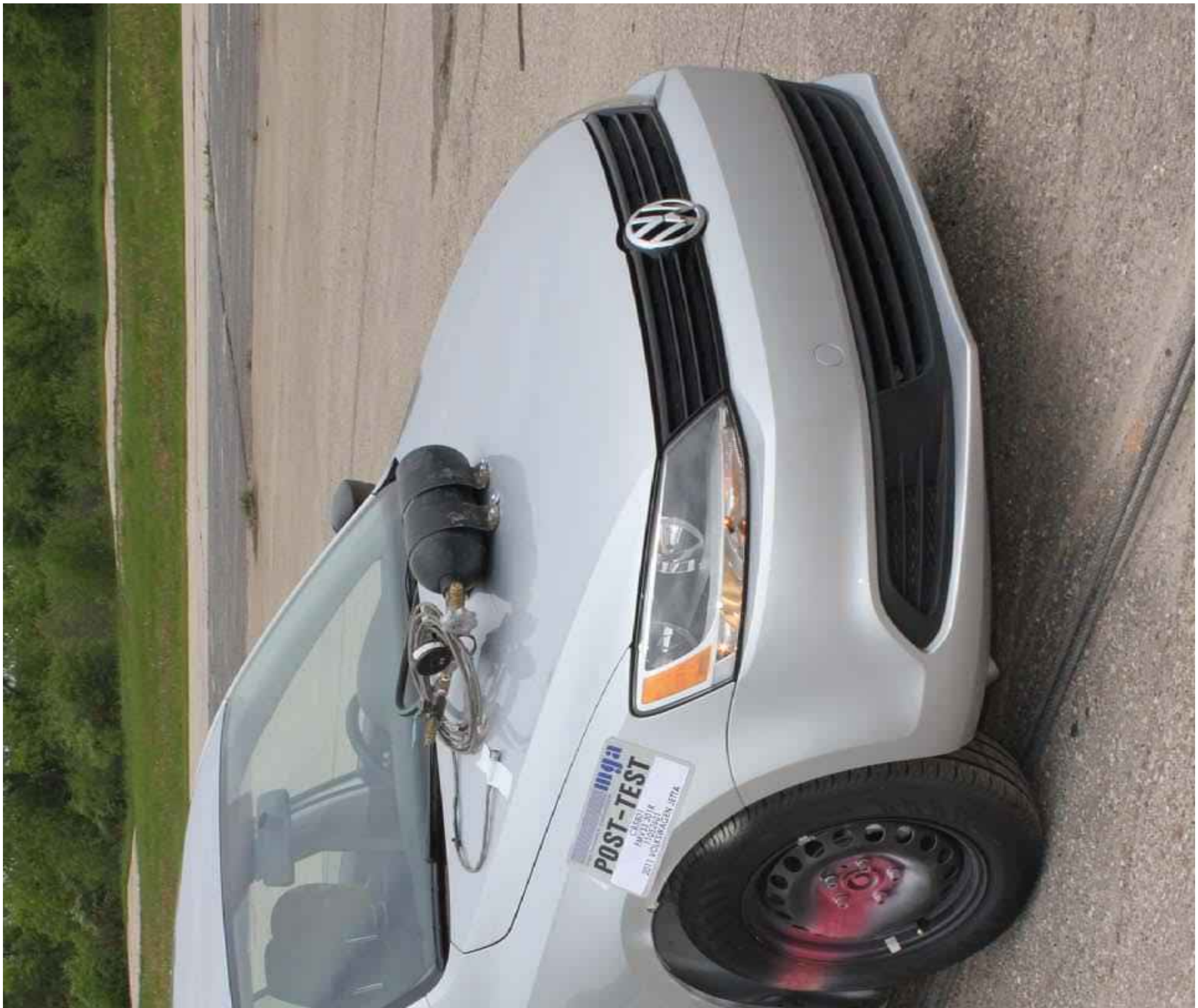
Post-Test Right Rear Close-up View of Vehicle

Pre-Test Rear View of Vehicle

Post-Test Rear View of Vehicle



Pre-Test ¾ Frontal View From Right Side of Vehicle

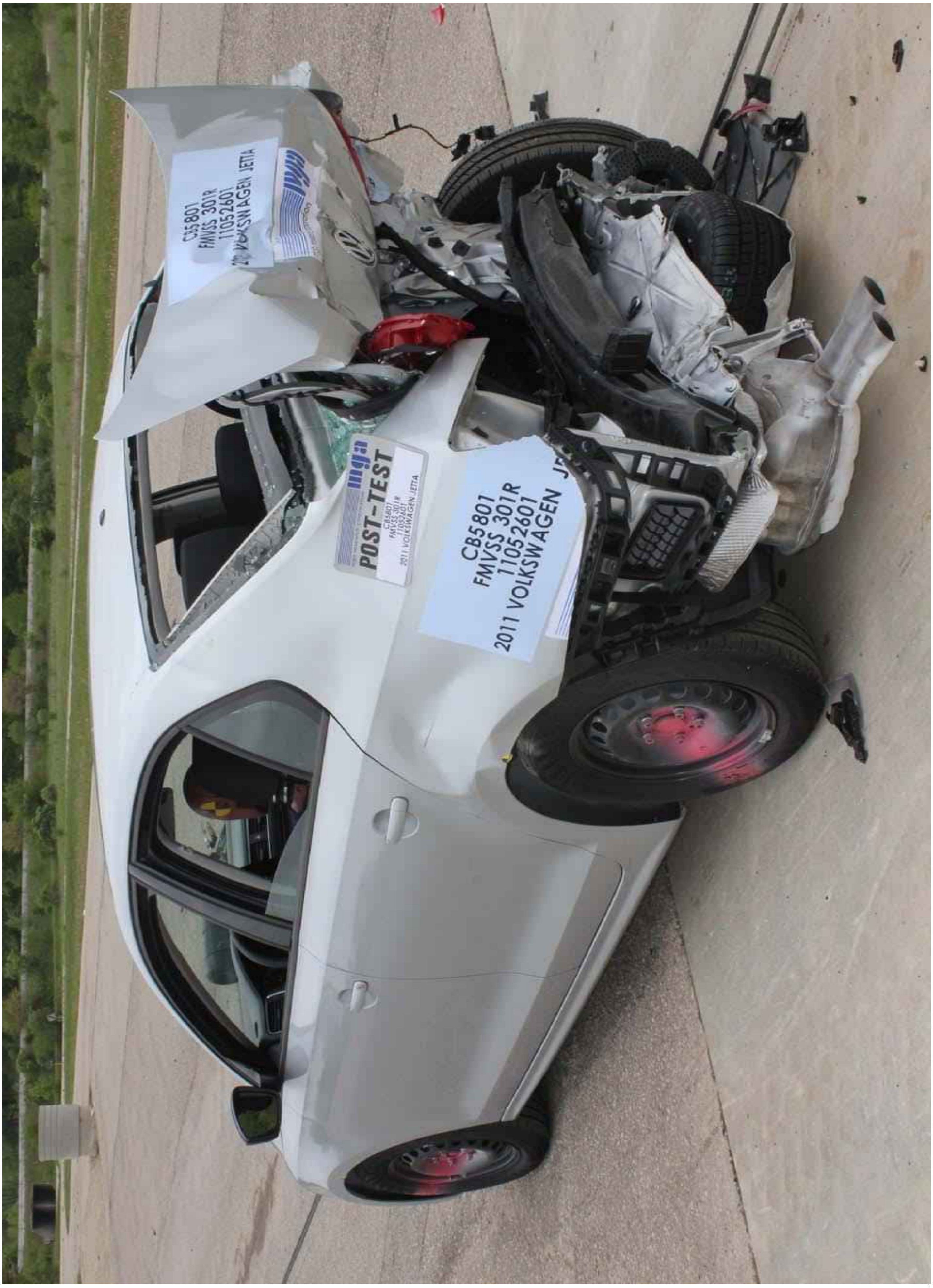


Post-Test ¾ Frontal View From Right Side of Vehicle

Pre-Test ¾ Rear View From Right Side of Vehicle

Post-Test ¾ Rear View From Right Side of Vehicle

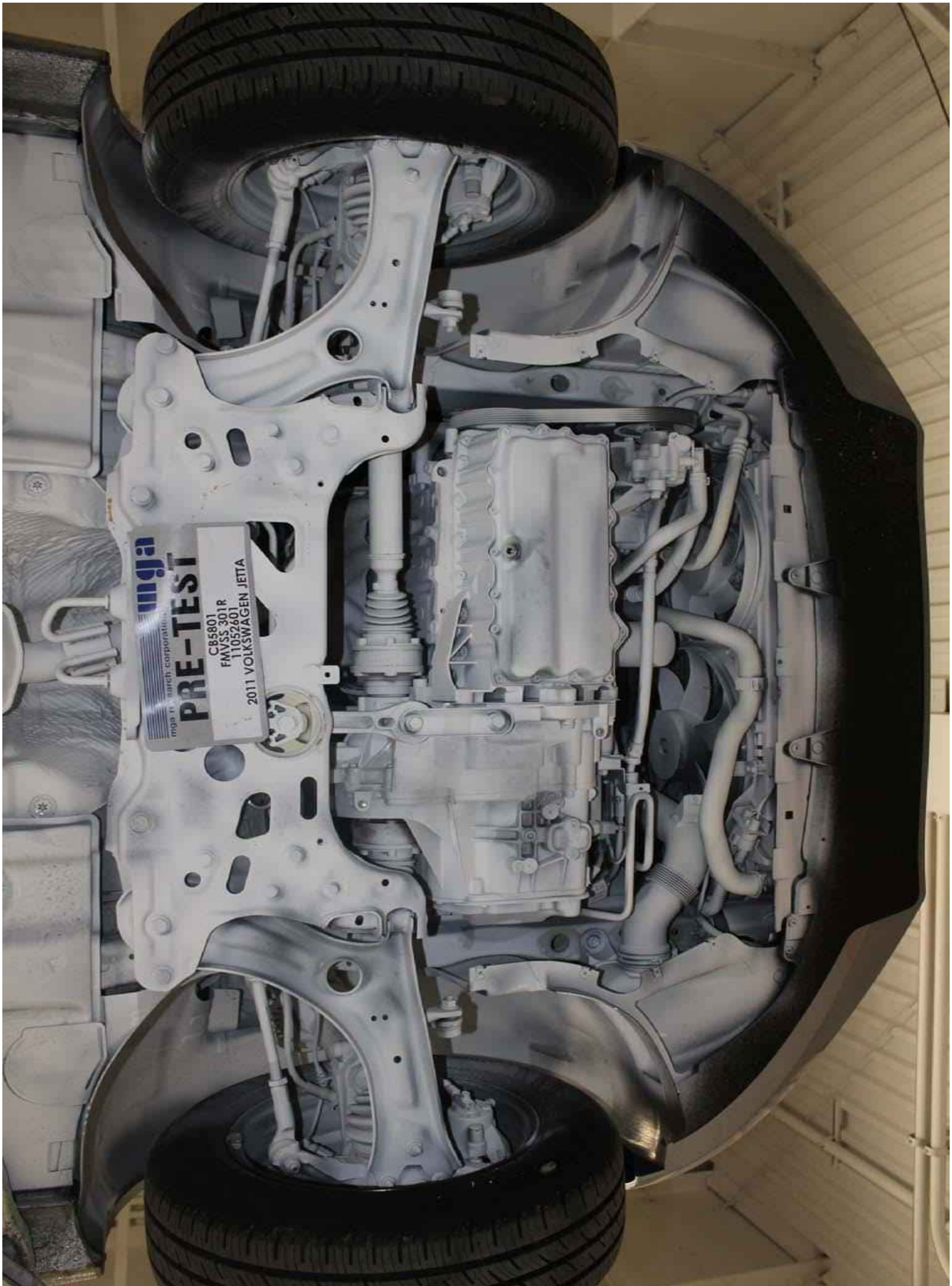
Pre-Test ¾ Rear View From Left Side of Vehicle



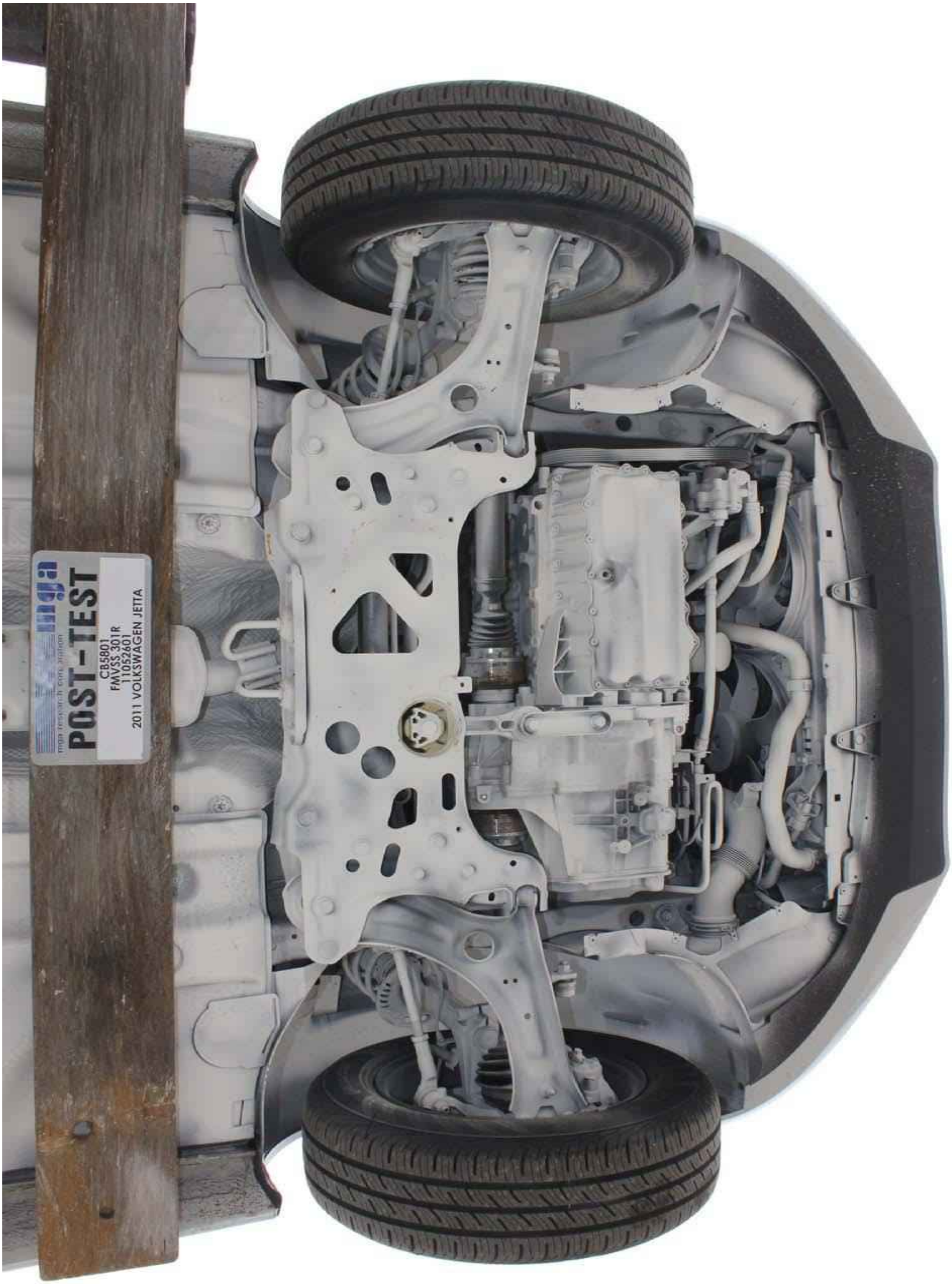
Post-Test ¾ Rear View From Left Side of Vehicle

Pre-Test Impact Point

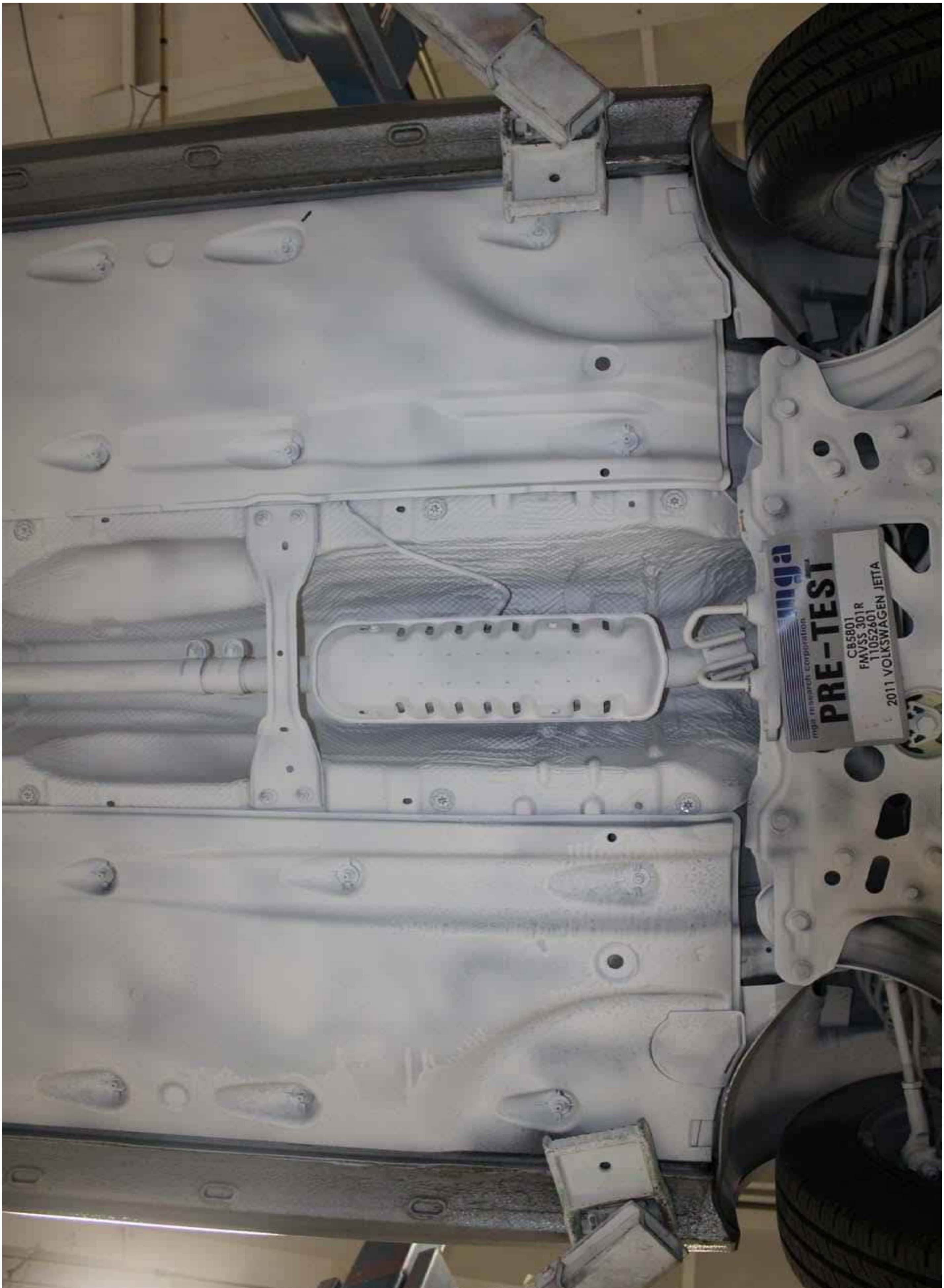
Post-Test Impact Point



Pre-Test Underbody View 1



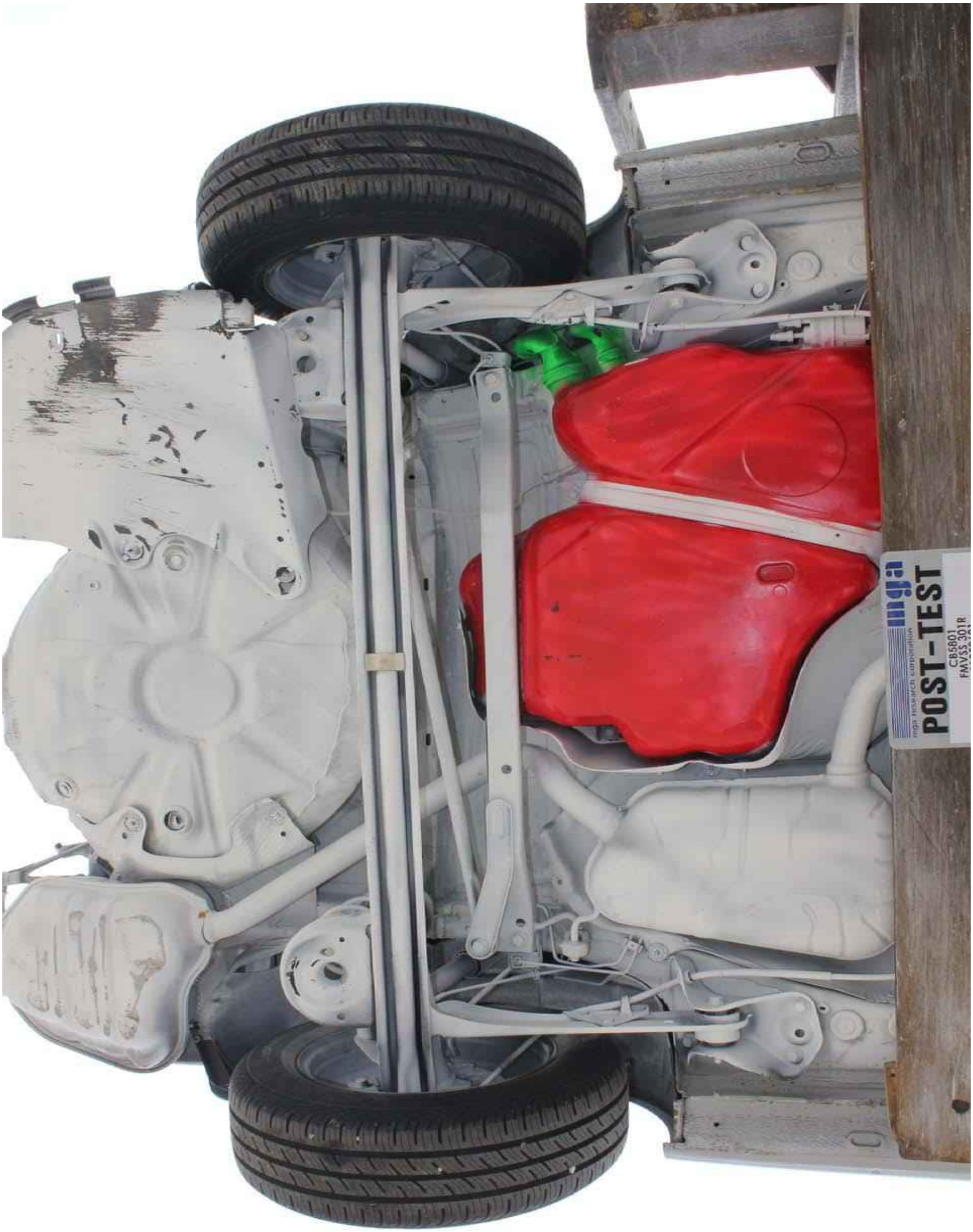
Post-Test Underbody View 1



Pre-Test Underbody View 2

Post-Test Underbody View 2

Pre-Test Underbody View 3



Post-Test Underbody View 3

Pre-Test Front View of MDB

Post-Test Front View of MDB

Pre-Test ¾ Right Side View of MDB

Post-Test ¾ Right Side View of MDB

Pre-Test ¾ Left Side View of MDB

Post-Test ¾ Left Side View of MDB

Pre-Test Top View of MDB

Post-Test Top View of MDB

Static Rollover at 90 Degrees

Static Rollover at 180 Degrees

Static Rollover at 270 Degrees

Static Rollover at 360 Degrees

Crash Test Report

C90503
9718
2009 Hyundai Accent Rear

REPORT NUMBER: 301-CAL-09-01

SAFETY COMPLIANCE TESTING FOR FMVSS 301
FUEL SYSTEM INTEGRITY – REAR IMPACT

HYUNDAI MOTOR COMPANY
2009 HYUNDAI ACCENT
4-DOOR SEDAN

NHTSA NUMBER: C90503

CALSPAN
TRANSPORTATION SCIENCES CENTER
P.O. BOX 400
BUFFALO, NEW YORK 14225

April 09,2009

FINAL REPORT

U. S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
Enforcement
Office of Vehicle Safety Compliance (NVS-224)
1200 New Jersey Avenue, SE
Washington, DC 20590

This Final Test Report was prepared for the U.S. Department of Transportation, National Highway Traffic Safety Administration, under Contract No. DTNH22-06-C-00031. This publication is distributed by the U.S. Department of Transportation, National Highway Traffic Safety Administration, in the interest of information exchange. The opinions, findings and conclusions expressed in this publication are those of the author(s) and not necessarily those of the Department of Transportation or the National Highway Traffic Safety Administration. The United States Government assumes no liability for its contents or use thereof. If trade or manufactures' names or products are mentioned, it is only because they are considered essential to the object of the publication and should not be construed as an endorsement. The United States Government does not endorse products or manufacturers.

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By james.czarnecki at 2:13 pm, 4/30/09

FINAL REPORT ACCEPTANCE BY:

Accepted By: ______________________________

Acceptance Date: ______________________________

TECHNICAL REPORT STANDARD TITLE PAGE

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4. Title and Subtitle Final Report of FMVSS 301 Compliance Rear Impact Testing of a 2009 Hyundai Accent 4-door Sedan NHTSA No.: C90503		5. Report Date April 09,2009 6. Performing Organization Code CAL
7. Author(s) James Czarnecki, Project Engineer David J. Travale, Program Manager		8. Performing Organization Report No.
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15. Supplementary Notes		

16. Abstract

Compliance tests were conducted on the subject 2009 Hyundai Accent 4-door Sedan in accordance with the specifications of the Office of Vehicle Safety Compliance Test Procedure No. TP-301R-02 for the determination of FMVSS 301 compliance. Test failures identified were as follows:

The test vehicle appeared to comply with all requirements of FMVSS 301R-02 "Fuel System Integrity – Rear Impact."

17. Key Words Compliance Testing Safety Engineering FMVSS 301	18. Distribution Statement Copies of this report are available from: National Highway Traffic Safety Administration Technical Reference Division (TIS) (NPO-230) 1200 New Jersey Avenue, SE Washington, D.C. 20590 Telephone No. (202) 366-4946

19. Security Classification of Report	20. Security Classification of Page	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	38	

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	Data Sheet 3 - Moving Deformable Barrier (MDB) Data	3-5
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SECTION 1

PURPOSE AND TEST PROCEDURE

This rear impact test is part of the FMVSS 301 Compliance Test Program sponsored by the National Highway Traffic Safety Administration (NHTSA) under Contract No. DTNH22-06-C-00031. The purpose of this test was to determine if the subject vehicle, a 2009 Hyundai Accent 4-door Sedan, meets the performance requirements of FMVSS No. 301R-02 “Fuel System Integrity – Rear Impact.” The test was conducted in accordance with the Office of Vehicle Safety Compliance's Laboratory Test Procedure (TP-301R-02, dated January 17, 2007).

SECTION 2

COMPLIANCE TEST RESULTS SUMMARY

A 1350 kg 2009 Hyundai Accent 4-door Sedan was impacted from the rear by a 1362.5 kg moving barrier at a velocity of 78.54 kph (48.8 mph). The test was performed by Calspan Corporation on April 09,2009.

The test vehicle was equipped with a 44.7 liter fuel tank which was filled to 92 percent capacity with stoddard fluid prior to impact. Additional ballast (30 kg) was secured in the vehicle cargo area. Two ballast Part 572E 50th percentile male Anthropomorphic Test Device (ATD) were placed in the front occupant seating positions.

The crash event was recorded by three high-speed cameras and one real-time camera. High-speed camera locations and other pertinent camera information are found on page 3-6 of this report. Pre- and post-test photographs of the vehicle can be found in Appendix A.

There was no fuel system fluid spillage following the impact or during any portion of the static rollover test. The average vehicle longitudinal crush was 666 millimeters. The vehicle appeared to comply with all the requirements of FMVSS No. 301 "Fuel System Integrity."

SECTION 3

SUMMARY OF TEST RESULTS

DATA SHEET 1

TEST VEHICLE SPECIFICATIONS

TEST VEHICLE INFORMATION:

Year/Make/Model/Body Style: 2009 Hyundai Accent 4-door Sedan

Vehicle Body Color: Gray NHTSA Number: C90503

Engine Data: 4 Cylinders; - CID; 1.6 Liters; - cc

Transmission: 4 Speed; - Manual; x Automatic; - Overdrive

Final Drive: - Rear Wheel Drive; x Front Wheel Drive; - Four Wheel Drive

MAJOR TEST VEHICLE OPTIONS:

x AC; x Pwr Steering; x Power Brakes; - Power Locks; - Power Seats
- ABS; - Tilt Wheel; - Stab Control - Traction Control - Anti-Theft

DEALER AND DELIVERY INFORMATION:

Date Received: 9/26/08 ; Odometer Reading 63 km

Selling Dealer: Transitowne Hyundai

Dealer Address: 7420 Transit Rd Williamsville, NY 14221

DATA FROM VEHICLE'S CERTIFICATION LABEL:

Vehicle Manufacturer: Hyundai Motor Company

Vehicle Build Date: 12/08

VIN:: KMHCN46C39U285639

GVWR: 1650 kg; GAWR: 870 kg FRONT; 850 kg REAR

DATA FROM VEHICLE'S TIRE LABEL AND SIDEWALL:

Location of Tire Placard: Lower B-Pillar

Type of Spare Tire: Temporary

	Front	Rear
Maximum Tire Pressure (sidewall - kPa)	300	300
Cold Pressure (tire placard - kPa) – test pressure	220	220
Recommended Tire Size (tire placard)	P185/65R14	P185/65R14
Vehicle Tire Size with load index & speed symbol	85H	85H
Tire Manufacturer	Kumho	Kumho
Tire Name	Solus	Solus
Treadwear, Traction, Temperature	440 AA A	440 AA A

VEHICLE CAPACITY DATA:

Type of Front Seats: - Bench; x Bucket; - Split Bench

Number of Occupants: 2 Front; 3 Rear; 5 Total

Vehicle Capacity Weight (VCW) = 385 kg

No. of Occupants x 68.04 kg = 340 kg

Rated Cargo/Luggage Weight (RCLW) = 45 kg

DATA SHEET 2

PRE-TEST DATA

WEIGHT OF TEST VEHICLE AS RECEIVED FROM DEALER (with maximum fluids)= UDW:

	Left Side (kg)	Right Side (kg)	Ratio (%)	Total (kg)
Front =	365	363	62.9	728.0
Rear =	222	207	37.1	429.0
			Total Delivered Weight (UDW) =	1157.0

CALCULATION OF VEHICLE'S TARGET TEST WEIGHT:

Total Delivered Weight (UDW) =	1157.0	kg
Rated Cargo/Luggage Weight (RCLW) =	45.0	kg
Weight of 2 p.572E Dummies @ 78 each =	156	kg
TARGET TEST WEIGHT =	1358.0	kg

WEIGHT OF TEST VEHICLE WITH TWO DUMMIES AND 37.0 KG OF CARGO WEIGHT:

	Left Side (kg)	Right Side (kg)	Ratio (%)	Total (kg)
Front =	417	410	61.3	827.0
Rear =	264	259	38.7	523.0
			Total Vehicle Test Weight (ATW) =	1350.0

Weight of Ballast Secured in Vehicle[1] = 30 kg Ballast Type Lead Shot

Method of securing Ballast: Compartment placement

Components Removed for Weight Reduction: None

VEHICLE ATTITUDE (all dimension in millimeters):

	Left Front	Right Front	Left Rear	Right Rear	CG[2]
AS DELIVERED:	657	663	657	660	928
AS TESTED:	641	645	639	638	970

Vehicle's Wheel Base: 2504 mm

[1]Ballast weight does not include the weight of instrumentation, on-board cameras and data acquisition system

[2]Rearward of the front axle centerline.

VEHICLE PRE-TEST WIDTH AND IMPACT OFFSET MEASUREMENT:

Vehicle Width at Widest Point: 1694 mm Location: Rear Axle

Centerline offset for impact line: 339 / 1355 mm

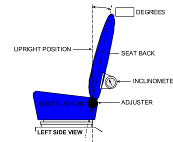
Filler neck side (left/right) Left

DATA SHEET 2 (continued)

PRE-TEST DATA

Vehicle: 2009 Hyundai Accent 4-door Sedan NHTSA No. C90503

Nominal Design Riding Position for adjustable driver and passenger seat backs. Please describe how to position the inclinometer to measure the seat back angle. Include description of the location of the adjustment latch detent, if applicable.



FRONT SEAT ASSEMBLY

Seat back angle for driver's seat: 25 degrees

Measurement instructions: Found with h-point machine in seat

Seat back angle for passenger's seat: 25 degrees

Measurement instructions: Found with h-point machine in seat

2. SEAT FORE AND AFT POSITIONING:

Positioning of the driver's seat: Full forward full rear 0-240mm seat was set at 120 using front of seat cushion in lowest position – Notch 12 was mechanical middle

Positioning of the passenger's seat: Full forward full rear 0-22 notches; seat was set in notch 11

3. FUEL TANK CAPACITY DATA:

3.1 A. "Usable Capacity" of the standard equipment fuel tank is 44.67 liters

B. "Usable Capacity" of the optional equipment fuel tank is - liters

C. "Usable Capacity" of the vehicle(s) used for certification testing to requirements of FMVSS 301 = 41.1 to 41.99 liters

3.2 Actual Amount of Stoddard solvent added to vehicle for test = 41.64 liters

Stoddard Fluid: specific gravity: 0.764 ; kinematic viscosity: 0.96 centistokes; color: Red

3.3 Is vehicle equipped with electric fuel pump? Yes- x ; No- -

If YES, explain the vehicle operating conditions under which the fuel pump will pump fuel.

With ignition turned "ON"

4. STEERING COLUMN ADJUSTMENTS:

Steering wheel and column adjustments are made so that the steering wheel hub is at the geometric center of the locus it describes when it is moved through its full range of driving positions. If the tested vehicle has any of these adjustments, does your company use any specific procedures to determine the geometric center.

Operational Instructions: No adjustment

5. SEAT BELT UPPER ANCHORAGE:

Nominal design riding position: 0 to 3 detents - placed in detent 1

6. COMMENTS:

None

DATA SHEET 3

MOVING DEFORMABLE BARRIER (MDB) DATA

Vehicle: 2009 Hyundai Accent 4-door Sedan NHTSA No. C90503

MDB FACE MANUFACTURER AND SERIAL NUMBER:

N/A

MDB DETAILS:

Overall Width of Framework Carriage	=	1250	millimeters
Overall Length of MDB (incl. honeycomb impact face)	=	4120	millimeters
Wheelbase of Framework Carriage	=	2591	millimeters
Tread of Framework Carriage (Front & Rear)	=	1875	millimeters
C.G. Location Rearward of Front Axle	=	1139	millimeters

MDB WEIGHT:

Left Front	=	357.0	kg	Left Rear	=	323.0	kg
Right Front	=	404.0	kg	Right Rear	=	273.5	kg
TOTAL FRONT	=	761.0	kg	TOTAL REAR	=	596.5	kg
TOTAL MDB WEIGHT	=	1357.5	kg				

Tires (Mfr, line, size): N/A

TIRE PRESSURE:

Left Front	=	207	kPa	Left Rear	=	207	kPa
Right Front	=	207	kPa	Right Rear	=	207	kPa

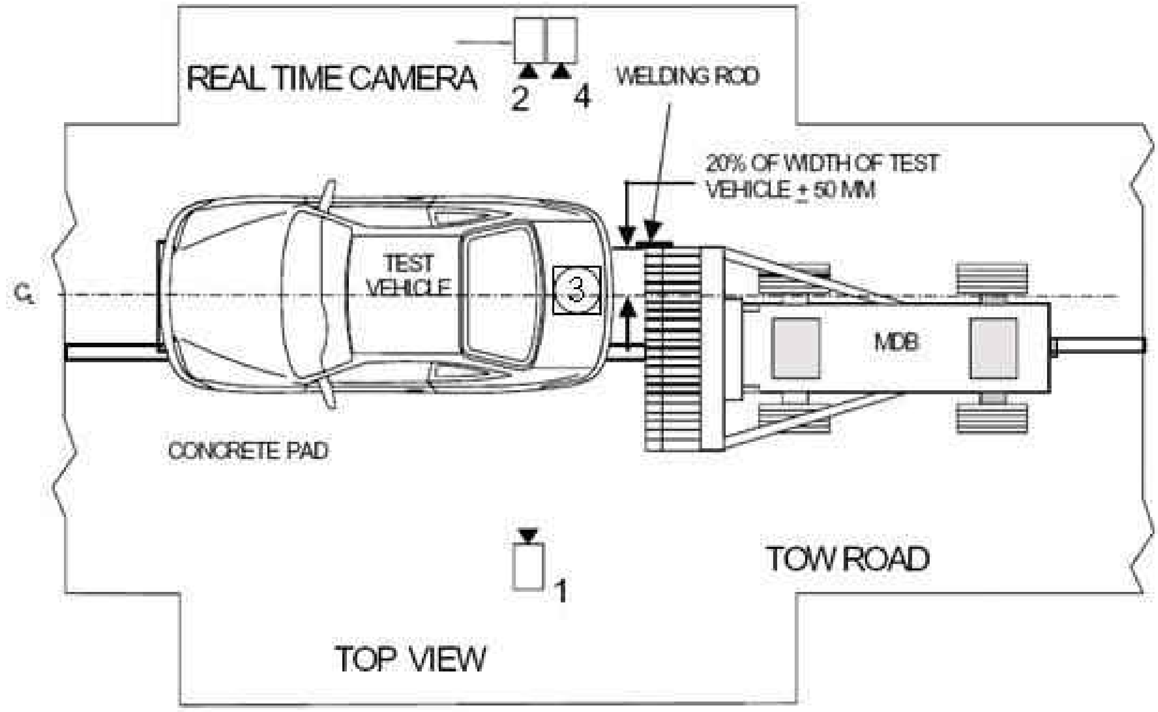
Brake Abort System? (Yes/No) Yes

Date of Last Calibration: 06/07

DATA SHEET 4

HIGH SPEED CAMERA LOCATIONS AND DATA SUMMARY

Vehicle: 2009 Hyundai Accent 4-door Sedan NHTSA No. C90503



Camera No.	View	Coordinates (millimeters)			Angle (deg.)	Lens (mm)	Film Speed (fps)
		X*	Y*	Z*			
1	Left Side View	7117	1805	1094	3.6	25	1000
2	Real-Time Camera	-	-	-	-	-	30
3	Overhead View	0	0	4880	90	12.5	1000
4	Right Side View	7764	1423	954	1.1	25	1000

* Reference (from point of impact); all measurements accurate to within ±6 mm.
X = (Impact Point) + Forward
Y = (Impact Point) + To Right
Z = (Ground Level) + Down

DATA SHEET 5

POST-TEST DATA

Vehicle: 2009 Hyundai Accent 4-door Sedan NHTSA No. C90503

REQUIRED IMPACT VELOCITY RANGE:: 78.5 to 80.1 km/h

ACTUAL IMPACT VELOCITY WITHIN 1.5 M OF IMPACT PLANE:

Trap No. 1 = 78.54 km/h Trap No. 2 = 78.54 km/h

Average Impact Speed = 78.54 km/h

WELDING ROD IMPACT POINT:

0 Vertical distance from target center (+ is above) Tolerance: ±40 mm

0 Horizontal distance from target center (+ is right) Tolerance: ±50 mm

STODDARD SOLVENT SPILLAGE MEASUREMENT:

A. Front impact until vehicle motion ceases -

Actual = 0 g Maximum Allowable = 28 g

B. For 5 minute period after vehicle motion ceases -

Actual = 0 g Maximum Allowable = 28 g

C. For next 25 minutes -

Actual = 0 g/minute Maximum Allowable = 28 g/minute

D. Provide Spillage Details:

None

DATA SHEET 5

POST-TEST DATA (Continued)

Vehicle: 2009 Hyundai Accent 4-door Sedan NHTSA No. C90503

POST TEST SEAT DATA

LOCATION	SEAT MOVEMENT (mm)	SEAT BACK FAILURE
P1 (Left Front)	0	None
P2 (Right Front)	0	None

POST TEST ATD CONTACT DATA

LOCATION	Position 1 (Driver)	Position 2 (Passenger)
Head	Back of head to head restraint	Back of head to head restraint
Chest	None	None
Abdomen	None	None
Left Knee	None	None
Right Knee	None	None

VEHICLE DIMENSIONS:

Vehicle length:

	Left Side	Centerline	Right Side
Pre-Test	4153	4279	4153
Post-Test	3555	3613	3580
Crush	598	666	573

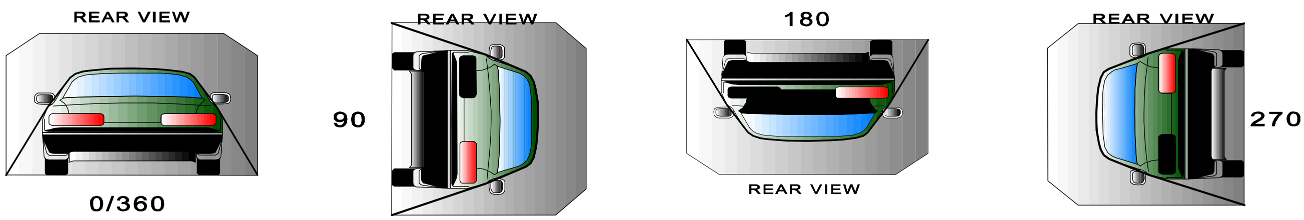
Vehicle Wheel Base:

	Left Side	Right Side
Pre-Test	2503	2503
Post-Test	2425	2503
Crush	78	0

DATA SHEET 6

FMVSS 301 ROLLOVER DATA

Vehicle: 2009 Hyundai Accent 4-door Sedan NHTSA No.: C90503



I. DETERMINATION OF SOLVENT COLLECTION TIME PERIOD:

Rollover Stage	Rotation Time (spec. 1 -3 min)				FMVSS 301 Hold Time		Total Time				Next Whole Minute Interval	
0º - 90º	1	minutes	05	seconds	5	minutes	6	minutes	5	seconds	7	minutes
90º - 180º	1	minutes	12	seconds	5	minutes	6	minutes	12	seconds	7	minutes
180º-270º	1	minutes	09	seconds	5	minutes	6	minutes	9	seconds	7	minutes
270º-360º	1	minutes	06	seconds	5	minutes	6	minutes	6	seconds	7	minutes

II. FMVSS 301 REQUIREMENTS: (Maximum allowable solvent spillage):

First 5 minutes from onset of rotation	6th min.	7th min.	8th min. (if required)
142 g	28 g	28 g	28 g

III. ACTUAL TEST VEHICLE SOLVENT SPILLAGE:

Rollover Stage	First 5 minutes from onset of rotation (g)	6th min. (g)	7th min. (g)	8th min. (if required) (g)
0º - 90º	0	0	0	N/A
90º - 180º	0	0	0	N/A
180º-270º	0	0	0	N/A
270º-360º	0	0	0	N/A

Note: Record spillage for whole minute intervals only as determined above.

IV. SOLVENT SPILLAGE LOCATION(S):

Rollover Stage	Spillage Location
0º - 90º	None
90º - 180º	None
180º-270º	None
270º-360º	None

APPENDIX A

PHOTOGRAPHS

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Figure A- 4	POST-TEST FRONT VIEW	A- 4
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Figure A-1: Vehicle Certification Placard

Figure A-2: Vehicle Tire Placard

Figure A-3: Pre-Test Front View

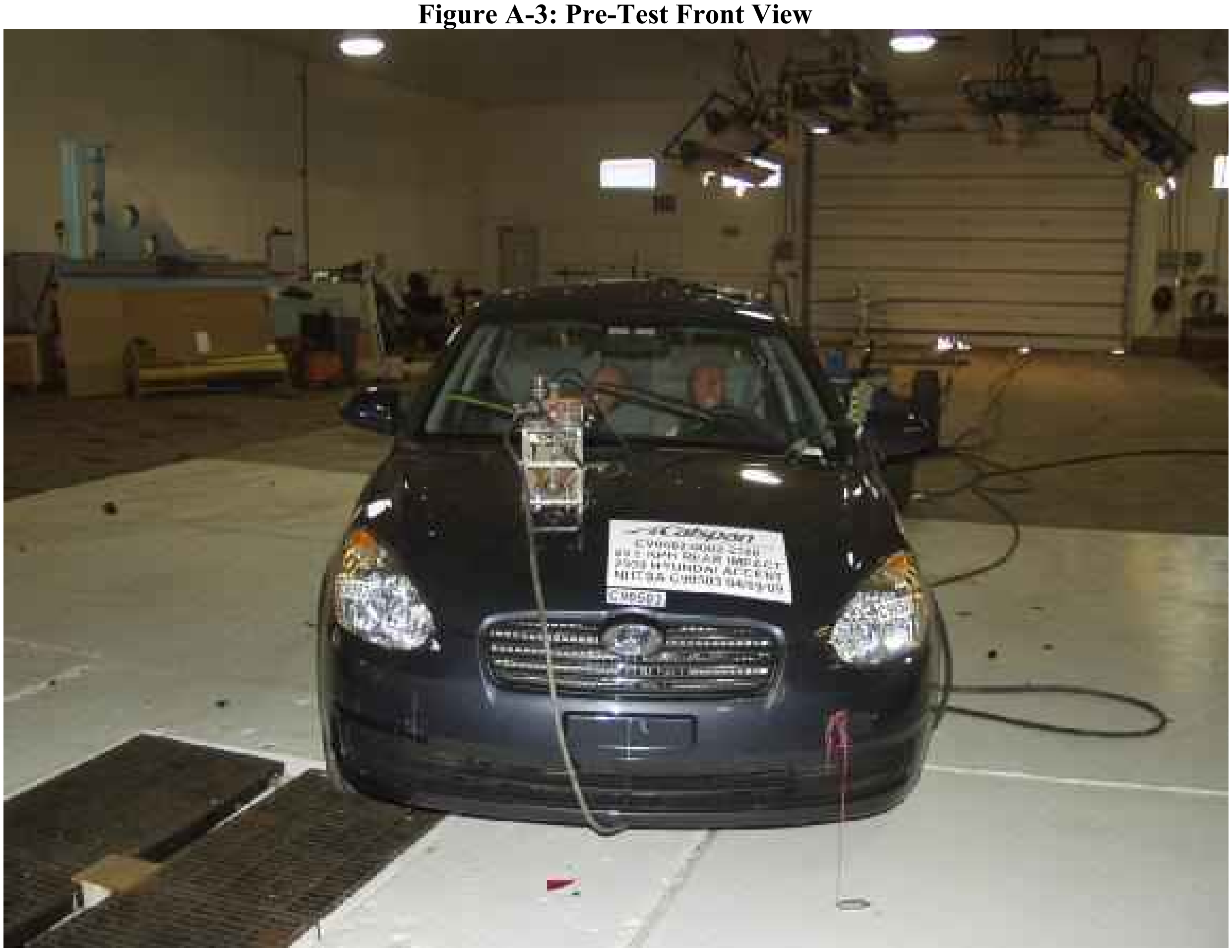


Figure A-4: Post-Test Front View

Figure A-5: Pre-Test Left Side View

Figure A-6: Post-Test Left Side View

Figure A-7: Pre-Test Right Side View

Figure A-8: Post-Test Right Side View

Figure A-9: Pre-Test Left Front Three-Quarter View

Figure A-10: Post-Test Left Front Three-Quarter View


Figure A-11: Pre-Test Right Front Three-Quarter View


Figure A-12: Post-Test Right Front Three-Quarter View

Figure A-13: Pre-Test Left Rear Three-Quarter View

Figure A-14: Post-Test Left Rear Three-Quarter View

Figure A-15: Pre-Test Right Rear Three-Quarter View

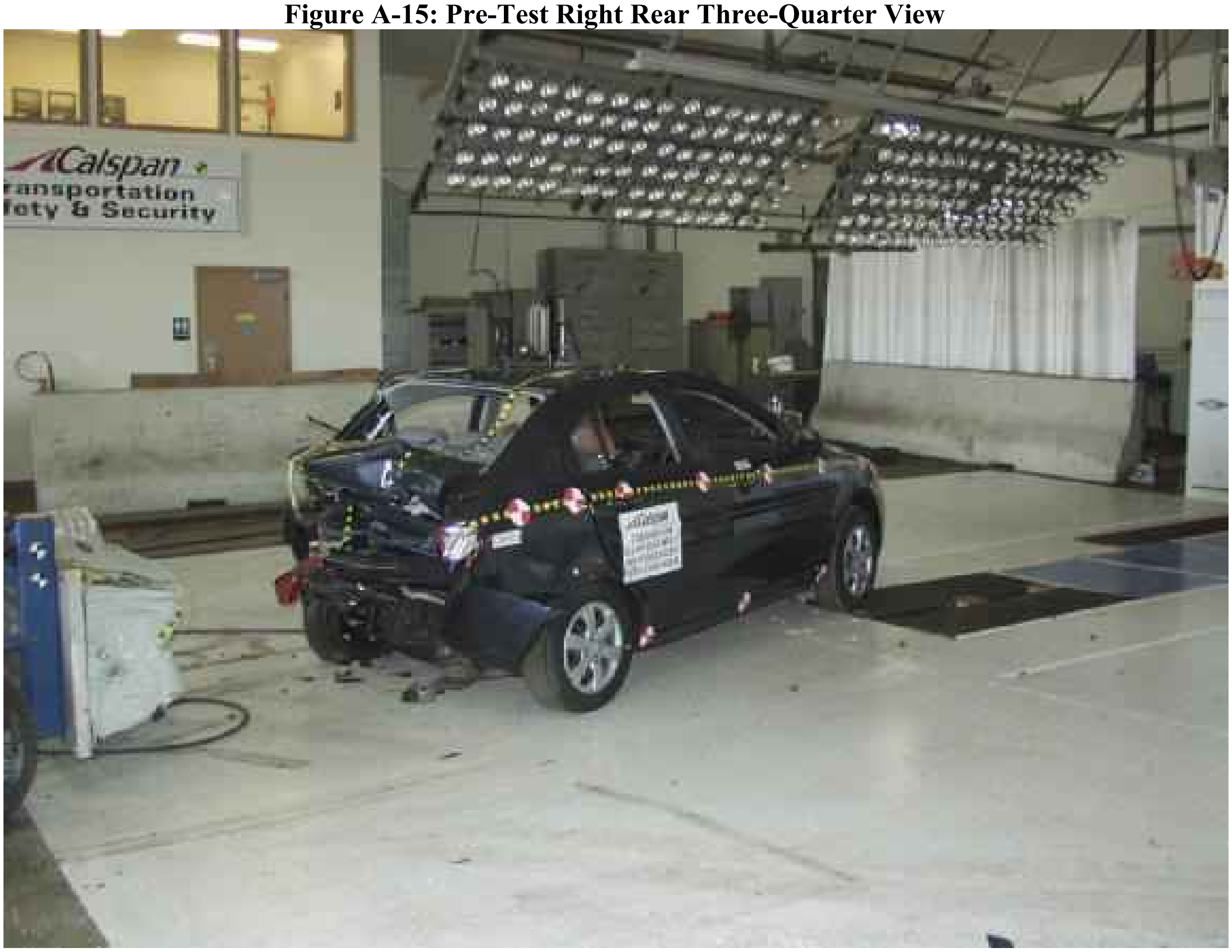


Figure A-16: Pre-Test Right Rear Three-Quarter View

Figure A-17: Pre-Test Rear View

Figure A-18: Post-Test Rear View

Figure A-19: Pre-Test MDB Front View

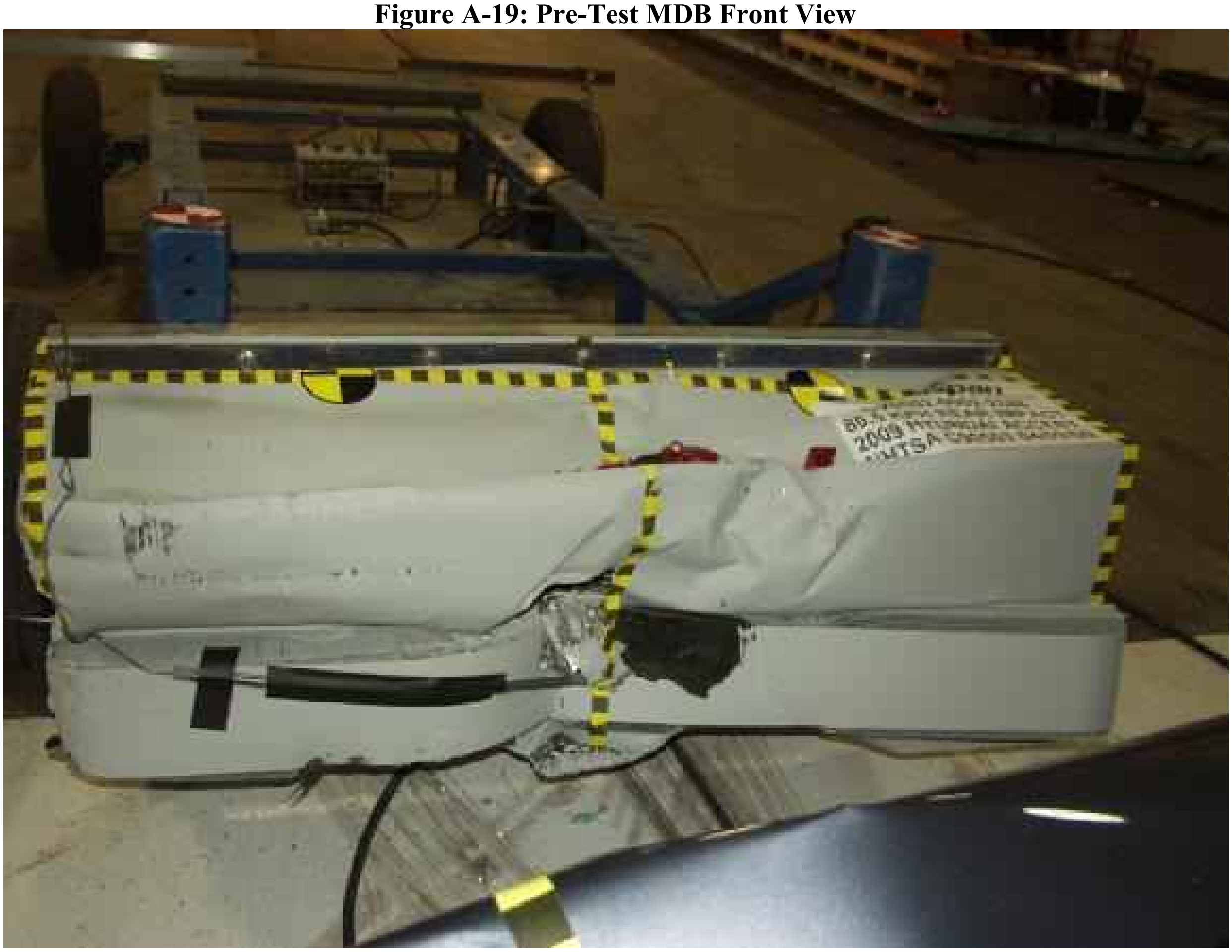


Figure A-20: Post-Test MDB Front View

Figure A-21: Pre-Test MDB Left Side View

Figure A-22: Post-Test MDB Left Side View

Figure A-23: Pre-Test MDB Right Side View


Figure A-24: Post-Test MDB Right Side View

Figure A-25: Pre-Test MDB Top View


Figure A-26: Post-Test MDB Top View

Figure A-27: Pre-Test Overhead Vehicle and MDB View

Figure A-28: Post-Test Impact Target View

Figure A-29: Pre-Test Front Underbody View

Figure A-30: Post-Test Front Underbody View

Figure A-31: Pre-Test Mid Underbody View

Figure A-32: Post-Test Mid Underbody View

Figure A-33:Pre-Test Rear Underbody View

Figure A-34: Post-Test Rear Underbody View

Figure A-35: Pre-Test Fuel Filler Cap View

Figure A-36: Post-Test Fuel Filler Cap View


Figure A-37: Impact View

Figure A-38: Rollover 90° View

Figure A-39: Rollover 180° View


Figure A-40: Rollover 270° View


Figure A-41: Rollover 360° View

Speed Evaluation Report Florida Case Study

Subject: Preliminary Speed calculations for Mediation on 9/15/2023
From: Daniel Vomhof III <dv3@4n6xprt.com>
Date: 9/8/2023, 1:05 PM
To: N[redacted]
BCC:[redacted]

Mr. E[redacted]-

Per your request a preliminary speed calculation for the FDLE vehicle has been prepared. These calculations are based upon estimates from photographs of post vehicle travel for both the FDLE vehicle and the Go[redacted]'s vehicle, as well as crush to both vehicles. Unfortunately, due to the lack of documentation of physical evidence obtained and/or provided by the FDLE and FHP, estimates from photographs are the best that can be done. It should be noted that there is a discrepancy between the Point of Rest for the Go[redacted]'s vehicle in the FHP report, and where it is located in the scene photographs.

Based on the limited scene photographs showing the points of rest of both vehicles, some post impact travel distances were obtained using Google maps. These pages are attached. Post impact travel of about 53 feet for the FDLE vehicle and about 52 feet for the Go[redacted]'s vehicle were obtained.

From photographs of the Go[redacted]'s vehicle in the tow/storage yard, and the FDLE vehicle at the scene, preliminary maximum crush measurements for the Go[redacted]'s vehicle of 19 inches and for the FDLE vehicle of 10 inches were obtained.

Using commonly accepted formulas for calculating "speed from skid" and "speed from crush" the following calculations were completed -

Post Impact Travel Speed (**pits**) = SQR(30 * distance in feet * friction)

FDLE vehicle = SQR (30 * 53 * 0.7) = SQR (1113) = 33.4 mph
Gouin's Vehicle = SQR (30 * 52 * 0.7) = SQR (1092) = 33.0 mph

Speed from Crush (**sfc**) = SQR (30 * max crush distance in feet * Crush Factor) *(Note, I have been told that FHP teaches this method and equation for calculating speed from crush to their officers as a preliminary speed determination formula for them to use in the field)*

FDLE vehicle = SQR (30 * 10/12 * 21) = SQR (525) = 22.9 mph
Gouin's vehicle = SQR (20 * 19/12 * 21) = SQR(997.5) = 31.6 mph

Since all of the energy losses expressed as speed in the northeastward direction came from the FDLE vehicle, and all of the crush energy losses expressed as a speed came from the FDLE vehicle, an impact speed for the FDLE vehicle can be calculated by combining the above 4 speeds.

FDLE Impact speed = SQR (FDLE**pits**^2 + GOUIN**pits**^2 + FDLE**sfc**^2 + GOUIN**sfc**^2)
FDLE Impact speed = SQR (33.4^2 + 33.0^2 +22.9^2 + 31.6^2)
FDLE Impact speed = SQR (1113 + 1092 + 525 + 997.5)
FDLE Impact speed = SQR (3727.5)

FDLE Impact speed = 61.0 mph

Based upon this analysis, the speed of the FDLE vehicle was in the neighborhood of 61 mph at impact with the G[redacted]'s vehicle. If there was any pre-impact skid/braking by the FDLE vehicle, the speed at start of braking would have been higher than this.

Based upon the information available to me at this time, the above information is correct to a reasonable degree of scientific certainty. If any additional information becomes available regarding the physical evidence at the scene of this crash, these calculations will have to be re-visited with that additional information in hand.

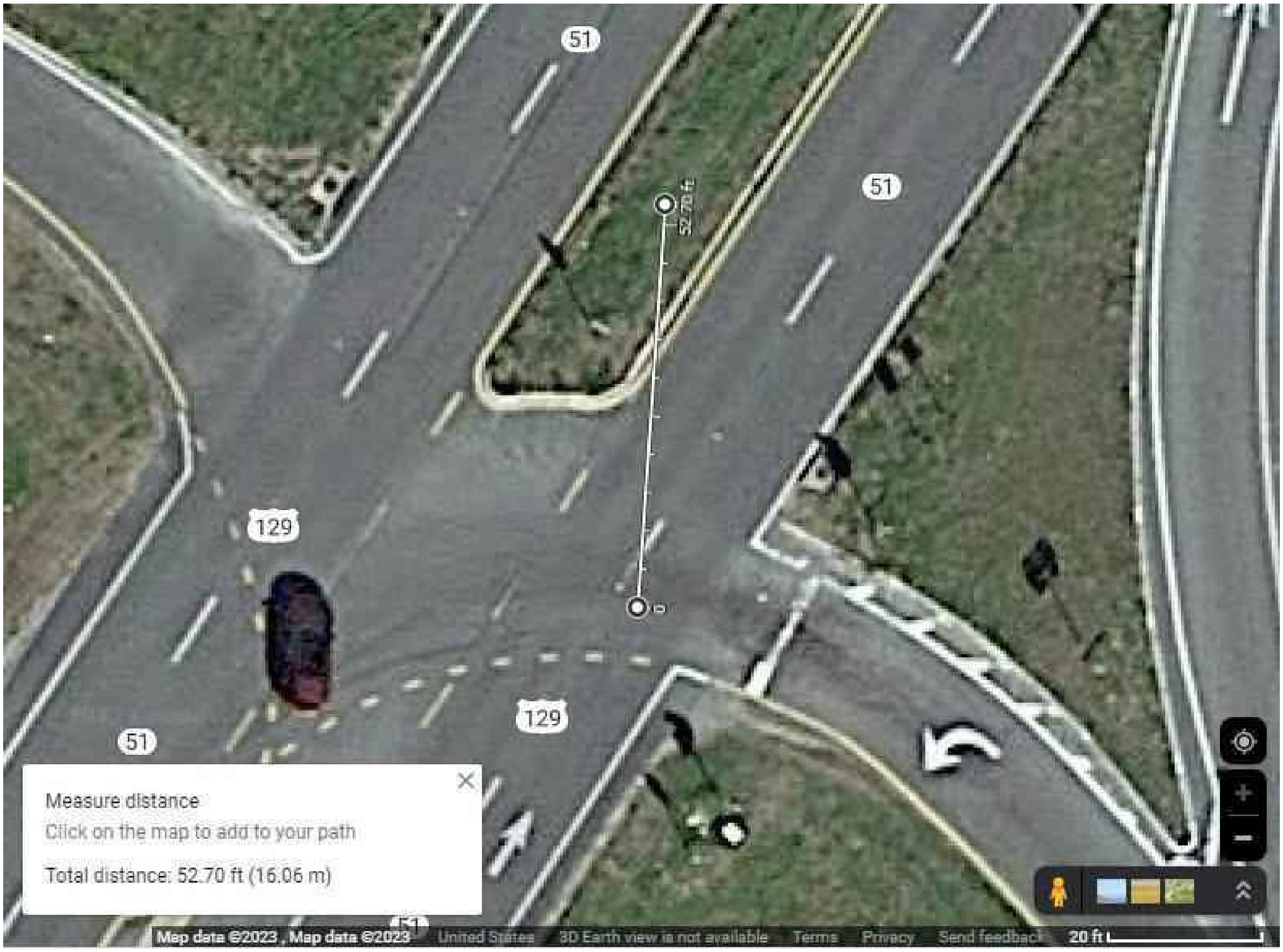
Error rate allotments of +/- 10% are typically assigned to variables used in the above calculations. Applying this +/- 10% error rat to the calculated final speed arrives at a Impact speed range for the FDLE vehicle of ~56-67 mph.

Please keep me advised if any additional evidence documentation data becomes available.

Respectfully,

Daniel W. Vomhof III, ACTAR # 484
Expert Witness Services, Inc.
8387 University Avenue
La Mesa, CA 91942-9342
Phone: (619) 464-3477
Fax: (619) 464-2206
E-mail: dv3@4n6xprt.com
Expert Witness Services web site: http://www.ews-4n6xprt.com/

23F006 - GMC Post Travel.jpg



23F006 - Ford Post Travel.jpg

Attachments:

23F006 - GMC Post Travel.jpg	92.8 KB
23F006 - Ford Post Travel.jpg	105 KB

Speed Evaluation Report California Case Study

EXPERT WITNESS SERVICES, INC.

FORENSIC RESEARCH LABORATORIES 8387 University Avenue, La Mesa, CA 91942
Phone: (619) 464-3477

June 28, 2024

C[redacted], Esq
Attorney at Law
[redacted]

RE: People vs F[redacted]
Case # CH[redacted]
OUR CASE FILE: 24-F-[redacted]
SUBJECT: File Review and Preliminary Speed Calculations

Dear Ms. B[redacted],

Pursuant to your request, I have reviewed the following supplied materials:

* Felony Complaint dated 4/25/2023
* 4 pages of "WebWS 5.7" printout
* 1 page of nearly illegible "Crime Summary Information"
* 3 page "Driving Under the Influence Arrest - Investigation Report"
* 16 page Traffic Crash Report # 9[redacted] dated 07/06/2022
* 1 page Property Receipt - Control # E[redacted] Disc Containing Video of Crash
* 1 page CHP Vehicle Report A[redacted] for a 2020 Nissan 370Z
* 1 page Narrative/Supplemental dated 2/28/23
* Video with file name "**VIDEO DISCOVERY - F**[redacted]" showing the Ford Fusions movements immediately prior to the first collision along with the first collision and the Nissan 370Z's movement away from the first collision.

SCOPE OF WORK

Expert Witness Services Inc was to conduct an accident reconstruction, and if possible, arrive at a speed determination for the vehicles involved from the information available.

DATA CONSIDERED

The majority of the information came from the Traffic Crash report, primarily pages 1, 2, 6, 7, 9, 10, 11, & 14.

- Page 1 & 2 identified the vehicles involved, for which weights were obtained. Page 1 also indicates that no photographs were taken.
- Page 6 and 7 showed the basic intersection configuration, some dimensions, and generally the locations and movements of the vehicles.
- Page 9-11 give a general description of the damage to each vehicle
- Page 14 identifies the "approximate" locations of each of the "four" impacts

No dimensions were given for points of rest for any of the vehicles.

The information within the Traffic Crash Report was supplemented by observations made from the video of the crash and the time immediately prior to and post crash.

DISTANCES & DIMENSIONS & OTHER PHYSICAL CONSTRAINTS

Using the 4 AOI's identified in the Traffic Crash report, the following distances to be used in subsequent calculations were obtained.

AOI #2 is about 19.66 feet North of AOI #1. This is important for the speed calculations as all of the energy to move the Ford Fusion North of AOI #1 came from the Nissan 370Z.

The distance from AOI #1 to AOI #3 is about 90.5 feet

The distance from AOI # 3 to AOI #4 is about 14.75 feet.

The Roadway surface is identified as dry and of asphalt and concrete construction (pages 3 & 8). From tables, a typical friction value of rubber to pavement is 0.75.

Vehicle 1, a 2020 Nissan 370Z has a published curb weight of 3533 pounds.
Vehicle 2, a 2020 Ford Fusion Hybrid has a published curb weight of 3615 pounds.
Vehicle 3, a 1995 Toyota Tercel has a published curb weight of 1950 pounds and an overall length of 13.50 feet.
Vehicle 4, a 2020 Jaguar F-Pace SUV has a published curb weight of 4015 pounds.

SPEED CALCULATIONS

All speed calculations are directly or indirectly based on, and limited by, the documentation within the Traffic Crash Report.

No photographs or other documentation, other than a general description of the damage to each vehicle, was made for the damage of any of the vehicles.

No final rest positions of any of the involved vehicles was documented. Therefore, post impact movements of vehicles need to be estimated in order to conduct the calculations.

The standard method of conducting speed calculations in a multiple impact collision is to start at the end, and move “back” to the start of the events.

Using Inline Momentum calculations, at AOI #4 an impact speed of 5-10 mph for the Toyota Tercel into the Jaguar F-Pace was calculated. An impact speed of this magnitude is consistent with the description of bumper damage only for the Jaguar. This is also consistent with the sketch of the damage to the Toyota as contained on Page 1 of the Crash Report as the Toyota would tend to dip down and slide under the bumper of the Jaguar, thus “denting” the hood and grille, and breaking the left headlight assembly as described on page 10.

Again, using Inline Momentum calculations, at AOI # 3 an impact speed of about 9 mph was calculated for the Nissan 370Z into the rear of the Toyota Tercel. This impact speed is consistent with the described damage to the Rear of the Tercel of a “dented rear bumper” with no other rear end damage noted.

A calculation for the energy loss expressed as a speed for the Nissan 370Z as it traveled from AOI #1 to AOI #3 was conducted using braking efficiencies of 0.1, 0.25, 0.5, 0.75, and 1.0. These calculations resulted in a energy loss range expressed in units of speed of 14-45 mph.

A calculation for the energy for the Northbound movement of the Ford Fusion as it traveled from AOI #1 to AOI #2 was calculated. As stated earlier, all of this energy came from the Nissan 370Z traveling in the Northbound direction. The calculations for this energy “loss” expressed as a speed was just under 19 mph.

If one combines the calculated impact speed for the Nissan 370Z at AOI #3, the “speed” for the travel distance from AOI #1 to AOI #3, and the Northbound “speed” for the Ford Fusion from AOI #1 to AOI #2, the resultant speed will be the impact speed for the Nissan 370Z at impact. This speed calculates out to a speed range of about 25-50 mph. The biggest variable here is the energy loss while traveling from AOI #1 to AOI #3. This energy loss is determined by the braking “efficiency” (i.e. - brake application percentage) over this distance.

A breakdown of the resultant speeds by braking efficiencies are as follows:

Efficiency = 0.10	AOI #1 Impact Speed = ~ 25.3 mph
Efficiency = 0.25	AOI #1 Impact Speed = ~ 30.7 mph
Efficiency = 0.50	AOI #1 Impact Speed = ~ 38.1 mph
Efficiency = 0.75	AOI #1 Impact Speed = ~ 44.3 mph
Efficiency = 1.00	AOI #1 Impact Speed = ~ 49.7 mph

If better documentation of vehicle Points of Rest, damage, and evidence on the ground had been conducted, more refined calculations for the speed of the Nissan 370Z at impact could have been completed.

VIDEO

Several items of note were observed within the video of the collision

1. The Ford Fusion did not come to a full and complete stop, neither at the limit line nor at the curb line, prior to entering Holt Avenue.
2. Due to the lighting and the limited field of view, there are insufficient landmarks to conduct a video evaluation of the speed of the Nissan 370Z.
3. The rapidity of the rotation of the Ford Fusion as it departs from AOI #1 is a strong indication of the impact between the Ford Fusion and the Nissan 370Z occurring at the Rear axle or even further back on the Ford Fusion. The further rearward that the impact occurs on the Ford Fusion, the greater the rotation of the Ford Fusion will be. Impact at the driver's door or directly behind the drivers door will not impart the rotation of the Ford Fusion that is observed in the video.
4. The Nissan 370Z as it departs AOI #1 towards AOI #3 has some slowing due to the impact with the Ford Fusion, but does not appear to be slowing as it travels from the AOI #1 to out of screen on the right frame of the video.
5. The headlights for the Nissan 370Z were on and both were functional.

FINDINGS

The lack of full documentation of damage to the 4 vehicles along with a lack of documentation of the vehicles Points of Rest limits the ability to calculate a speed of Impact for the Nissan 370Z at AOI #1.

The lack of a CDR/EDR download of either or both of the Nissan 370Z and the Ford Fusion results in a failure to document the speed of the Nissan 370Z at impact, the speed of the Ford Fusion at impact, and whether the Ford Fusion came to a full and complete stop, and if it did, for how long.

The Ford Fusion, based on observations of the vehicle in the video of the collision, failed to come to a full and complete stop prior to entering Holt Avenue. The vehicle definitely was not "*.... stopped at the intersection of Holt Avenue and Vanderlip Avenue, getting ready to make a left turn to go southbound on Holt Avenue. Party #2 looked both ways, ...*" as stated on page 12 of the Crash Report. It is also inconsistent with the statement that Vehicle #2 "*.... was at a complete stop, at the limit line, preparing to make a left turn ....*" As stated on page 13. The failure of the Ford Fusion to come to a full and complete stop prior to entering Holt Avenue would eliminate the ability of the driver to carefully look in both directions prior to entering Holt Avenue and thereby reduce the driver of the Ford Fusion's ability to fully check for, and properly evaluate the speed of, any oncoming vehicles.

I have been present for, observed, and helped document over 160 vehicle to vehicle crash tests. Many of these tests involved a driver operating the "bullet" vehicle. The comment made by these drivers when asked about their foot on the brake pedal is that if they had their foot on the brake pedal at impact, the foot was displaced from the brake pedal at impact and it took a period of time before they could get their foot back onto the brake pedal.

The "normal speed" for this area, established in part by the speed limit, argues against the two lower "braking efficiencies" of 0.10 and 0.25 as they result in impact speeds that are unreasonably low for normal traffic on this roadway. In the same manner,

-the lack of described damage to the Nissan 370Z regarding fenders into and locking either of the front wheels,
- the various driver comments during crash testing regarding foot position on the brake pedal,
- the lack of any roadway markings left by the Nissan 370Z within the report, and
- the limited speed reduction for the Nissan 370Z observed post AOI #1 in the video

argues against a "braking efficiency" of 1.00, as this braking action would be visible and apparent in the video and would be expected to leave some roadway markings.

The "braking efficiencies" of 0.50-0.75 resulting in a calculated impact speed range of ~38-~44 mph is consistent with some braking on the part of the Nissan 370Z while keeping with the lack of noticeable slowing post impact #1 for the Nissan 370Z observed in the video.

The location of the damage to the Ford Fusion is indicated by the rapid spin of the vehicle as it departed AOI #1. The rapid spin indicates that the major force on the Ford Fusion by the Nissan 370Z would have been applied to the Ford Fusion at some distance behind the drivers seat and in a rearward direction. This is inconsistent with the driver suffering a "crushed right ankle" as a result of this collision as stated in the Narrative/Supplemental dated 2/28/23. An impact at this general location and with an impact force towards the rear of the Ford Fusion is also inconsistent with the windshield of the Ford Fusion being "crushed" as described on page 10 of the Crash Report. It is very likely that the windshield was broken, not by the force of the impact, but by the deployment of the vehicle's frontal airbags.

There is nothing within the Traffic Crash Report to substantiate nor support the speed of "*greater than 65 miles per hour*" attributed to the Nissan 370Z on page 13 of the report.

The most likely speed of the Nissan 370Z at impact was ~40-45 mph, based upon the documentation of the collision scene that is contained within the Crash Report. This speed is consistent with the speed of "*approximately 45 mph*" stated by Mr. R[redacted] in his statement as contained on page 12 of the Crash Report.

Part of setting speed limits is to consider traffic on the roadway, road width and road surface. There are no documented weather conditions limiting visibility, or roadway surface conditions reducing the ability to control a vehicle. There are no documented unusual traffic conditions on the roadway for the time period around the time of the collision. The posted speed limit for Holt Avenue at the location of this collision is 45 mph. The calculated most probable speed for the Nissan 370Z based on the information available is in the range of 40-45 mph. Given that the calculated most probable speed for Mr. R[redacted] of 40-45 mph is at or near the posted speed limit of 45 mph and there are no other documented adverse roadway or traffic elements as described in the Basic Speed Law, there is no support for the statement that Mr. R[redacted] was traveling at an unsafe speed and thus was in violation of 22350 V.C. Therefore, Mr. R[redacted] speed would not be a contributing factor to this collision.

Based on physics, and time-speed-distance relationships, there is a two-fold "cause" of this crash on Ms. M[redacted]'s part. The first is Ms. M[redacted]'s failure to bring her vehicle to a full and complete stop at the limit line prior to entering Holt Avenue from Vanderlip Avenue. This failure to come to a full and complete stop limited her ability to properly observe and evaluate oncoming traffic. This in turn led to her entering the intersection and attempting to make a left turn in front of the oncoming Nissan 370Z when it was "*so close as to constitute a immediate hazard*" to her and her vehicle.

OPINIONS AND CONCLUSIONS

Based upon the information available to me at this time:

1 - Mr. R[redacted] was traveling at or near the speed limit of 45 mph when his Nissan 370Z impacted the Ford Fusion. As such, he was not driving "*a vehicle upon a highway at a speed greater than is reasonable or prudent having due regard for weather, visibility, the traffic on, and the surface and width of, the highway.*" and thus was not in violation of 22350 V.C.

2 - Irrespective of the level of possible intoxication of Mr. R[redacted] at the time of the collision, the cause of the collision was Ms. M[redacted]'s failure to fully stop before pulling into the intersection in front of Mr. R[redacted] when he was operating a vehicle "*approaching from another highway or so closely that it's an immediate hazard.*" As such 21802 V.C. requires that "*Drivers approaching a stop sign at an intersection must yield to vehicles approaching from another highway or so closely that it's an immediate hazard.*"

If additional information, testimony, or reports are submitted, my opinions may be modified depending on the information submitted. Additional opinions may also be expressed if questions requiring them are asked during deposition or other sworn testimony.

Respectfully submitted,

Daniel Vomhof III

Daniel W. Vomhof III, EIT
ACTAR # 484