Impact Speed Change (ΔV)

Impact speed-change is defined as the impulsive change in vehicle speed (i.e., produced by an impact) that occurs along the direction of action of the principal collision force[1].

The magnitude and direction of the impact speed-change of a vehicle, that occurs during a collision, serve as primary descriptors of impact severity, since they reflect the effect of the ratio of the masses of the two colliding bodies as well as that of the closing speed. The impact speed-change is expressed in miles per hour and the clock direction from which the principal force was applied is generally stated.

For example, a 20 MPH, 06 o'clock impact speed-change would correspond to a principal force acting from the 06 o'clock direction (i.e., a longitudinal rear-ender) with a sufficient impulse (i.e., time-integral of applied force) to produce a 20 MPH impact speed-change of the subject vehicle.

In a central, collinear collision, the impact speed-change of vehicle #1, ΔV_1, and the closing velocity, $(V_{10} - V_{20})$, are related as follows:

$$\Delta V_1 = \frac{\left(V_{10} - V_{20}\right)}{\left(1 + {W_1}/{W_2}\right)} \left(1 + \in\right)$$

where W_1 = weight of vehicle #1, lbs.,

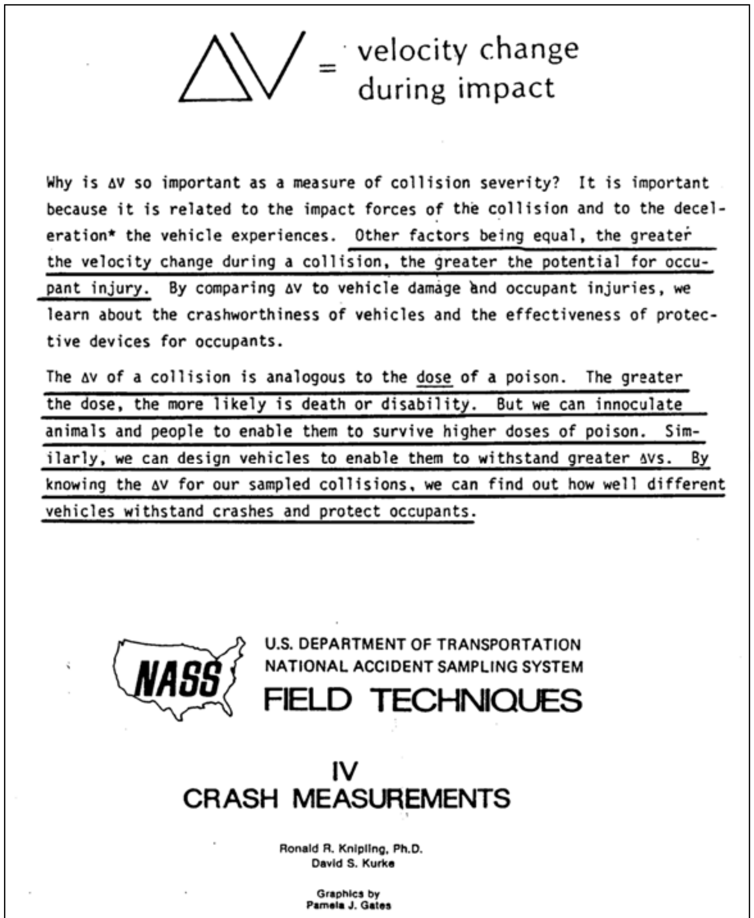
W_2 = weight of vehicle #2, lbs., and

ε = coefficient of restitution.

The terms barrier-equivalent speed and impact speed-change are sometimes used interchangeably. However, this is appropriate only for that portion of the impact speed-change that precedes restitution.

A further discussion of impact speed-change is presented in **Figure 1** from **Reference** [2].

[1] See "Collision Deformation Classification," Society of Automotive Engineers Technical Report J224a, 1972, for further discussion of the principal collision force and its direction of action.
[2] Knipling, R.R., Kurke, D.S., "**NASS Field Techniques – Volume IV – CRASH MEASUREMENTS**", US Department of Transportation, National Accident Sampling System



ΔV = velocity change during impact

Why is ΔV so important as a measure of collision severity? It is important because it is related to the impact forces of the collision and to the deceleration* the vehicle experiences. Other factors being equal, the greater the velocity change during a collision, the greater the potential for occupant injury. By comparing ΔV to vehicle damage and occupant injuries, we learn about the crashworthiness of vehicles and the effectiveness of protective devices for occupants.

The ΔV of a collision is analogous to the dose of a poison. The greater the dose, the more likely is death or disability. But we can innoculate animals and people to enable them to survive higher doses of poison. Similarly, we can design vehicles to enable them to withstand greater ΔVs. By knowing the ΔV for our sampled collisions, we can find out how well different vehicles withstand crashes and protect occupants.

NASS

U.S. DEPARTMENT OF TRANSPORTATION
NATIONAL ACCIDENT SAMPLING SYSTEM
FIELD TECHNIQUES

IV
CRASH MEASUREMENTS

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Figure 1 The significance of Impact Speed Change

Barrier Equivalent Velocity (BEV)

Confusion in the interpretation of damage in actual accidents can be created by the use of the term Barrier Equivalent Velocity as opposed to Barrier Impact Velocity in the specification of corresponding test conditions. Such confusion comes from the following definition (e.g., Reference [3]) of the Barrier Equivalent Velocity (BEV):

BEV is “the equivalent impact velocity of a vehicle into a fixed, rigid barrier that would result in the same magnitude of crush as observed on a subject vehicle under analysis.”

Clearly, when a vehicle with a stiff front structure collides with the softer rear of another vehicle, the magnitude of crush on the striking vehicle will be less than that in a corresponding barrier crash with the same impact speed-change. Thus, a simplistic crush comparison on the striking vehicle, using the above BEV definition and the specified BEV values for air bag deployment, will generally lead to the conclusion that the BEV was below that specified for the airbag deployment threshold. Note that this confusion could be overcome by either (a) the definition of deployment thresholds in terms of Barrier Impact Velocity rather than BEV, or (b) a more proper definition of BEV as meaning “that portion of the impact speed-change that precedes the achievement of a common velocity.”

The concept of assessing impact severity by relating the damage sustained in a collision to that which the same vehicle sustains in an experimental barrier impact test (e.g., the Barrier Equivalent Velocity (BEV)

[3] Kerkhoff, J.F., Husher, S.E., et al, **“An Investigation into Vehicle Frontal Impact Stiffness, BEV and Repeated Testing for Reconstruction”,** Society of Automotive Engineers Paper No. 930899.

concept) was first described by Mackay in 1968 (Ref. [4]). When the two vehicles involved in a car-to-car collision have essentially similar deformation and weight characteristics, such a BEV method of assessing impact severity can be reasonably reliable for use in statistical studies. However, if the vehicles have dissimilar characteristics, the BEV ratings can be considerably in error as a measure of impact severity. For example, if a heavy soft car collides with a light stiff car, it is possible for the stiffer car to experience a substantial change in velocity with no appreciable damage (Ref. [4], [5]).

A barrier impact velocity of X MPH produces an impact speed-change, Delta-V, of X MPH plus the rebound velocity, if any. If the barrier is replaced by a standing, "mirror-image" vehicle, the same extent of damage and the same impact speed-change, Delta-V, as occurred in the barrier impact will be produced by a closing velocity twice as large as the barrier impact velocity (i.e., a closing velocity of 2X). The interpretation of damage in actual collisions in terms of BEV, or Delta-V, requires proper consideration of the mass and stiffness ratios of the collision partners and of the effects of any collision offset (e.g., Reference 3).

Airbag Deployment in Terms of BEV.

In view of (a) the wide variety of obstacles that are encountered in actual automobile accidents and (b) the non-homogenous nature of automobile structures, it must be recognized that the crush resistance for narrow contacts in local areas, the corresponding vehicle deceleration values, and the detailed residual damage profiles that occur in actual collisions are not the same as those in perpendicular collisions against a flat, rigid, fixed barrier. Thus, the "BEV" (Barrier Equivalent Velocity) values that are sometimes specified for airbag deployment in simple, repeatable barrier tests are selected on the basis of collision research to achieve specific performance objectives in terms of the ranges of impact speed-change, or Delta-V, for deployment in actual accidents. It is necessary to recognize the fact that the test "BEV" values do not constitute precisely defined deployment thresholds for actual accidents. Also, the interpretation of collision damage in actual accidents, in terms of the specified test "BEV" values, must include proper consideration of the damage and weight of the collision partner. The preceding discussion of the prevalent definition of Barrier Equivalent Velocity (BEV) indicates an important need for either revision of the definition or for abandonment of BEV in favor of Barrier Impact Velocity.

[4] Ashton, S.J., Hardy, J.L.G., Mackay, G.M., **"The Use of the Vehicle Deformation Index and Collision Speed Assessments",** Proceedings of the International Accident Investigation Workshop, Pilot Study on Road Safety, NATO, Brussels, Belgium, June 28-29, 1973.

[5] Hight, P.V., Lent-Koop, D.B., Hight, R.A., **"Barrier Equivalent Velocity, Delta-V, and CRASH3 Stiffness in Automobile Collisions",** Society of Automotive Engineers Paper No. 850437.

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Accident Reconstruction

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