SHORT PAPER PCB 5-2006

OBLIQUE COLLISIONS

ENGINEERING EQUATIONS, INPUT DATA AND MARC 1 APPLICATIONS

By:

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2006

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PURPOSE OF PCB SHORT PAPERS

To provide the accident reconstruction practitioner with a concise discussion of the engineering equations and limiting factors involved, evaluation of critical input data, and the analysis of actual cases by use of the MARC 1 computer software.

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We hope that our Short Papers will assist the practitioner in better understanding the limitations inherent in any derivation of engineering equations, to properly use critical input data, to more accurately and effectively formulate his or her case under consideration, to become a better prepared expert in the field of accident reconstruction, and to more effectively utilize the full potential of the MARC 1 computer program.

Comments and suggestions are always invited by visiting our Discussion Forum and/or by writing to:

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Throughout the Short Papers we will extensively reference the 5th Edition of "Motor Vehicle Accident Reconstructions and Cause Analysis" by Rudolf Limpert, the "Accident Reconstruction Catalog" (ARC) CD, as well as the MARC 1 software.

OBLIQUE COLLISIONS

Part One

Standard Linear Momentum

1. DEFINITION OF LINEAR MOMENTUM

Linear momentum is discussed in Sections 33-1(b) and 33-2(a) of the Text. With the assumption that all tire forces, such as braking or side forces existing during impact, are excluded from the analysis, the impulse P (Equation 33-1) between two colliding vehicles has the same magnitude for each vehicle, except their directions are opposite. The impulse is assumed to act through the center-of-mass of each vehicle. No rotational aspects of the crash can be analyzed by the standard linear momentum method. The summation of all momenta, or products of mass and velocity, before impact equals the summation of all momenta after impact.

The rest positions of both vehicles must be consistent with the approach directions of both vehicles. For example, if the approach is North and East, the rest positions must be in the North-East quadrant. If one of the vehicles were inadvertently coming to rest in a different quadrant, meaning its impact-related rest position is unknown, standard linear momentum can not be used.

Low velocity impacts where the tire forces can not be ignored are discussed in Chapter 43 of the Text (2006 Supplement).

Velocity changes or Delta-V values for a vehicle apply to the center-of-gravity only, and may still have a certain level of error associated with it, depending upon the actual impact configuration analyzed. A complete study of the Delta-V error associated with the standard linear momentum method can only be evaluated in connection with rotational momentum (see PCB 8 – 2006).

2. WHAT ENGINEERING PRINCIPLES APPLY

In a two-vehicle oblique collision we have four unknown velocities, namely two before and two after impact. The after-impact velocities must be known in terms of their magnitude as well as velocity directions. The directions are determined by their departure angles. The departure angle is that velocity vector direction that a vehicle has achieved at the instant of vehicle separation, that is, approximately 100 to 200 ms after initial contact was made. The reader is encouraged to study the crash video of Section 2.3.2 where a Suburban side-impacts a Ford Taurus. The center-of-gravity velocity direction of a vehicle immediately after impact may not be the same as the one established by a vehicle's rest position.

Example 33-1 of the Text shows an illustration of a two-car collision using the manual calculations generally employed many years ago. The example was the first law suit-related accident reconstruction done by the author over 30 years ago.

3. 71 GMC PICKUP SIDE-IMPACTS 81 HONDA CIVIC

The Honda travels zero degree direction (due East), when the GMC traveling 90 degrees (due North) side-impacts the Honda fully in the right side. The rest position and damage sustained by the Honda are illustrated in PCB 1 2006.

The GMC's center-of-gravity traveled 44 ft on asphalt and 33.7 ft on grass before coming to rest. It rotated approximately 30 degrees as illustrated on Figure 1 (collision sketch). The Honda traveled approximately 30 ft on asphalt and 18 ft on grass before rear-impacting a power pole. The Honda rotated 90 degrees.

The crash reconstruction is shown in MARC 1 X – 5, RUN 1. The after-impact deceleration used for the GMC was 0.45 on asphalt, and 0.35 on grass. If more detailed accident scene and vehicle inspection data are available (braking, skid marks, tire marks, engine braking, scuff marks, tire/wheel wedging) a detailed run-out analysis may yield a more probable after-impact deceleration for the GMC. The Honda's after-impact deceleration used was 0.55 to account for both linear and rotational tire scuffing after impact. The secondary crush energy of 17,781 lbft was obtained from PCB 1 – 2006 for the Honda crashing against a power pole before coming to rest. RUN 1 indicates impact velocities of 47.9 and 18.7 mph for the GMC and Honda, respectively.

RUN 1 shows delta-V = 18.92 mph for the GMC, and 30.75 mph for the Honda, with their directions 289.76 and 109.76 degrees, respectively. Section 33-2(c) of the Text describes the delta-V velocity vector diagram. Figure 2 illustrates the velocity vector diagram for the Honda. The Honda diagram indicates the delta-Vector pointing in the 109.8 degree direction, that is, slightly to the left of 12:00 o'clock. The Honda vehicle body at its center-of-gravity experienced a velocity change from 18.7 mph in the zero direction to 30.10 mph after impact in the 74 degree direction. This is the same as if the Honda vehicle body (and its occupants) had been stationary and the body suddenly experienced a velocity change at its center-of-gravity from zero to 30.75 mph in the 109.76 degree direction. Any right side occupants will experience an impact with the interior door and quarter panel of the Honda at approximately 31 mph.

The major impulse relative to the Honda was central, that is, its line of direction was located through or near the Honda's center-of-gravity. The rotation was primarily produced by the front of the GMC slowing the right side of the Honda.

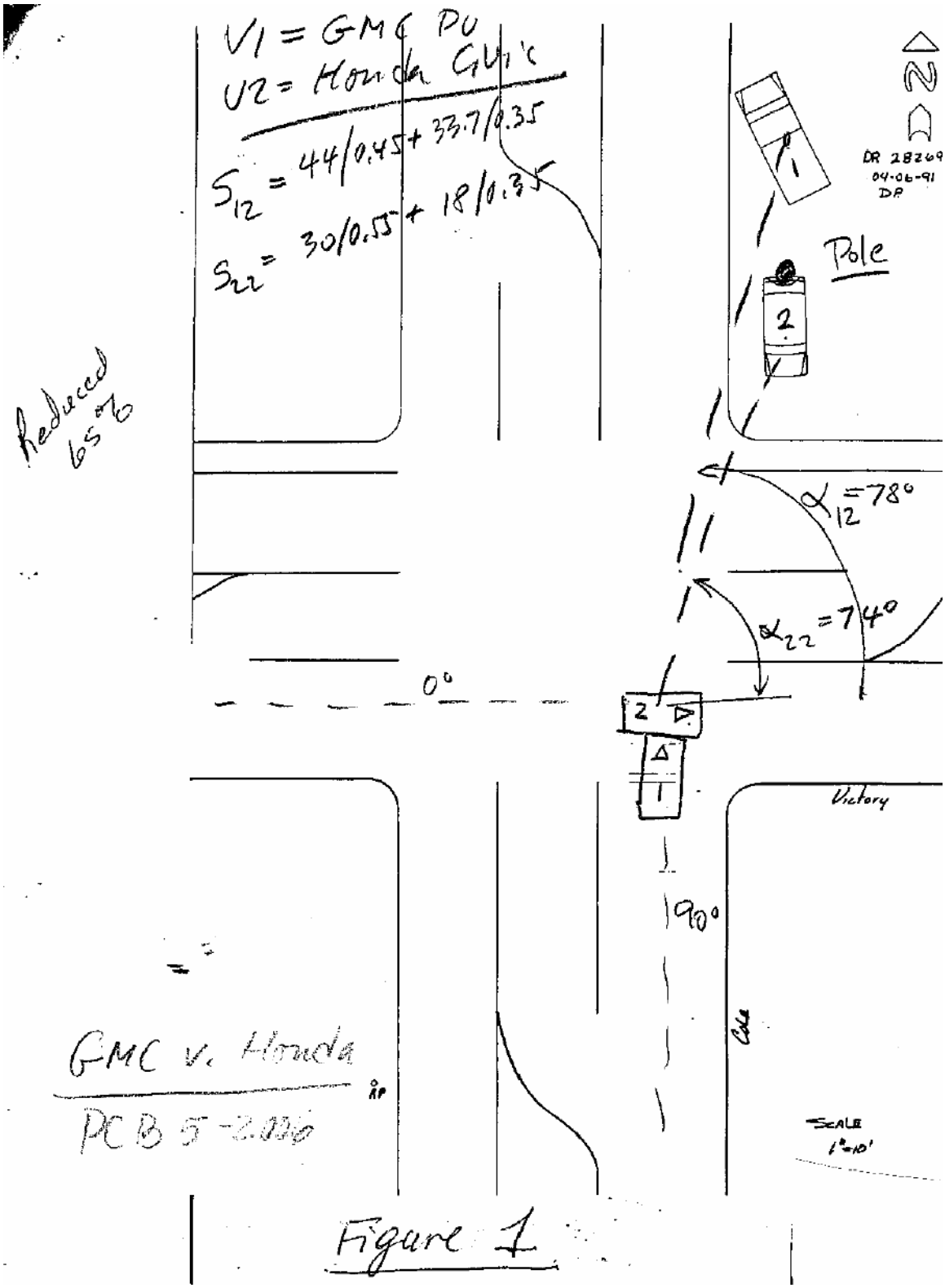
V1 = GMC PU
V2 = Honda CVCC
S_{12} = 44/0.45 + 33.7/0.35
S_{22} = 30/0.55 + 18/0.35
Reduced 65%
DR 28269
04-06-91
DP
Pole
α_{12} = 78°
α_{22} = 74°
0°
Victory
190°
SCALE
1"=10'
GMC v. Honda
PCB 5-2.086

Figure 1

Wednesday, March 15, 2006

MOTOR VEHICLE ACCIDENT RECONSTRUCTION AND CAUSE ANALYSIS
****** PROGRAM 'X-5' RUN FOR PCB 5 - 2006, X - 5, RUN 1 ******
OBLIQUE COLLISION/LINEAR MOMENTUM

Information For Vehicles		1971 GMC 1500	1981 HONDA CIVIC
Vehicle Weight, LBS:	===>	3900.00	2400.00
Surface #1			
Pre-Impact Braking Distance, FT:	===>	0.00	0.00
Pre-Impact Deceleration, g-UNITS:	===>	0.00	0.00
Surface #1			
Distance Traveled After Impact, FT:	===>	44.00	30.00
After-Impact Deceleration, g-UNITS:	===>	0.45	0.55
Surface #2			
Distance Traveled After Impact, FT:	===>	33.70	18.00
After-Impact Deceleration, g-UNITS:	===>	0.35	0.35
Amount to Vary Departure Angle, DEG:	===>	0.00	0.00
Energy from Secondary Impacts, FT·LBS.	===>	0.00	17781.00

PRINT OUT 1 OF 1 PCB 5 - 2006, X - 5, RUN 1

Approach Angle, DEG:	===>	90.00	0.00
Departure Angle, DEG:	===>	78.00	74.00
Pre-Impact Speed, MPH:	===>	47.92	18.70
Speed at Impact, MPH:	===>	47.92	18.70
After-Impact Speed, MPH:	===>	30.79	30.10
Delta V in X-Direction, MPH:	===>	6.40	-10.40
Delta V in Y-Direction, MPH:	===>	-17.81	28.94
Delta V Resultant, MPH:	===>	18.92	30.75
Angle of Delta V, DEG:	===>	289.76	109.76

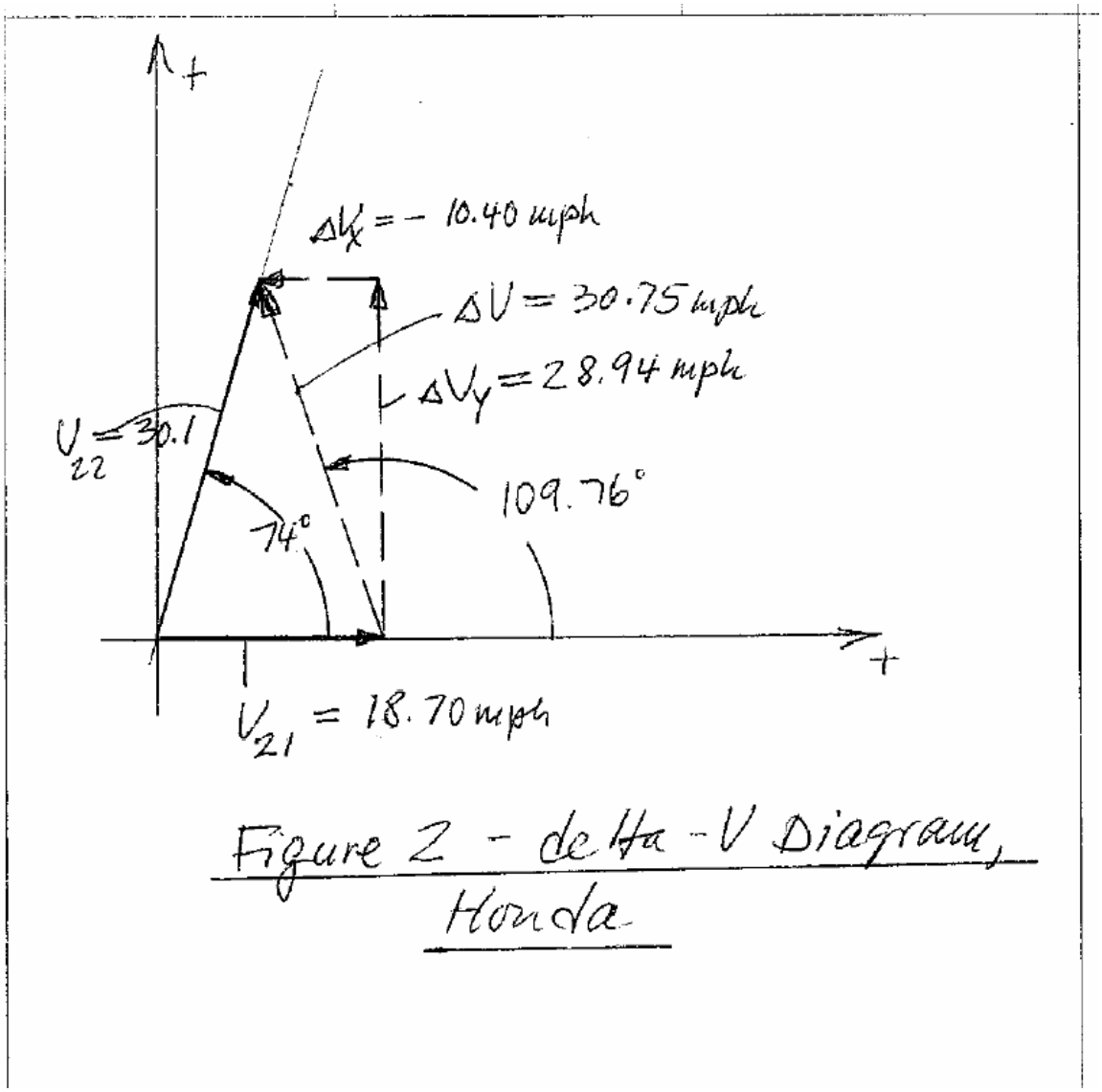

Figure 2 - delta-V Diagram, Honda

4.0 NON-CENTRAL OBLIQUE COLLISION

The standard linear momentum method may calculate impact velocities reasonable well in a non-central impact. Velocity changes or delta-V values at locations different from the vehicle's center-of-gravity can not be analyzed since angular velocities are not computed in the standard linear momentum method. For example, when a pickup truck impacts the right front side/corner of a car at an angle of 90 degrees, both the right and left rear occupants will experience the vehicle's linear center-of-gravity delta-V, however, the resultant delta-V of the left rear occupant will greater due to the counter-clockwise rotation of the vehicle body.

Consequently, linear momentum, while predicting impact velocities reasonably accurately in non-central impacts, must be applied carefully when analyzing velocity changes or delta-Vs for locations other than the center-of-gravity of the vehicle.

4.1. VW GOLF I SIDE-IMPACTS STATIONARY VW DERBY

The engineering office of Schimmelpfennig and Becke conducted the two-vehicle crash test. The report and findings were published in Verkehrsunfall und Fahrzeugtechnik, May 1994, Number 5.

The collision configuration is illustrated in Figure 3. The stationary VW Derby had its manual transmission in first gear and the parking brake was applied. The VW Golf had its brakes applied at the moment of impact resulting in four-wheel skid marks after impact.

The rest positions are illustrated in Figure 4. The grid points are 1 m apart. The impact velocity of the Golf was 29.2 mph (47 km/h). Inspection of Figure 4 indicates the following after-impact data: Golf: distance 10.2 ft, departure angle 97 deg., Derby: 9.8 ft, 80 deg. Using after-impact decelerations of 0.9g and 0.45g, respectively, yields the crash reconstruction shown in MARC 1 X – 5, RUN 2 with an impact velocity of 28.32 mph and 0.06 mph, respectively. Decreasing the after-impact deceleration of the Golf to 0.75g (probably more reasonable), results in impact velocities of 26.89 and 0.23 mph, respectively. The delta-Vs are approximately equal with 12 mph.

Inspection of RUN 2 indicates after-impact velocities of 16.6 and 11.5 mph, respectively. In a central plastic impact both after-impact velocities must nearly identical.

The damage sustained by the crash test vehicles is shown in Figures 5 and 6.

The Golf/Derby crash test will be analyzed in detail in the next three Short Papers in connection with combined linear and rotational momentum to more accurately study non-central impacts.

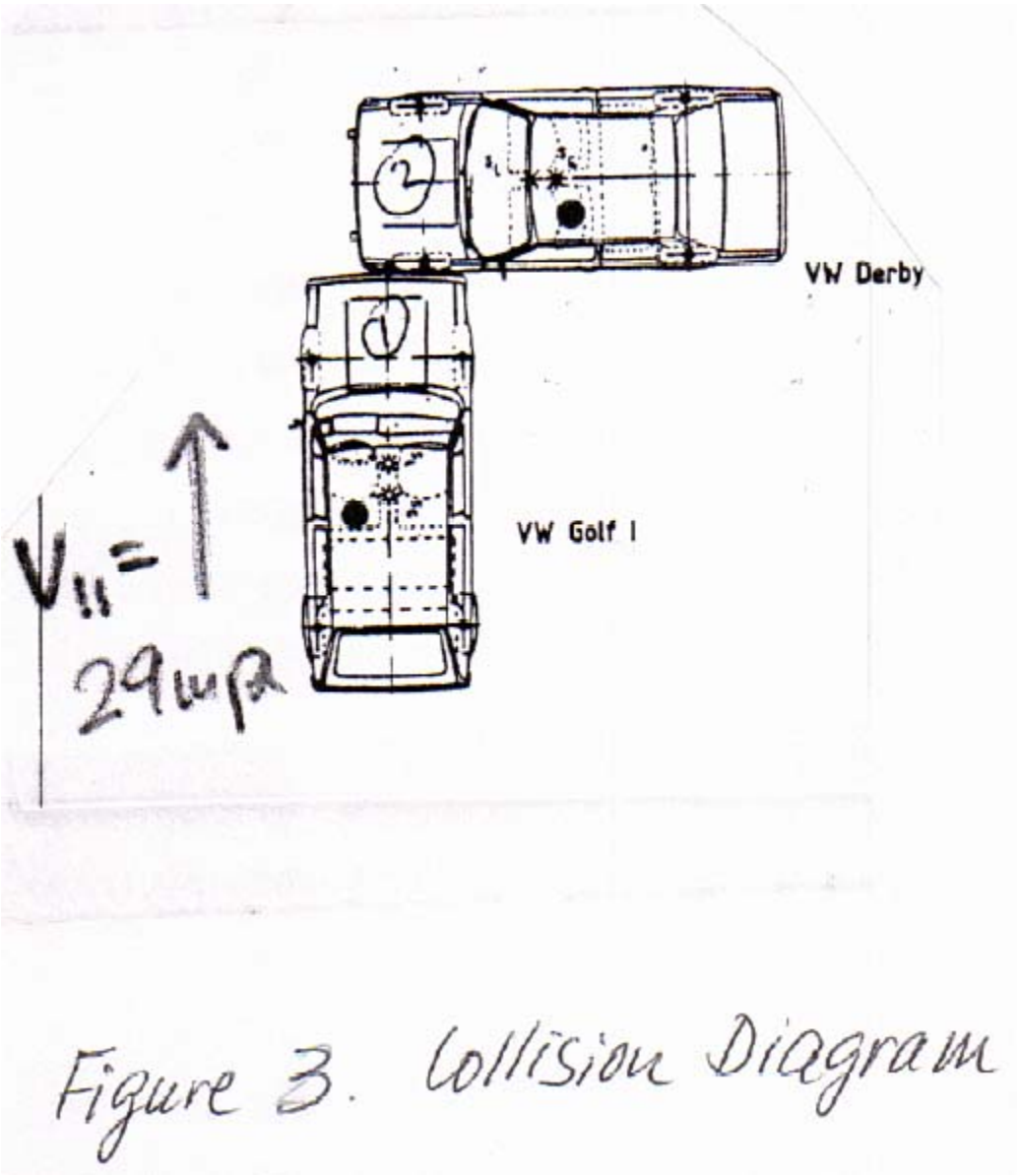

Figure 3. Collision Diagram

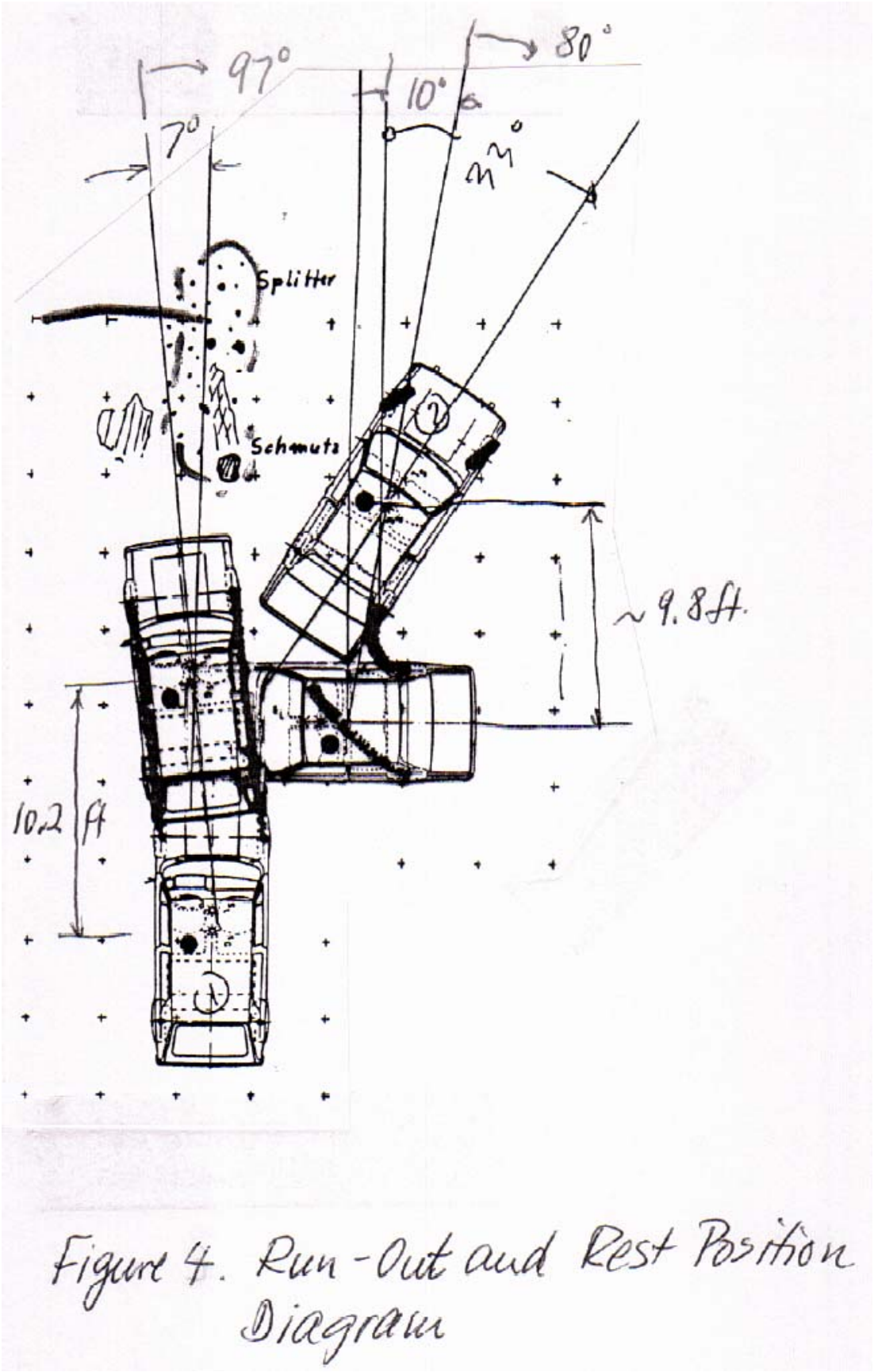

Figure 4. Run-Out and Rest Position Diagram

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MOTOR VEHICLE ACCIDENT RECONSTRUCTION AND CAUSE ANALYSIS
****** PROGRAM 'X-5' RUN FOR PCB 5 - 2006, X-5, RUN 2 ******
OBLIQUE COLLISION/LINEAR MOMENTUM

Information For Vehicles		1993 VW GOLF	1993 VW DERBY
Vehicle Weight, LBS:	===>	1918.00	2007.00
Surface #1			
Pre-Impact Braking Distance, FT:	===>	0.00	0.00
Pre-Impact Deceleration, g-UNITS:	===>	0.00	0.00
Surface #1			
Distance Traveled After Impact, FT:	===>	10.20	9.80
After-Impact Deceleration, g-UNITS:	===>	0.90	0.45
Amount to Vary Departure Angle, DEG:	===>	0.00	0.00
Energy from Secondary Impacts, FT·LBS.	===>	0.00	0.00

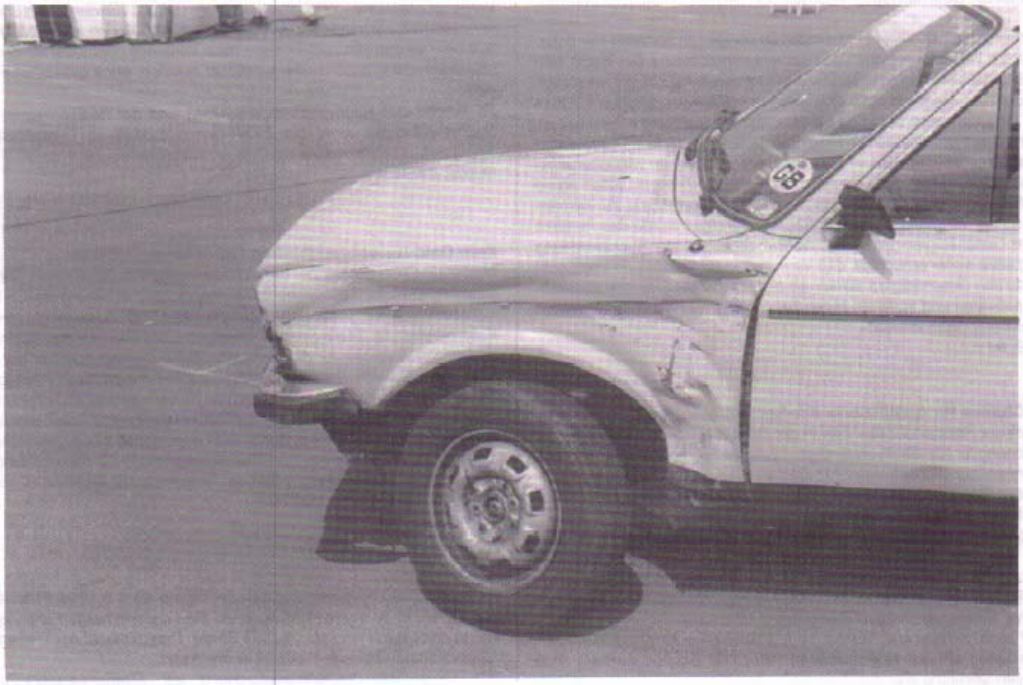
PRINT OUT 1 OF 1 PCB 5 - 2006, X-5, RUN 2

Approach Angle, DEG:	===>	90.00	180.00
Departure Angle, DEG:	===>	97.00	80.00
Pre-Impact Speed, MPH:	===>	28.32	0.06
Speed at Impact, MPH:	===>	28.32	0.06
After-Impact Speed, MPH:	===>	16.60	11.50
Delta V in X-Direction, MPH:	===>	-2.02	2.06
Delta V in Y-Direction, MPH:	===>	-11.85	11.33
Delta V Resultant, MPH:	===>	12.02	11.51
Angle of Delta V, DEG:	===>	260.32	79.68

Damage

Schadenbild VW Golf

Figure 5



Damage

Schadenbild VW Derby

Figure 6