Applying A-B-G and Crush Factor Values to the Evaluation of Impact Speed from Crush Damage for Frontal Crush to the 1989-1996 Ford Thunderbird

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Introduction:

In the time frame of 1983 to 1998 there has been a switch in "mainstream" thinking and practice with regards to calculating speed from crush within the Accident Reconstruction community. In 1983 it was not uncommon to hear a statement like "You can't calculate vehicle speed from crush because there are too many uncertainties" made within an Accident Investigation/Reconstruction course. These comments were made despite the existence of formulas to compute the speed from crush and the development of the CRASH (Calspan Reconstruction of Accident Speeds on the Highway) model. One source of data was J. Stannard Baker's "Traffic Accident Investigation Manual" which cites a drag factor of -20 for a car crash into a solid fixed object[1]. Today there are week long courses where the calculation of speed from crush is one of the major, if not the major, topic of the course. These courses primarily concentrate on the application of some flavor of the CRASH model.

A-B-G Stiffness Values - Sources and problems:

Of prime importance to the application of the current generation of the CRASH model are the A-B-G stiffness values. Values of A-B-G may be obtained for a large number of vehicles from a variety of sources, including deriving the data from the NHTSA or other crash test results yourself. Other sources of this data include 4N6XPRT Systems[2], Neptune Engineering, Inc. (NEI)[3], *Accident Reconstruction Journal*[4], and various SAE papers.

Use of the CRASH models "determination" of speed based upon crush damage has a number of potential pitfalls as detailed below:

Problems with the data and derived A-B-G values include:

- Reliance on one crash test for data will generate a "correct" calculated speed only for that crash. Speed calculations for other crashes will be "incorrect" to some degree.
- Reliance on an averaged set of A-B-G values will generate "incorrect" speed values for all of the "non-average" crashes, and most likely for the actual crash in question.
- Calculation of A-B-G values are directly dependent upon a damage width measurement. Depending upon your school of thought (Pre-CRASH3 v. Post-CRASH3) the "correct" damage width is either the contact damage only (Pre-CRASH3), or contact plus induced damage up to the maximum pre-crash dimension (Post- CRASH3).
- Due to the fact that data are not available all vehicles for all model years they were manufactured, the A-B-G values often need to be generated based upon a similar (sister or clone) vehicle.
- When no crash data is available for the vehicle model year in question, or an identified similar (sister or clone) vehicle, one must resort to either default vehicle stiffness values such as those provided by NHTSA based on vehicle wheelbase and weight, or apply the WAGNER** method in choosing a "similar" vehicle which has been tested.

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- Seldom are the "real" crashes a duplication of the test crashes.

Problems with the application of the data and derived A-B-G values to a "real" crash include:

- Data gathered from the vehicle(s) may be incomplete or inadequate
- Data gathered from the vehicle(s) may be incorrect
- Data which should have been gathered from the vehicle(s) is non-existent
- Data is incomplete, inadequate, AND incorrect

The problems with the answers derived by application of A-B-G values to a "real" crash include:

- The equations are sensitive to changes in the A-B-G values.
- The equations are sensitive to widely varying crush measurements.
- The speeds determined through the use of A-B-G values tend to give the Accident Investigator/ Reconstructionist a sense of precision, accuracy, and correctness which may be, and probably is, false!
- The answers are usually arrived at by plugging numbers into a computer program and printing out results. The program uses formulas to achieve these results that the user only partially understands, if at all (The term GIGO comes to mind).
- Even when the user understands and can duplicate the speed from damage calculations without the help of a computer, rapid calculation is ONLY possible through the use of a computer or programmable calculator.

The A-B-G Envelope Values Derived from NHTSA Crash Test Data:

The "standard" form that A-B-G values have taken to date are A) One set of values, which are B) based on a "no damage" speed of typically in the range of 4-5 mph, and C) based on an average crush depth. In discussions with a number of reconstructionists around the United States, the request for an alternative form of A-B-G values has been made repeatedly over the last 3 years. In making this request the following wishes have been expressed:

- Let the Reconstructionist exercise his/her judgement as to the measurement(s) to use and the appropriate "no damage" speed instead of making all of the decisions for them.
- Allow for quick "ranging" of speeds.
- Present the data in a "clean" format.
- Present the data, and results, so that the results can be duplicated, if needed, by the Reconstructionist.

In answer to these requests, we have developed an "envelope" of twelve A-B-G values using four different "no damage" speeds and three different crush measurements. The three measurements used are Minimum, Average, and Maximum crush as reported by NHTSA. These values are calculated from the measurements taken at the two "ends" of the damage and the "centerline". For each of these crush measurements, a set of A-B-G values are calculated for

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no damage speeds of 2.5, 5.0, 7.5 and 10.0 mph for front and rear impact tests, and at 1.0, 2.0, 3.0, and 5.0 mph for side impact tests.

Alternative Methods to Determine Speed from Crush:

In 1968, R. I. Emori presented a formula in SAE paper 680016 for determining vehicle impact speed into a barrier based upon the maximum permanent crush measurement[5]. This formula is simply:

$$v = 1.1 * C$$

Where:
v = *speed, (miles/hour)*
C = *maximum permananent crush, (in)*

Although this formula tends to underestimate the speed of present day vehicles and is not considered further here, it is important for the following three reasons: 1) the date of its publication, 2) its simplicity of use, and 3) the measurements it considers.

As mentioned previously, J. Stannard Baker presented a "f" value of -20 for a car crash into a barrier as early as 1975. 4N6XPRT Systems® has further refined this value and published it in the Expert AutoStats®[6] program as a Crush Factor (CF) value of 21.

Formulas Employed:

Both the A-B-G values and the CF values are determined through the use of standard formulas. One source for these formulas is the "Equation Directory for the Reconstructionist"[7]

A	=	Constant (stiffness coefficient), Maximum force per inch of damage width without permanent damage, lb/in
B	=	Constant (stiffness coefficient), Crush resistance per inch of damage width, lb/in^2
G	=	Constant (stiffness coefficient), Energy dissipated without permanent damage, lb
g	=	Acceleration of gravity, 32.2 ft/sec^2 = 386.4 in/sec^2
b_0	=	Intercept (no damage speed. In our tables: Front & Rear = 2.5, 5.0, 7.5, and 10.0 mph. Side = 1.0, 2.0, 3.0, and 5.0 mph), in/sec
b_1	=	Slope of the speed v. crush relation (change in impact speed to the change in crush), 1/sec
V_i	=	Impact velocity of test vehicle, in/sec
C_r	=	Crush measurement from test vehicle (In our tables: Minimum, Average, and Maximum crush), in
L_T	=	Width of crush (of test vehicle), in
W_T	=	Static Weight (of test vehicle(s)), lb
E	=	Energy dissipated due to crush, in*lb
CF	=	Crush Factor (of test vehicle), dimensionless
V_{mph}	=	Impact velocity of test vehicle, miles/hour

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First step is to calculate the slope of the speed versus the crush relation:

$$b_1 = \frac{V_i - b_0}{C_r} \quad (1 \ / \ \text{sec})$$

Where:

$$V_i = V_{mph} * \frac{12 \ inch/foot * 5280 \ feet/mile}{3600 \ seconds/hour} \quad (in \ / \ \text{sec})$$

and

$$b_0 = (No \ damage \ speed)_{mph} * \frac{12 \ inch/foot * 5280 \ feet/mile}{3600 \ seconds/hour} \quad (in \ / \ \text{sec})$$

Next step, calculate the A stiffness value:

$$A = \frac{W_T * b_0 * b_1}{g * L_T} \quad (lb \ / \ in)$$

Next step, calculate the B stiffness value:

$$B = \frac{W_T * b_1^2}{g * L_T} \quad (lb \ / \ in^2)$$

Finally, calculate the G stiffness value:

$$G = \frac{A^2}{2 * B} \quad (lb)$$

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6 Applying A-B-G and CF values to Speed from Crush

The reverse calculation of speed from the derived A-B-G values to check their validity is completed by first using a Two Point Damage Profile equation to determine the Energy absorbed by the crush deformation:

$$E=(1+\tan^2\sigma)*L_T*[\frac{A}{2}*(C_1+C_2)+(\frac{B}{6})*(C_1^2+(C_1*C_2)+C_2^2)+G] \quad (in * lb)$$

For the purposes of checking frontal impact tests, the equation is simplified as follows:

$$\sigma=0$$

$$Therefore: (1+\tan^2\sigma)=1$$

Leaving the simplified equation

$$E=L_T*[\frac{A}{2}*(2*C_r)+(\frac{B}{6})*(3*C_r^2)+G] \quad (in * lb)$$

Where C_r is the Minimum, Average, or Maximum Crush measurement from the test

The next step is to calculate the *ebv* (equivalent barrier velocity) for vehicle. This is more properly called the KE Equivalent Speed, the speed equivalent to the Kinetic Energy necessary to cause the crush deformation in the vehicle. This speed is calculated as follows:

$$ebv=\sqrt{\frac{(2*\frac{E}{12\ inches/foot}*\gamma)}{(\frac{W_T}{32.2\ feet/second/second})}} \quad (ft\ /\ sec)$$

and

$$Speed=ebv*\frac{3600 seconds/hour}{5280 feet/mile} \quad (miles/hour)$$

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For the purposes of checking frontal impact tests, the equation is simplified as follows:

$$\gamma = \frac{k^2}{k^2 + F_{MA}^2}$$

Where k^2 is the Yaw Radius of Gyration
and F_{MA} is the Moment arm of Force offset from the vehicle CG.

On Full Frontal Barrier Tests $F_{MA}=0$

$$\textit{Therefore:}\ \gamma = \frac{k^2}{k^2} = 1$$

Thus:

$$ebv = \sqrt{\frac{\left(\frac{2*E}{12\ inches/foot}\right)}{\left(\frac{W_T}{32.2\ feet/second/second}\right)}} \quad (ft\ /\ \text{sec})$$

and

$$Speed = ebv * \frac{3600\ seconds/hour}{5280\ feet/mile} \quad (miles/hour)$$

By comparison, the Crush Factor (CF) is calculated in the same way that a coefficient of friction or drag factor would be calculated from a set of test skids. As stated in the Expert AutoStats® program, it is based on the maximum crush measurement:

$$CF = \frac{V_{mph} * V_{mph}}{30 * \left(\frac{C_{r_{max}}\ inch}{12\ inch/foot}\right)} \quad (dimensionless)$$

Note that the crush measurement is converted from inches to feet as a part of the calculation.

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8 Applying A-B-G and CF values to Speed from Crush

The reverse calculation of speed from the derived CF value to check its validity is completed using the Minimum Speed from Skid formula as follows:

$$Speed = \sqrt{30 * CF * \left(\frac{C_r \ inches}{12 \ inches/foot}\right)} \quad (miles/hour)$$

Note that the crush measurement is again converted from inches to feet as a part of the calculation. When applying the CF value to calculate a speed from crush value, **the crush distance must be in feet.** The major source of error in using this formula is a failure to convert the crush measurement from inches to feet.

Reference Data - CRASH 98 Ford Thunderbird Test Vehicles:

Pages A-14 through A-21 are the Expert VIN DeCoder® and Expert AutoStats® output for the 1989 Ford Thunderbird vehicles to be tested at The Crash 98 Conference.

Pages A-22 through A-54 are the NHTSA Crash Test Reports for the four crash tests which test the 1989 through 1994 Ford Thunderbird 2 door Coupes. This is a portion of the year range 1989-1996 identified by the Sisters/Clones[8] list as representing the "same" vehicle. This year range is also included in the Mitchell Manual[9] for the Ford Thunderbird as having substantially interchangeable major body parts. The Sisters/Clones list also identifies the Mercury Cougar as being a sister/similar vehicle. There are no crash tests within the year range of 1989-1996 in the NHTSA crash test database for frontal impact tests for the Mercury Cougar.

Pages A-55 through A-73 give further information regarding how NHTSA tests vehicles, and how to interpret some of the results reported as part of the NHTSA crash test database.

The Expert AutoStats® Crush Factor (CF) Value:

In calculating speeds from crush damage, an alternative to the CRASH3 model is the use of a Crush Factor (CF) as published in the Expert AutoStats® three page printed reports. The CF values listed in that program were arrived at in late 1991 after analyzing the NHTSA crash test data as published in the Accident Reconstruction Journal up to that time.

The goal of determining these CF values was two fold. The first goal was to provide a means of rapidly calculating a speed from crush damage where the crush measurement was readily determined (maximum crush) and should not vary significantly from one data gatherer to another. The second goal was to provide a means of rapidly calculating a speed from crush damage where the calculation was simple to complete, readily explainable, used formulas already familiar to the Accident Reconstructionist, and was not overly sensitive to differences in crush measurement or vehicle-to-vehicle variations. We believe that we have achieved both of these goals.

In the stiffness calculation sheets which are a part of the NHTSA Crash Reports provided

by 4N6XPRT Systems®, a comparison of the speed calculated per the method contained in Expert AutoStats® is made against the reported Impact speed for the subject test. A calculated Test Specific CF value for that test is also provided. This data is provided in addition to the A-B-G Envelope values.

There are two immediately recognizable applications for the Test Specific CF value. The first application is to use the Test Specific CF value instead of or in addition to the Standard CF value included in Expert AutoStats® to the calculation of speed from the crush damage. The second application of the Test Specific CF value is as a general guide to how "stiff" or "soft" the vehicle is when compared to the "average vehicle" which has the stiffness values stated in Expert AutoStats®.

A third application of the Test Specific CF value comes into play when more than one test has been conducted on a subject vehicle. The Test Specific CF value then becomes a measuring stick for comparing how similar or different the response to impact is from vehicle to vehicle and speed to speed. An application of this measuring stick to NHTSA Test #1282, 1390, and 2240 (Table 6) indicates that the Ford Thunderbird in Test #1282 was somewhat "stiffer" than average and that the Ford Thunderbird's in Test #1390 and 2240 were somewhat "softer" than average. Therefore, speed estimates derived from data contained in Test #1282 will be expected to OVERESTIMATE the impact speeds of Test # 1390 and 2240. Similarly, Test # 1390 and 2240 will be expected to provide similar "confirming" speed estimates of each other and UNDERESTIMATE the impact speed of Test #1282.

A-B-G Envelope & CF Value Application to NHTSA Tests 1282, 1390, & 2044:

Tables 1 through 24 on pages A1 through A13 summarize some of the results contained in the stiffness calculation sheets located on pages on A-29, A-37, A-45, A-46, and A-54. Table 13 and Table 24 summarize the data on Tables 1 through 12 and Tables 14 through 23, respectively.

Table 1 summarizes the data needed to derive the A-B-G and CF values from the crash tests. Test # 2047, due to reporting errors either by the testing entity or during input into the NHTSA database, has none of the needed crush depth measurements. Therefore no estimate values will be able to be derived from this test.

Test # 2047 was included both for the information contained in other areas of the report and as an example of some of the data errors within the NHTSA crash test database which should be expected.

Table 2 and Table 3 illustrate the A-B-G and Test Specific CF values derived for test #1282 and # 1390 respectively.

Table 4 illustrates the A-B-G and Test Specific CF values derived for test # 2044 both for the "Full" width crush length as well as the Crush Indentation Length.

The A-B-G values for these three tables were calculated from the Minimum, Average, and Maximum crush measurements using a "no damage" speed of 5.0 mph. The Test Specific

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CF value for each test was calculated from the Maximum Crush as specified in the Expert AutoStats® program.

Table 5 contains the "Generic" stiffness values and a statistical analysis of the A-B-G values.

- The first three rows of the "Generic" values are the average A, B, and G values for test # 1282, test # 1390, and the "Full" width values for test # 2044 using a "no damage" speed of 5.0 mph and the Minimum, Average and Maximum crush measurements calculated for each test.

- Row four contains the average NEI A & B values (with the G value calculated from those A & B values).

- Row five contains the NHTSA Default table values from Column 4.

- Row six contains the Standard CF value of 21 from the Expert AutoStats® program.

The commonly used statistical measures of Minimum, Average, Median, Maximum, Population Standard Deviation and Sample Standard Deviation are applied to the A, B, and G values found in rows one through 5 of the upper box in Table 5. It should be realized that the measures were applied to each value as a separate entity, rather than as a part of a set. Thus, applying the Minimum A, B, and G values as an A-B-G set would be an incorrect application of these values.

Table 6 is a tabulation of the Test Specific CF values and an application of the commonly used statistical measures of Minimum, Average, Median, Maximum, Population Standard Deviation and Sample Standard Deviation. It can be seen, and may be surprising to some people, that even in this small sample size of three tests the average Test Specific CF value rapidly approaches the Standard CF value of 21 from the Expert AutoStats® program. The fact that it does is one validation of the Standard CF value.

Tables 7 through 10 check the validity of the stiffness values derived in Tables 2 through 4. Table 7 tests the stiffness values derived in Table 2, Table 8 tests the stiffness values derived in Table 3, and Table 9 and Table 10 test the stiffness values derived in Table 4 by calculating theoretical impact speeds of the three tests based on those stiffness values. A calculated impact speed using the Standard CF value is also included in each table for reference purposes. The darker, larger speed values are the values obtained by comparing apples to apples and oranges to oranges. In other words, the speed calculated from Minimum Crush, based on stiffness values obtained from the minimum crush is highlighted, as is speed from Average Crush using Average Crush derived A-B-G values, etc. This is one method of developing the impact speed envelope from stiffness values based on one test crash.

Table 11 contains theoretical impact speed calculations based upon the "Generic" stiffness values derived in Table 5. The highlighted speeds are highlighted in the same manner as the highlighted values in Tables 7 through 10.

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Table 12 is another application of the commonly used statistical measures of Minimum, Average, Median, Maximum, Population Standard Deviation and Sample Standard Deviation. This time the measures are applied to the calculated speeds in Table 11. The speeds calculated with the Standard CF value are also included for reference purposes. It can rapidly be seen that the Standard CF value estimates a speed that is very similar to the average speed determined by the A-B-G values.

Table 13 contains a summary of the Minimum, Average, and Maximum crush A-B-G values calculated for test numbers 1282, 1390, and 2044 at a 5.0 mph "no damage" value. These values are then used to calculate a speed for each of the tests based on those values as a check of the reliability of those A-B-G values.

Table 14 and Table 15 illustrate the A-B-G and Test Specific CF values derived for test #1282 and # 1390 respectively.

Table 16 illustrates the A-B-G and Test Specific CF values derived for test # 2044 both for the "Full" width crush length as well as the Crush Indentation Length.

The A-B-G values for these three tables were calculated from the calculated Average crush measurements using a range of "no damage" speeds of 2.5 mph, 5.0 mph, ad 7.5 mph. The Test Specific CF value for each test was calculated from the Maximum Crush as specified in the Expert AutoStats® program.

Table 17 contains the "Generic" stiffness values and a statistical analysis of the A-B-G values.

- The first three rows of the "Generic" values are the average A, B, and G values for test # 1282, test # 1390, and the "Full" width values for test # 2044 using "no damage" speeds of 2.5 mph, 5.0 mph, and 7.5 mph and the average crush measurement calculated for each test.

- Row four contains the average NEI A & B values (with the G value calculated from those A & B values).

- Row five contains the NHTSA Default table values from Column 4.

- Row six contains the Standard CF value of 21 from the Expert AutoStats® program.

The commonly used statistical measures of Minimum, Average, Median, Maximum, Population Standard Deviation and Sample Standard Deviation are applied to the A, B, and G values found in rows one through 5 of the upper box in Table 17. It should be realized that the measures were applied to each value as a separate entity, rather than as a part of a set. Thus, applying the Minimum A, B, and G values as an A-B-G set would be an incorrect application of these values.

Tables 18 through 21 check the validity of the stiffness values derived in Tables 14 through 16. Table 18 tests the stiffness values derived in Table 14, Table 19 tests the stiffness

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values derived in Table 15, and Table 20 and Table 21 test the stiffness values derived in Table 16 by calculating theoretical impact speeds of the three tests based on those stiffness values. A calculated impact speed using the Standard CF value is also included in each table for reference purposes. The darker, larger speed values are the values obtained by comparing pears to pears and plums to plums. These values are highlighted similarly to Tables 7 through 10. In other words, the speed calculated from a no damage speed of 2.5 mph and average crush, based on stiffness values obtained from a no damage speed of 2.5 mph and average crush. This ranging of the "no damage" speed is another way of building the impact speed envelope based upon stiffness values developed from one test crash.

Table 22 contains theoretical impact speed calculations based upon the "Generic" stiffness values derived in Table 17. The highlighted speeds are highlighted in the same manner as the highlighted values in Tables 7 through 11 and Tables 18 through 21.

Table 23 is another application of the commonly used statistical measures of Minimum, Average, Median, Maximum, Population Standard Deviation and Sample Standard Deviation. This time the measures are applied to the calculated speeds in Table 22. The speeds calculated with the Standard CF value are also included for reference purposes. It can rapidly be seen that the again the Standard CF value estimates a speed that is very similar to the average speed determined by the A-B-G values.

Table 24 contains a summary of the A-B-G values calculated for "no damage" speeds of 2.5, 5.0 and 7.5 mph using the average crush measurements from each of the tests. These values are then used to calculate a speed for each of the tests based on those values as a check of the reliability of those A-B-G values.

For comparison purposes, Test Specific CF and "Generic" A-B-G values are also included in the Table 13 and Table 24 data summarizations.

Only the "Full Width" tests are used for the back check speed calculations due to damage being recorded across the full width of each of the vehicles.

Examination of Table 13 and Table 24 shows that:

- The A-B-G and CF values calculated for tests # 1282 underestimate the speed of test #1390 and 2044 as predicted from our Test Specific CF measuring stick.
- The A-B-G and CF values calculated for tests # 1390 and 2044 provide reasonable speed estimates for each other, however both tend to over estimate the speed for test # 1282, again as predicted from our Test Specific CF measuring stick.

Examination of Table 11 and Table 22 shows that:

- The average stiffness values calculated from the three tests underestimate the speed of test # 1282 by 2-4 mph, overestimate the impact speed of test # 1390 by 1-2 mph, and overestimate the speed of test # 2044 by up to 4 mph.
- The NEI values underestimate the impact speed of test # 1282 by over 5 mph and Test # 1390 by about 1 mph. These values also slightly overestimate the impact speed

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of test # 2044.

- The NHTSA Default Values underestimate the impact speed of all three tests by 5-10 mph.
- The Standard CF value of 21, when used as suggested in the Expert AutoStats® program, underestimates the impact speed of test # 1282 by 1-2 mph. This CF value overestimates the impact speed of test # 1390 by 2-3 mph and test # 2044 by 1-2 mph.
- The Standard CF value of 21, when used as suggested in the Expert AutoStats® program, estimates the impact speed of the three tests as well or better than any of the "Generic" A-B-G values.

Other Useful Information in a NHTSA Crash Test Report

The Stiffness calculation sheets are only a small part of the NHTSA Crash Test report which is provided by 4N6XPRT Systems®. Additional sheets are provided for the General Test Information, Barrier or Impactor Information, Occupant (Dummy) Data, and Vehicle Data when the information is contained in the NHTSA database.

The General Test Information page covers basic information regarding the crash test and the test objectives. This information helps in determining why some information may be incomplete or non-existent, as well as likely reasons for data errors. One example of a possible data error is as follows - the data is now stored in the database in metric units. Early tests were measured in English units. If the original data was not converted before being entered into the current database, the results extracted from the database will be in error.

The Barrier Information page indicates the type of barrier or impactor which was used in the test. This information may be of use in evaluating what appear to be discrepancies in the amount of crush damage sustained from test to test by the vehicle.

The Occupant (Dummy) Data pages often include Left and Right Femur Peak Load(s), a HIC value, Chest Severity Index (TTI), Thorax (Chest) Peak acceleration, first and second contact areas for the crash dummy(s), and distance measurements from critical "body" parts to areas of the vehicle interior which are normally contacted by the occupants. This data is all potentially important when evaluating injury potential and/or causation in a traffic collision.

There are four "Injury Risk Function Curve" graphs within the supplemental material printed from the NHTSA web site. These graphs are located on pages A-58, A-59, and A-60. These graphs relate back to the loading and acceleration information contained in the Occupant (Dummy) Data pages.

Summary

- Impact speeds based on crush damage can be estimated, but not precisely and accurately calculated without considerable effort.
- The Standard Crush Factor (CF) published in the Expert AutoStats® program estimates speed from crush damage at least as well as the A-B-G values.

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- The Standard CF can be used in the field to estimate the impact speed from the observed damage. This in turn may assist the Accident Investigator in documenting items at the scene through a better understanding of the accident itself.

- The Standard CF value may be used to quickly, but reliably "check" the Impact speed calculated through the use of A-B-G values.

- When necessary, the investigator or reconstructionist can use the Standard CF value in trial or deposition to reliably yet rapidly estimate "crush speed" in response to "what if's" and hypothetical questions without the use of a computer, or, if need be, a calculator.

- The Standard CF value meets the "scientific" requirements of "Daubert".

- The Test Specific Crush Factor can indicate whether the crash test vehicle is "stiffer" or "softer" than an "average" vehicle or other similar (sister or clone) vehicles which have also been tested.

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Definition of Terms

Engineering Approaches (Methods):

- WAG — Wild Asked Guess - an educated estimate from experience.*
- SWAG — Sophisticated Wild Asked Guess - an educated estimate from experience combined with some calculations.*
- WAGNER** — Wild Asked Guess Not Easily Refuted - an educated estimate from experience combined with lots of numbers and calculations which selectively support, or mask problems with, the estimate.*

*Original source of definitions unknown, but author first learned these from Gary Stephens in Jacksonville, FL.

Engineering Judgement:

The application of engineering education, training, and experience in determining the applicability of data, answers, and/or methods to resolving a problem.

Reconstruction Judgement:

The application of education, training, and experience in Accident Investigation and Reconstruction in determining the applicability of data, answers, and/or methods to resolving one or more problems in a Traffic Collision. (i.e. - Time(s), Speed(s), Distance(s), Force(s), Avoidance Potential(s), etc.)

GIGO:

Garbage In - Garbage Out, a common computer term.

No Damage Speed:

The maximum speed a vehicle can impact a barrier with no resulting permanent damage.

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1. "Traffic Accident Investigation Manual", ©1975, The Traffic Institute, Northwestern University.

2. 4N6XPRT Systems®, 8387 University Avenue, La Mesa, CA 91941, Phone: (619) 464-3477, Fax: (619) 464-3477, E-mail: 4n6xprt@4n6xprt.com

3. Neptune Engineering, Inc., P.O. Box 1597, Clovis, CA 93613

4. Accident Reconstruction Journal, P.O. Box 234, Waldorf, MD 20604, Phone: (301) 843-1371.

5. "Work, Energy and Speed from Damage in Traffic Accidents: Topic 870 of the *Traffic-Accident Investigation Manual*" by Gary W. Cooper, ©1989, The Northwestern University Traffic Institute.

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Table 1 - General Information for the 1989-1994 Ford Thunderbird from NHTSA Crash Test Database

Test #	Year	Make	Model	Weight pounds	Impact Speed MPH	Vehicle Width Inches	Crush Indentation Length Inches	Crush in inches Minimum	Average	Maximum
1282	1989	Ford	Thunderbird	4110	34.7	72.7	72.7	16.2	18.0	21.1
1390	1990	Ford	Thunderbird	4090	29.4	72.7	0.0	16.2	17.4	19.7
2044	1994	Ford	Thunderbird	3924	35.0	60.2	56.7	23.5	24.1	25.0
2047	1994	Ford	Thunderbird	4028	29.3	72.7	72.7	Null	Null	Null

Table 2 - Derived Ford Thunderbird A-B-G & CF Values from NHTSA Test # 1282

Test #	Year	Weight pounds	Impact Speed MPH	Vehicle Width Inches	Crush Indentation Length Inches	Crush in inches Minimum	Average	Maximum
1282	1989	4110	34.7	72.7	72.7	16.2	18.0	21.1

Values Calculated from NHTSA Test #1282 ("Full" Width - FW)

	A	B	G	CF			
Min Crush	415.4	152.3	566.5		16.2		
Avg Crush	373.9	123.4	566.5			18.0	
Max Crush	319.0	89.8	566.5				21.1
Test Specific CF				22.8			21.1

Width = 72.7" (FW), b0 = 5.0 mph = 88 in/sec

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Table 3 - Derived Ford Thunderbird A-B-G & CF Values from NHTSA Test # 1390

Test #	Year	Weight pounds	Impact Speed MPH	Vehicle Width Inches	Crush Indentation Length Inches	Crush in inches Minimum	Average	Maximum
1390	1990	4090	29.4	72.7	0.0	16.2	17.4	19.7

Values Calculated from NHTSA Test #1390 ("Full" Width)

	A	B	G	CF			
Min Crush	339.6	102.3	563.8		16.2		
Avg Crush	315.6	88.3	563.8			17.4	
Max Crush	279.3	69.2	563.8				19.7
Test Specific CF				17.6			19.7

Width = 72.7" (FW), b0 = 5.0 mph = 88 in/sec

Table 4 - Derived Ford Thunderbird A-B-G & CF Values from NHTSA Test # 2044

Test #	Year	Weight pounds	Impact Speed MPH	Vehicle Width Inches	Crush Indentation Length Inches	Crush in inches Minimum	Average	Maximum
2044	1994	3924	35.0	60.2	56.7	23.5	24.1	25.0

Values Calculated from NHTSA Test #2044 ("Full" Width)

	A	B	G	CF			
Min Crush	333.5	85.2	653.2		23.5		
Avg Crush	325.2	81.0	653.2			24.1	
Max Crush	313.5	75.2	653.2				25.0
Test Specific CF				19.6			25.0

Width = 60.2" (FW), b0 = 5.0 mph = 88 in/sec

Values Calculated from NHTSA Test #2044 (Indentation Length Only - IL)

	A	B	G	CF			
Min Crush	354.1	90.4	693.5		23.5		
Avg Crush	345.3	86.0	693.5			24.1	
Max Crush	332.9	79.9	693.5				25.0
Test Specific CF				19.6			25.0

Width = 56.7" (IL), b0 = 5.0 mph = 88 in/sec

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Table 5 - "Generic" A-B-G & CF values for 1989-1994 Ford Thunderbird

"Generic" Values

AVG of FW values ("Full" Width)	A	B	G	CF
Min Crush	362.8	113.3	581.1	
Avg Crush	338.2	97.6	586.3	
Max Crush	303.9	78.1	591.6	
NEI A & B Average Values	267.0	88.0	405.1	
NHTSA Default Table - Col. 4	356.0	34.0	1863.8	
Standard CF from Expert AutoStats				21

Average of Calculated A-B-G values from NHTSA test numbers 1282, 1390, and 2044 ("Full" Width)

b0 = 5.0 mph = 88 in/sec

Statistical Analysis of "Generic" A-B-G values

	A	B	G
Minimum	267.0	34.0	405.1
Average	325.6	82.2	805.6
Median	338.2	88.0	586.3
Maximum	362.8	113.3	1863.8
Pop. Std. Dev.	35.7	26.7	533.7
Sample Std. Dev.	39.9	29.9	596.7

Table 6 - Statistical Analysis of Test Specific CF Values for 1989-1994 Ford Thunderbird

Test Specific CF Values

NHTSA Test Number	CF
1282	22.8
1390	17.6
2044	19.6

Statistical Analysis of Test Specific CF Values

Minimum	17.6
Average	20.0
Median	19.6
Maximum	22.8
Pop. Std. Dev.	2.1
Sample Std. Dev.	2.6

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Table 7 - Calculation of Impact speeds (MPH) for NHTSA Tests #1282, 1390, and 2044 based on A-B-G & CF Values calculated for Test # 1282

Values Calculated from NHTSA Test #1282 ("Full" Width - FW)	A	B	G	CF
Min Crush	415.4	152.3	566.5	
Avg Crush	373.9	123.4	566.5	
Max Crush	319.0	89.8	566.5	
Test Specific CF				22.8
Standard CF from Expert AutoStats				21

Width = 72.7" (FW), b0 = 5.0 mph = 88 in/sec

Test "Actual" Impact Speed = 34.7 MPH			Test "Actual" Impact Speed = 29.4 MPH			Test "Actual" Impact Speed = 35.0 MPH		
Test # 1282 Speed Calculation Based on:			Test # 1390 Speed Calculation Based on:			Test # 2044 Speed Calculation Based on:		
Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush
34.7	38.0	43.7	**34.8**	37.0	41.2	**44.8**	45.8	47.3
31.7	**34.7**	39.8	31.8	**33.8**	37.6	40.8	**41.7**	43.1
27.8	30.3	**34.7**	27.9	29.6	**32.8**	35.5	36.3	**37.4**
30.4	32.0	**34.7**	30.4	31.5	**33.5**	36.6	37.1	**37.7**
29.2	30.7	**33.3**	29.2	30.2	**32.2**	35.1	35.6	**36.2**

Table 8 - Calculation of Impact speeds (MPH) for NHTSA Tests #1282, 1390, and 2044 based on A-B-G & CF Values calculated for Test # 1390

Values Calculated from NHTSA Test #1390 ("Full" Width)	A	B	G	CF
Min Crush	339.6	102.3	563.8	
Avg Crush	315.6	88.3	563.8	
Max Crush	279.3	69.2	563.8	
Test Specific CF				17.6
Standard CF from Expert AutoStats				21

Width = 72.7" (FW), b0 = 5.0 mph = 88 in/sec

Test "Actual" Impact Speed = 34.7 MPH			Test "Actual" Impact Speed = 29.4 MPH			Test "Actual" Impact Speed = 35.0 MPH		
Test # 1282 Speed Calculation Based on:			Test # 1390 Speed Calculation Based on:			Test # 2044 Speed Calculation Based on:		
Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush
29.3	32.0	36.7	**29.4**	31.2	34.7	**37.5**	38.4	39.6
27.6	**30.1**	34.4	27.7	**29.3**	32.6	35.2	**36.0**	37.1
25.0	27.2	**31.1**	25.1	26.6	**29.4**	31.7	32.4	**33.4**
26.7	28.1	**30.5**	26.7	27.7	**29.4**	32.2	32.6	**33.2**
29.2	30.7	**33.3**	29.2	30.2	**32.2**	35.1	35.6	**36.2**

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Table 9 - Calculation of Impact speeds (MPH) for NHTSA Tests #1282, 1390, and 2044 based on A-B-G & CF Values calculated for Test # 2044 (FW)

Values Calculated from NHTSA Test #2044 ("Full" Width)	A	B	G	CF
Min Crush	333.5	85.2	653.2	
Avg Crush	325.2	81.0	653.2	
Max Crush	313.5	75.2	653.2	
Test Specific CF				19.6
Standard CF from Expert AutoStats				21

Width = 60.2" (FW), b0 = 5.0 mph = 88 in/sec

	Test "Actual" Impact Speed = 34.7 MPH			Test "Actual" Impact Speed = 29.4 MPH			Test "Actual" Impact Speed = 35.0 MPH		
	Test # 1282 Speed Calculation Based on:			Test # 1390 Speed Calculation Based on:			Test # 2044 Speed Calculation Based on:		
	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush
Min Crush	**27.6**	30.0	34.3	**27.6**	29.3	32.5	**35.0**	35.8	36.9
Avg Crush	27.0	**29.4**	33.6	27.1	**28.7**	**31.8**	34.3	**35.0**	36.1
Max Crush	26.2	28.6	**32.5**	26.3	27.9	**30.8**	33.2	33.9	**35.0**
Test Specific CF	28.2	29.7	**32.2**	28.2	29.2	**31.1**	33.9	34.4	**35.0**
Standard CF from Expert AutoStats	29.2	30.7	**33.3**	29.2	30.2	**32.2**	35.1	35.6	**36.2**

Table 10 - Calculation of Impact speeds (MPH) for NHTSA Tests #1282, 1390, and 2044 based on A-B-G & CF Values calculated for Test # 2044 (IL)

Values Calculated from NHTSA Test #2044 (Indentation Length Only - IL)	A	B	G	CF
Min Crush	354.1	90.4	693.5	
Avg Crush	345.3	86.0	693.5	
Max Crush	332.9	79.9	693.5	
Test Specific CF				19.6
Standard CF from Expert AutoStats				21

Width = 56.7" (IL), b0 = 5.0 mph = 88 in/sec

	Test "Actual" Impact Speed = 34.7 MPH			Test "Actual" Impact Speed = 29.4 MPH			Test "Actual" Impact Speed = 35.0 MPH		
	Test # 1282 Speed Calculation Based on:			Test # 1390 Speed Calculation Based on:			Test # 2044 Speed Calculation Based on:		
	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush
Min Crush	**28.4**	31.0	35.3	**28.5**	30.2	33.4	**36.1**	36.9	38.0
Avg Crush	27.8	**30.3**	34.6	27.9	**29.6**	32.7	35.3	**36.1**	37.2
Max Crush	27.0	29.4	**33.5**	27.1	28.7	**31.8**	34.2	35.0	**36.1**
Test Specific CF	28.2	29.7	**32.2**	28.2	29.2	**31.1**	33.9	34.4	**35.0**
Standard CF from Expert AutoStats	29.2	30.7	**33.3**	29.2	30.2	**32.2**	35.1	35.6	**36.2**

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Table 11 - Calculation of Impact speeds (MPH) for NHTSA Tests #1282, 1390, and 2044 based on "Generic" A-B-G & CF Values

"Generic" Values					Test "Actual" Impact Speed = 34.7 MPH			Test "Actual" Impact Speed = 29.4 MPH			Test "Actual" Impact Speed = 35.0 MPH		
					Test # 1282 Speed Calculation Based on:			Test # 1390 Speed Calculation Based on:			Test # 2044 Speed Calculation Based on:		
AVG of FW Values ("Full" Width)	A	B	G	CF	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush
Min Crush	362.8	113.3	594.5		**30.7**	33.5	38.4	**30.8**	32.7	36.3	**39.3**	40.2	41.5
Avg Crush	338.2	97.6	594.5		28.9	**31.5**	36.1	28.9	**30.7**	34.1	36.9	**37.7**	38.9
Max Crush	303.9	78.1	594.5		26.4	28.7	**32.8**	26.4	28.0	**31.0**	33.5	34.2	**35.3**
NEI A & B Average Values	267.0	88.0	405.1		26.8	**29.3**	33.6	26.9	**28.5**	31.8	34.4	**35.2**	36.4
NHTSA Default Table - Col. 4	356.0	34.0	1863.8		23.1	**24.7**	27.3	23.2	**24.2**	26.2	27.4	**27.9**	28.6
Standard CF from Expert AutoStats				21	29.2	30.7	**33.3**	29.2	30.2	**32.2**	35.1	35.6	**36.2**

b0 = 5.0 mph = 88 in/sec

Table 12 - Statistical Analysis of Calculation of Impact speeds (MPH) for NHTSA Tests #1282, 1390, and 2044 based on "Generic" A-B-G Values contained in Table 11 and comparison to the Standard CF Value

	Test "Actual" Impact Speed = 34.7 MPH			Test "Actual" Impact Speed = 29.4 MPH			Test "Actual" Impact Speed = 35.0 MPH		
	Test # 1282 Speed Calculation Based on:			Test # 1390 Speed Calculation Based on:			Test # 2044 Speed Calculation Based on:		
	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush
Minimum	**23.1**	**24.7**	**27.3**	**23.2**	**24.2**	**26.2**	**27.4**	**27.9**	**28.6**
Average	27.2	29.5	33.7	27.2	28.8	31.9	34.3	35.0	36.1
Median	26.8	29.3	33.6	26.9	28.5	31.8	34.4	35.2	36.4
Maximum	**30.7**	**33.5**	**38.4**	**30.8**	**32.7**	**36.3**	**39.3**	**40.2**	**41.5**
Pop. Std. Dev.	2.6	3.0	3.7	2.6	2.8	3.4	4.0	4.1	4.3
Sample Std. Dev.	2.9	3.3	4.2	2.9	3.2	3.8	4.5	4.6	4.8
Standard CF from Expert AutoStats = 21	29.2	30.7	**33.3**	30.2	30.2	**32.2**	35.1	35.6	**36.2**

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Table 13 - Combined Summary Table of Tables 1-5 and 7-11

Test #	Year	Make	Model	Weight pounds	Impact Speed MPH	Vehicle Width Inches	Crush Indentation Length Inches	Crush in Inches Minimum	Crush in Inches Average	Crush in Inches Maximum	Test Specific CF
1282	1989	Ford	Thunderbird	4110	34.7	72.7	72.7	16.2	18.0	21.1	22.8
1390	1990	Ford	Thunderbird	4090	29.4	72.7	0.0	16.2	17.4	19.7	17.6
2044	1994	Ford	Thunderbird	3924	35.0	60.2	56.7	23.5	24.1	25.0	19.6
2047	1994	Ford	Thunderbird	4026	29.3	72.7	72.7	Null	Null	Null	ERR

Values Calculated from NHTSA Test #1282 ("Full" Width - FW)

	A	B	G	CF
Min Crush	415.4	152.3	566.5	
Avg Crush	373.9	123.4	566.5	
Max Crush	319.0	89.8	566.5	
Test Specific CF				22.6

Width = 72.7" (FW), b0 = 5.0 mph = 88 in/sec

Values Calculated from NHTSA Test #1390 ("Full" Width)

	A	B	G	CF
Min Crush	339.6	102.3	563.8	
Avg Crush	315.6	88.3	563.8	
Max Crush	279.3	69.2	563.8	
Test Specific CF				17.6

Width = 72.7" (FW), b0 = 5.0 mph = 88 in/sec

Values Calculated from NHTSA Test #2044 ("Full" Width)

	A	B	G	CF
Min Crush	333.5	85.2	653.2	
Avg Crush	325.2	81.0	653.2	
Max Crush	313.5	75.2	653.2	
Test Specific CF				19.6

Width = 60.2" (FW), b0 = 5.0 mph = 88 in/sec

Values Calculated from NHTSA Test #2044 (Indentation Length Only - IL)

	A	B	G	CF
Min Crush	354.1	90.4	693.5	
Avg Crush	345.3	86.0	693.5	
Max Crush	332.9	79.9	693.5	
Test Specific CF				19.6

Width = 56.7" (IL), b0 = 5.0 mph = 88 in/sec

"Generic" Values

AVG of FW values	A	B	G	CF
Min Crush	362.8	113.3	581.1	
Avg Crush	338.2	97.6	566.3	
Max Crush	303.9	78.1	591.8	
NEI A & B Average Values	267.0	88.0	405.1	
NHTSA Default Table - Col. 4	356.0	34.0	1863.8	
Standard CF from Expert AutoStats				21

b0 = 5.0 mph = 88 in/sec

Test "Actual" Impact Speed = 34.7 MPH				Test "Actual" Impact Speed = 29.4 MPH				Test "Actual" Impact Speed = 35.0 MPH			
Test # 1282 Speed Calculation Based on:				Test # 1390 Speed Calculation Based on:				Test # 2044 Speed Calculation Based on:			
Minimum Crush	Average Crush	Maximum Crush		Minimum Crush	Average Crush	Maximum Crush		Minimum Crush	Average Crush	Maximum Crush	
34.7	38.0	43.7		**34.8**	37.0	41.2		**44.8**	45.8	47.3	
31.7	**34.7**	39.8		31.8	**33.8**	37.6		40.8	**41.7**	43.1	
27.8	30.3	**34.7**		27.9	29.6	**32.8**		35.5	36.3	**37.4**	
30.4	32.0	**34.7**		30.4	31.5	**33.5**		36.6	37.1	**37.7**	
Test # 1282 Speed Calculation Based on:				Test # 1390 Speed Calculation Based on:				Test # 2044 Speed Calculation Based on:			
Minimum Crush	Average Crush	Maximum Crush		Minimum Crush	Average Crush	Maximum Crush		Minimum Crush	Average Crush	Maximum Crush	
29.3	32.0	36.7		**29.4**	31.2	34.7		**37.5**	38.4	39.6	
27.6	**30.1**	34.4		27.7	**29.3**	32.6		35.2	**36.0**	37.1	
25.0	27.2	**31.1**		26.1	26.6	**29.4**		31.7	32.4	**33.4**	
26.7	28.1	**30.5**		26.7	27.7	**29.4**		32.2	32.6	**33.2**	
Test # 1282 Speed Calculation Based on:				Test # 1390 Speed Calculation Based on:				Test # 2044 Speed Calculation Based on:			
Minimum Crush	Average Crush	Maximum Crush		Minimum Crush	Average Crush	Maximum Crush		Minimum Crush	Average Crush	Maximum Crush	
27.6	30.0	34.3		**27.6**	29.3	32.5		**35.0**	35.8	36.9	
27.0	**29.4**	33.6		27.1	**28.7**	31.8		34.3	**35.0**	36.1	
26.2	28.6	**32.5**		26.3	27.9	**30.8**		33.2	33.9	**35.0**	
26.2	29.7	**32.2**		26.2	29.2	**31.1**		33.9	34.4	**35.0**	
Test # 1282 Speed Calculation Based on:				Test # 1390 Speed Calculation Based on:				Test # 2044 Speed Calculation Based on:			
Minimum Crush	Average Crush	Maximum Crush		Minimum Crush	Average Crush	Maximum Crush		Minimum Crush	Average Crush	Maximum Crush	
28.4	31.0	35.3		**28.5**	30.2	33.4		**36.1**	36.9	38.0	
27.8	**30.3**	34.6		27.9	**29.6**	32.7		35.3	**36.1**	37.2	
27.0	29.4	**33.5**		27.1	28.7	**31.8**		34.2	35.0	**36.1**	
26.2	29.7	**32.2**		26.2	29.2	**31.1**		33.9	34.4	**35.0**	
Test # 1282 Speed Calculation Based on:				Test # 1390 Speed Calculation Based on:				Test # 2044 Speed Calculation Based on:			
Minimum Crush	Average Crush	Maximum Crush		Minimum Crush	Average Crush	Maximum Crush		Minimum Crush	Average Crush	Maximum Crush	
30.7	33.5	36.4		**30.7**	32.7	36.3		**39.3**	40.2	41.5	
28.9	**31.5**	36.0		28.9	**30.7**	34.1		36.8	**37.7**	38.9	
26.4	28.7	**32.8**		26.4	28.0	**31.0**		33.5	34.2	**35.3**	
26.8	**29.3**	33.6		26.9	**28.5**	31.8		34.4	**35.2**	36.4	
23.1	**24.7**	27.3		23.2	**24.2**	26.2		27.4	**27.9**	28.6	
29.2	30.7	**33.3**		29.2	30.2	**32.2**		35.1	35.6	**36.2**	

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Table 14 - Derived Ford Thunderbird A-B-G & CF Values from NHTSA Test # 1282

Test #	Year	Weight pounds	Impact Speed MPH	Vehicle Width Inches	Crush Indentation Length Inches	Crush in inches Minimum	Average	Maximum
1282	1989	4110	34.7	72.7	72.7	16.2	18.0	21.1

Values Calculated from NHTSA Test #1282 ("Full" Width - FW)

"no damage" speed	A	B	G	CF		
2.5 mph	202.7	145.0	141.6		18.0	
5.0 mph	373.9	123.4	566.5		18.0	
7.5 mph	513.6	103.5	1274.6		18.0	
Test Specific CF				22.8		21.1

Width = 72.7" (FW), Average Crush depth = 18.0"

Table 15 - Derived Ford Thunderbird A-B-G & CF Values from NHTSA Test # 1390

Test #	Year	Weight pounds	Impact Speed MPH	Vehicle Width Inches	Crush Indentation Length Inches	Crush in inches Minimum	Average	Maximum
1390	1990	4090	29.4	72.7	0.0	16.2	17.4	19.7

Values Calculated from NHTSA Test #1390 ("Full" Width)

"no damage" speed	A	B	G	CF		
2.5 mph	174	107.4	140.9		17.4	
5.0 mph	315.6	88.3	563.8		17.4	
7.5 mph	424.9	71.2	1268.4		17.4	
Test Specific CF				17.6		19.7

Width = 72.7" (FW), Average Crush depth = 17.4"

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Table 16 - Derived Ford Thunderbird A-B-G & CF Values from NHTSA Test # 2044

Test #	Year	Weight pounds	Impact Speed MPH	Vehicle Width Inches	Crush Indentation Length Inches	Crush in inches Minimum	Average	Maximum
2044	1994	3924	35.0	60.2	56.7	23.5	24.1	25.0

Values Calculated from NHTSA Test #2044 ("Full" Width)

"no damage" speed	A	B	G	CF		
2.5 mph	176.2	95.0	163.3		24.1	
5.0 mph	325.2	81.0	653.2		24.1	
7.5 mph	447.2	68.0	1469.6		24.1	
Test Specific CF				19.6		25.0

Width = 60.2" (FW), Average Crush depth = 24.1"

Values Calculated from NHTSA Test #2044 (Indentation Length Only - IL)

"no damage" speed	A	B	G	CF		
2.5 mph	187.0	100.9	173.4		24.1	
5.0 mph	345.3	86.0	693.5		24.1	
7.5 mph	474.8	72.2	1560.4		24.1	
Test Specific CF				19.6		25.0

Width = 56.7" (IL), Average Crush depth = 24.1"

Table 17 - "Generic" A-B-G & CF values for 1989-1994 Ford Thunderbird

"Generic" Values

AVG of FW values ("Full" Width)	A	B	G	CF
2.5 mph	184.3	115.8	148.6	
5.0 mph	338.2	97.6	594.5	
7.5 mph	461.9	80.9	1337.5	
NEI A & B Average Values	267.0	88.0	405.1	
NHTSA Default Table - Col. 4	356.0	34.0	1863.8	
Standard CF from Expert AutoStats				21

Average of Calculated A-B-G values from NHTSA test numbers 1282, 1390, and 2044 ("Full" Width)

A-B-G values based on Average crush depths

Statistical Analysis of "Generic" A-B-G values

	A	B	G
Minimum	184.3	34.0	148.6
Average	321.5	83.3	869.9
Median	338.2	88.0	594.5
Maximum	461.9	115.8	1863.8
Pop. Std. Dev.	92.7	27.3	635.4
Sample Std. Dev.	103.7	30.5	710.4

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Table 18 - Calculation of Impact speeds (MPH) for NHTSA Tests #1282, 1390, and 2044 based on A-B-G & CF Values calculated for Test # 128

Values Calculated from NHTSA Test #1282 ("Full" Width - FW)					Test "Actual" Impact Speed = 34.7 MPH			Test "Actual" Impact Speed = 29.4 MPH			Test "Actual" Impact Speed = 35.0 MPH		
					Test # 1282 Speed Calculation Based on:			Test # 1390 Speed Calculation Based on:			Test # 2044 Speed Calculation Based on:		
"no damage" speed	A	B	G	CF	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush
2.5 mph	202.7	145.0	141.6		31.5	34.7	40.2	31.6	33.7	37.8	41.5	42.5	44.0
5.0 mph	373.9	123.4	566.5		31.7	34.7	39.8	31.8	33.8	37.6	40.8	41.7	43.1
7.5 mph	513.6	103.5	1274.6		32.0	34.7	39.4	32.1	33.9	37.4	40.1	40.9	42.2
Test Specific CF				22.8	30.4	32.0	34.7	30.4	31.5	33.5	36.6	37.1	37.7
Standard CF from Expert AutoStats				21	29.2	30.7	33.3	29.2	30.2	32.2	35.1	35.6	36.2

Width = 72.7" (FW), Average Crush depth = 18.0"

Table 19 - Calculation of Impact speeds (MPH) for NHTSA Tests #1282, 1390, and 2044 based on A-B-G & CF Values calculated for Test # 139

Values Calculated from NHTSA Test #1390 ("Full" Width)					Test "Actual" Impact Speed = 34.7 MPH			Test "Actual" Impact Speed = 29.4 MPH			Test "Actual" Impact Speed = 35.0 MPH		
					Test # 1282 Speed Calculation Based on:			Test # 1390 Speed Calculation Based on:			Test # 2044 Speed Calculation Based on:		
"no damage" speed	A	B	G	CF	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush
2.5 mph	174	107.4	140.9		27.4	30.2	35.0	27.5	29.4	32.9	36.0	36.9	38.2
5.0 mph	315.6	88.3	563.8		27.6	30.1	34.4	27.7	29.3	32.6	35.2	36.0	37.1
7.5 mph	424.9	71.2	1268.4		27.8	30.0	33.9	27.9	29.4	32.3	34.4	35.1	36.1
Test Specific CF				17.6	26.7	28.1	30.5	26.7	27.7	29.4	32.2	32.6	33.2
Standard CF from Expert AutoStats				21	29.2	30.7	33.3	29.2	30.2	32.2	35.1	35.6	36.2

Width = 72.7" (FW), Average Crush depth = 17.4"

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Table 20 - Calculation of Impact speeds (MPH) for NHTSA Tests #1282, 1390, and 2044 based on A-B-G & CF Values calculated for Test # 2044 (FW)

Values Calculated from NHTSA Test #2044 ("Full" Width)					Test "Actual" Impact Speed = 34.7 MPH			Test "Actual" Impact Speed = 29.4 MPH			Test "Actual" Impact Speed = 35.0 MPH		
					Test # 1282 Speed Calculation Based on:			Test # 1390 Speed Calculation Based on:			Test # 2044 Speed Calculation Based on:		
"no damage" speed	A	B	G	CF	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush
2.5 mph	176.2	95.0	163.3		26.1	28.7	33.2	26.2	27.9	31.3	34.2	35.0	36.2
5.0 mph	325.2	81.0	653.2		27.0	29.4	33.6	27.1	28.7	31.8	34.3	35.0	36.1
7.5 mph	447.2	68.0	1469.6		27.9	30.1	33.9	28.0	29.4	32.3	34.3	35.0	36.0
Test Specific CF				19.6	28.2	29.7	32.2	28.2	29.2	31.1	33.9	34.4	35.0
Standard CF from Expert AutoStats				21	29.2	30.7	33.3	29.2	30.2	32.2	35.1	35.6	36.2

Width = 60.2" (FW), Average Crush depth = 24.1"

Table 21 - Calculation of Impact speeds (MPH) for NHTSA Tests #1282, 1390, and 2044 based on A-B-G & CF Values calculated for Test # 2044 (IL)

Values Calculated from NHTSA Test #2044 (Indentation Length Only - IL)					Test "Actual" Impact Speed = 34.7 MPH			Test "Actual" Impact Speed = 29.4 MPH			Test "Actual" Impact Speed = 35.0 MPH		
					Test # 1282 Speed Calculation Based on:			Test # 1390 Speed Calculation Based on:			Test # 2044 Speed Calculation Based on:		
"no damage" speed	A	B	G	CF	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush
2.5 mph	187.0	100.9	173.4		26.9	29.6	34.2	27.0	28.8	32.2	35.2	36.1	37.3
5.0 mph	345.3	86.0	693.5		27.8	30.3	34.6	27.9	29.6	32.7	35.3	36.1	37.2
7.5 mph	474.8	72.2	1560.4		28.7	31.0	34.9	28.8	30.3	33.2	35.4	36.1	37.1
Test Specific CF				19.6	28.2	29.7	32.2	28.2	29.2	31.1	33.9	34.4	35.0
Standard CF from Expert AutoStats				21	29.2	30.7	33.3	29.2	30.2	32.2	35.1	35.6	36.2

Width = 56.7" (IL), Average Crush depth = 24.1"

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Table 22 - Calculation of Impact speeds (MPH) for NHTSA Tests #1282, 1390, and 2044 based on "Generic" A-B-G & CF Values

"Generic" Values					Test "Actual" Impact Speed = 34.7 MPH			Test "Actual" Impact Speed = 29.4 MPH			Test "Actual" Impact Speed = 35.0 MPH		
					Test # 1282 Speed Calculation Based on:			Test # 1390 Speed Calculation Based on:			Test # 2044 Speed Calculation Based on:		
AVG of FW values ("Full" Width)	A	B	G	CF	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush
2.5 mph	184.3	115.8	148.6		28.4	31.3	36.3	28.5	30.4	34.1	37.4	38.2	39.6
5.0 mph	338.2	97.6	594.5		28.9	31.5	36.1	28.9	30.7	34.1	36.9	37.7	38.9
7.5 mph	461.9	80.9	1337.5	**	29.3	31.7	35.8	29.4	31.0	34.0	36.4	37.1	38.2
NEI A & B Average Values	267.0	88.0	405.1		28.8	29.3	33.6	26.9	28.5	31.8	34.4	35.2	36.4
NHTSA Default Table - Col. 4	356.0	34.0	1863.8		23.1	24.7	27.3	23.2	24.2	26.2	27.4	27.9	28.6
Standard CF from Expert AutoStats				21	29.2	30.7	33.3	29.2	30.2	32.2	35.1	35.6	36.2

A-B-G values based on Average crush depths

Table 23 - Statistical Analysis of Calculation of Impact speeds (MPH) for NHTSA Tests #1282, 1390, and 2044 based on "Generic" A-B-G Values contained in Table 22 and comparison to the Standard CF Value

	Test "Actual" Impact Speed = 34.7 MPH			Test "Actual" Impact Speed = 29.4 MPH			Test "Actual" Impact Speed = 35.0 MPH		
	Test # 1282 Speed Calculation Based on:			Test # 1390 Speed Calculation Based on:			Test # 2044 Speed Calculation Based on:		
	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush	Minimum Crush	Average Crush	Maximum Crush
Minimum	23.1	24.7	27.3	23.2	24.2	26.2	27.4	27.9	28.6
Average	27.3	29.7	33.8	27.4	29.0	32.0	34.5	35.2	36.3
Median	28.4	31.3	35.8	28.5	30.4	34.0	36.4	37.1	38.2
Maximum	29.3	31.7	36.3	29.4	31.0	34.1	37.4	38.2	39.6
Pop. Std. Dev.	2.3	2.7	3.4	2.3	2.5	3.1	3.7	3.8	4.0
Sample Std. Dev.	2.5	3.0	3.8	2.5	2.8	3.4	4.1	4.3	4.5
Standard CF from Expert AutoStats = 21	29.2	30.7	33.3	30.2	30.2	32.2	35.1	35.6	36.2

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Table 24 - Combined Summary Table of Tables 14-22

Test #	Year	Make	Model	Weight pounds	Impact Speed MPH	Vehicle Width inches	Crush Indentation Length inches	Crush in inches Minimum	Crush in inches Average	Crush in inches Maximum	Test Specific CF
1282	1989	Ford	Thunderbi	4110	34.7	72.7	72.7	16.2	18.0	21.1	22.8
1390	1990	Ford	Thunderbi	4090	29.4	72.7	0.0	16.2	17.4	19.7	17.6
2044	1994	Ford	Thunderbi	3924	35.0	60.2	56.7	23.5	24.1	25.0	19.6
2047	1994	Ford	Thunderbi	4028	29.3	72.7	72.7	Null	Null	Null	ERR

Test "Actual" Impact Speed = 34.7 MPH (Test # 1282); Test "Actual" Impact Speed = 29.4 MPH (Test # 1390); Test "Actual" Impact Speed = 35.0 MPH (Test # 2044)

All ABG values are calculated from AVERAGE crush

Speed Calculation Based on: Minimum / Average / Maximum Crush, for Test # 1282, Test # 1390 and Test # 2044.

Values Calculated from NHTSA Test #1282 ("Full" Width - FW)

"no damage" speed	A	B	G	CF	1282 Minimum Crush	1282 Average Crush	1282 Maximum Crush	1390 Minimum Crush	1390 Average Crush	1390 Maximum Crush	2044 Minimum Crush	2044 Average Crush	2044 Maximum Crush
2.5 mph	202.7	145.0	141.6		31.5	34.7	40.2	31.6	33.7	37.8	41.5	42.5	44.0
5.0 mph	373.9	123.4	566.5		31.7	34.7	39.8	31.8	33.8	37.6	40.8	41.7	43.1
7.5 mph	513.6	103.6	1274.6		32.0	34.7	39.4	32.1	33.9	37.4	40.1	40.9	42.2
Test Specific CF				22.8	30.4	32.0	34.7	30.4	31.5	33.5	36.6	37.1	37.7

Width = 72.7" (FW), Average Crush depth = 18.0"

Values Calculated from NHTSA Test #1390 ("Full" Width)

"no damage" speed	A	B	G	CF	1282 Minimum Crush	1282 Average Crush	1282 Maximum Crush	1390 Minimum Crush	1390 Average Crush	1390 Maximum Crush	2044 Minimum Crush	2044 Average Crush	2044 Maximum Crush
2.5 mph	174	107.4	140.9		27.4	30.2	35.0	27.5	29.4	32.9	36.0	36.9	38.2
5.0 mph	315.6	88.3	563.8		27.6	30.1	34.4	27.7	29.3	32.6	35.2	36.0	37.1
7.5 mph	424.9	71.2	1268.4		27.8	30.0	33.9	27.9	29.4	32.3	34.4	35.1	36.1
Test Specific CF				17.6	26.7	28.1	30.5	26.7	27.7	29.4	32.2	32.6	33.2

Width = 72.7" (FW), Average Crush depth = 17.4"

Values Calculated from NHTSA Test #2044 ("Full" Width)

"no damage" speed	A	B	G	CF	1282 Minimum Crush	1282 Average Crush	1282 Maximum Crush	1390 Minimum Crush	1390 Average Crush	1390 Maximum Crush	2044 Minimum Crush	2044 Average Crush	2044 Maximum Crush
2.5 mph	176.2	95.0	163.3		26.1	28.7	33.2	26.2	27.9	31.3	34.2	35.0	36.2
5.0 mph	325.2	81.0	653.2		27.0	29.4	33.6	27.1	28.7	31.8	34.3	35.0	36.1
7.5 mph	447.2	68.0	1469.6		27.9	30.1	33.9	28.0	29.4	32.3	34.3	35.0	36.0
Test Specific CF				19.6	28.2	29.7	32.2	28.2	29.2	31.1	33.9	34.4	35.0

Width = 60.2" (FW), Average Crush depth = 24.1"

Values Calculated from NHTSA Test #2044 (Indentation Length Only - IL)

"no damage" speed	A	B	G	CF	1282 Minimum Crush	1282 Average Crush	1282 Maximum Crush	1390 Minimum Crush	1390 Average Crush	1390 Maximum Crush	2044 Minimum Crush	2044 Average Crush	2044 Maximum Crush
2.5 mph	187.0	100.9	173.4		26.9	29.6	34.2	27.0	28.8	32.2	35.2	36.1	37.3
5.0 mph	345.3	86.0	693.5		27.8	30.3	34.6	27.9	29.6	32.7	35.3	36.1	37.2
7.5 mph	474.8	72.2	1560.4		28.7	31.0	34.9	28.8	30.3	33.2	35.4	36.1	37.1
Test Specific CF				19.6	28.2	29.7	32.2	28.2	29.2	31.1	33.9	34.4	35.0

Width = 56.7" (IL), Average Crush depth = 24.1"

"Generic" Values

"no damage" speed	A	B	G	CF	1282 Minimum Crush	1282 Average Crush	1282 Maximum Crush	1390 Minimum Crush	1390 Average Crush	1390 Maximum Crush	2044 Minimum Crush	2044 Average Crush	2044 Maximum Crush
2.5 mph (AVG - FW)	184.3	116.8	146.7		28.4	31.3	36.3	28.5	30.4	34.1	37.4	38.2	39.6
5.0 mph (AVG - FW)	338.2	97.6	586.3		28.9	31.5	36.0	28.9	30.7	34.1	36.8	37.7	38.9
7.5 mph(AVG - FW)	461.9	80.9	1318.6		29.3	31.7	35.8	29.3	31.0	34.0	36.3	37.1	38.2
NEI A & B Average Values	267.0	88.0	405.1		26.8	29.3	33.6	26.9	28.5	31.8	34.4	35.2	36.4
NHTSA Default Table - Col. 4	356.0	34.0	1863.8		23.1	24.7	27.3	23.2	24.2	28.2	27.4	27.9	28.6
Standard CF from Expert AutoStats				21	29.2	30.7	33.3	29.2	30.2	32.2	35.1	35.6	36.2

A-B-G values based on Average crush depths

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