

**(R) Guidelines for Evaluating Child Restraint System  
 Interactions with Deploying Airbags**

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**1. Scope**—This SAE Information Report prescribes dummies, procedures, and configurations that can be used for investigating the interactions that might occur between a deploying airbag and a child restrained by a child restraint system (CRS). During the inflation process, airbags generate a considerable amount of kinetic energy which can result in substantial forces being applied to a child who is restrained in a CRS in the front seat of a vehicle. Field data collected by the special crash investigation team of the National Highway Traffic Safety Administration (NHTSA) indicate that fatal forces can be developed. In response to these field data, NHTSA added a series of airbag/child interaction tests and limits to the Code of Federal Regulations (CFR 571.208) that deal with occupant protection, commonly known as Federal Motor Vehicle Safety Standards (FMVSS 208). The bases for NHTSA tests are the various test procedures that were developed by the International Standards Organization (ISO) and the Society of Automotive Engineers (SAE). This document was one of those reports.

This document describes static and dynamic tests that can be used to assess the injury potential of such interactions. The static tests can be used to sort these interactions on a comparative basis in either an actual or a simulated vehicle environment. Systems that appear to warrant further testing can be subjected to an appropriate dynamic test. Engineering judgment will be needed to identify the test conditions that produce the most severe interactions.

Mild-severity and high-severity crash pulses are described in 8.2. These pulses are not vehicle-specific but represent general acceleration-time histories for two crash conditions. The mild-severity pulse approximates a crash that would just deploy a typical airbag. This pulse would be used to evaluate the effect of the energy of the deploying airbag when the CRS and dummy are exerting the least amount of inertial force in the forward direction, but the dummy and/or CRS is moved forward by that inertial force. The high-severity pulse is similar to that specified in FMVSS 213 to evaluate CRS performance and would be used here to evaluate the airbag as an additional variable in a well-documented crash environment. These generic pulses or other vehicle-specific pulses may be used as appropriate. Differences in shape between the generic and the vehicle-specific pulses are expected to be greater for the high-severity than the mild-severity, with corresponding differences expected in dummy responses.

This document encourages the use of a wide range of test configurations and conditions, while recognizing that the range of possible interactions is essentially limitless and beyond testing capability. Further, measurements of primary importance for the various configurations are given in Section 10, Table 1, but performance limits are not specified. FMVSS 208 does specify performance limits which are based on the injury risk curves given in References SAE 973318 and SAE 2000-01-SC005.

## 2. References

**2.1 Applicable Publications**—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated, the latest revision of the publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J211-1—Instrumentation for Impact Test—Part 1: Electronic Instrumentation

SAE826040—Description and Basis of a Three-Year-Old Dummy for Evaluating Passenger Inflatable Restraint Concepts, M.J. Wolanin et al.

SAE 973318—Injury Risk Curves for Children and Adults in Frontal and Rear Collisions, H.J. Mertz et al.

SAE2000-01-SC05—Improved Neck Injury Risk Curves for Tension and Extension Moment Measurements of Crash Dummies, H.J. Mertz and P. Prasad

2.1.2 ISO PUBLICATION—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ISO/TR 12349-2—Road vehicles—Child dummies for restraint system testing

2.1.3 CODE OF FEDERAL REGULATIONS (CFR) PUBLICATIONS—Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

49 CFR, Part 571.208—Occupant Crash Protection (FMVSS 208)

49 CFR, Part 571.213—Child Restraint Systems (FMVSS 213)

49 CFR, Part 572—Anthropomorphic Test Dummies

2.1.4 CMVSS PUBLICATION—Available from Canadian Government Publishing Center, Ottawa, Canada K1A0S9.

CMVSS 213—Child Restraint Systems

2.1.5 OTHER PUBLICATIONS

Weber, K., "Child Passenger Protection," Accidental Injury: Biomechanics and Prevention, New York, Springer-Verlag, 1993

Special Crash Investigation Reports—Air Bags, National Center for Statistics and Analysis, NHTSA web site: <http://www.nhtsa.doc.gov/people/mcsa/scirepts.htm>

**2.2 Related Publications**—The following publications are provided for information purposes only and are not a required part of this document.

2.2.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1733—Sign Convention for Vehicle Crash Testing

SAEJ1980—Guidelines for Evaluating Out-of-Position Vehicle Occupant Interactions with Deploying Airbags

SAE 826047—Responses of Animals Exposed to Deployment of Various Passenger Inflatable Restraint System Concepts for a Variety of Collision Severities and Animal Positions, H.J. Mertz et al.

SAE826048—Interpretations of the Impact Responses of a Three-Year-Old Child Dummy Relative to Child Injury Potential, H.J. Mertz and D.A. Weber

SAE841656—A Biomechanical Analysis of Head, Neck, and Torso Injuries to Child Surrogates Due to Sudden Torso Acceleration, P. Prasad and R.P. Daniel

SAEPT-31—Passenger Car Inflatable Restraint Systems: a Compendium of Published Safety Research, D.C. Viano

SAE SP-736—Automatic Occupant Protection Systems

2.2.2 ISO PUBLICATIONS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ISO/TR 14645—Road vehicles—Test procedures for evaluating child restraint system interactions with deploying airbags

ISO/TR 10982—Road vehicles—Test procedures for evaluating out-of-position vehicle occupant interactions with deploying air bags

ISO 6487—Road vehicles—Measurement techniques in impact tests—Instrumentation

ISO/TR 14933—Road vehicles—Test procedures for evaluating occupant interactions with deploying side impact air bags

2.2.3 ECE PUBLICATION—Available from Swedish Road and Traffic Research Institute, S-581-95, Linköping, Sweden.

ECE Regulation44—Uniform Provisions Concerning the Approval of Restraining Devices for Child Occupants of Power-Driven Vehicles (“Child Restraint System”)

3. **Test Dummies**—Three sizes of child dummies (infant, 3-year-old, and 6-year-old) have been recommended for CRS/airbag investigations by the ISO (see ISO/TR 12349-2). For infant dummies, the ISO has recommended the CRABI 6, 12, and 18-month-old dummies and the TNO P 3/4 and P 1 1/2 dummies. FMVSS 208 prescribes testing only with the CRABI 12 month. For 3-year-old dummies, the ISO recommends using either the GM airbag dummy or the Hybrid III, 3-year-old dummy. FMVSS 208 prescribes testing only with the Hybrid III, 3-year-old dummy. For 6-year-old dummies, both the ISO and FMVSS 208 prescribe only the Hybrid III, 6-year old dummy. Complete descriptions of the CRABI 12 month and the Hybrid III, 3- and 6-year old dummies are given in 49 CFR 572 - Anthropomorphic Test Dummies. The GM air bag dummy is described in SAE 826040. For SAE J2189, the CRABI Infant and Hybrid III child dummies are prescribed.

4. **Test Dummy Measurements**—All dummy measurements should be recorded and filtered according to the latest version of SAE J211-1. These measurements should be continuous functions of time, so that other quantities referred to in the references may be derived.

#### 4.1 CRABI 6, 12, 18 Month

Head triaxial acceleration

Head angular acceleration in sagittal plane (1 channel)

Upper neck forces and moments (6 channels)

Lower neck forces and moments (6 channels)

Chest triaxial acceleration

Lumbar spine forces and moments (6 channels)

Pelvic triaxial acceleration

#### 4.2 Hybrid III 3-Year-Old

Head triaxial acceleration

Head angular acceleration in sagittal plane (1 channel)

Upper neck forces and moments (6 channels)

Lower neck forces and moments (5 channels)

Chest triaxial acceleration

Chest mid-sternum displacement (1 channel)

Sternal Ax Acceleration (2 channels)

Lumbar spine forces and moments (5 channels)

Pelvic triaxial acceleration

Pelvic submarining (4 channels)

#### 4.3 Hybrid III 6-Year-Old

Head triaxial acceleration  
 Head angular acceleration in sagittal plane (1 channel)  
 Upper neck forces and moments (6 channels)  
 Lower neck forces and moments (5 channels)  
 Chest triaxial acceleration  
 Chest mid-sternum displacement (1 channel)  
 Sternal Ax Acceleration (2 channels)  
 Lumbar spine forces and moments (5 channels)  
 Pelvic triaxial acceleration  
 Pelvic submarining (4 channels)  
 Femur forces and moments (6 channels)

5. **CRABI Fixture**—A schematic for a test fixture is shown in Figure 1. This fixture has been designed to simulate the geometry of a range of vehicle/airbag systems, in order to facilitate the evaluation of CRSs with deploying airbags. The fixture includes a simulated partial instrument panel and a partial vehicle bench seat. The seat moves longitudinally (from A-rear to A-forward), and the instrument panel (IP) moves vertically (from C-high to C-low), so that a wide range of geometric relationships can be accommodated. The range-of-motion limits reflected in Figure 1 are based on a manufacturer survey of April 1991. The seat back and bottom cushions pivot independently within 20 degree and 10 degree ranges, respectively. Although only the surface of the seat back and bottom cushions are shown in the schematic, the seating foam and depth (150 mm) specified in FMVSS 213 are recommended. The width of the partial bench may vary, but 900 mm is recommended in order to accommodate both a right and a center seat position. The vertical centerline of the IP should coincide with the centerline of the right seat position.

The cylindrical or similarly shaped IP, within which the passenger airbag module is mounted, rotates to simulate a range of airbag mounting locations and deployment angles. An opening is provided on the flat face of the IP through which the airbag deploys. It is expected that a supplementary mounting plate will be needed to accommodate the front brackets of the particular airbag module used. This plate would in turn be affixed to the flat face. Further structure within the IP will also be needed to mount each airbag module. A flat surface simulating a windshield pivots about an edge that is fixed with respect to the IP and thus moves up and down with the IP. A flat panel between the IP and the floor and a transparent partial side panel are also recommended to help contain the airbag during deployment.

Unless the particular configuration being studied has different requirements, lap belt anchorages, which move with the seat, should be located directly below point A, with the inboard anchor 400 mm from the outboard anchor. A shoulder belt anchor, if needed, should be located above the top right corner of and along the same line as the seatback.

6. **Test Temperature**—Normally, testing should be conducted within a temperature range of 20.6 to 22.2 °C (69 to 72°F). If it is desired to investigate CRS/airbag interactions outside this temperature range, the temperature of the dummy should still be maintained within the previous range.
7. **Static Tests**—Static tests may be used for preliminary evaluation of CRS/airbag interactions and to select configurations that appear to warrant further dynamic testing.

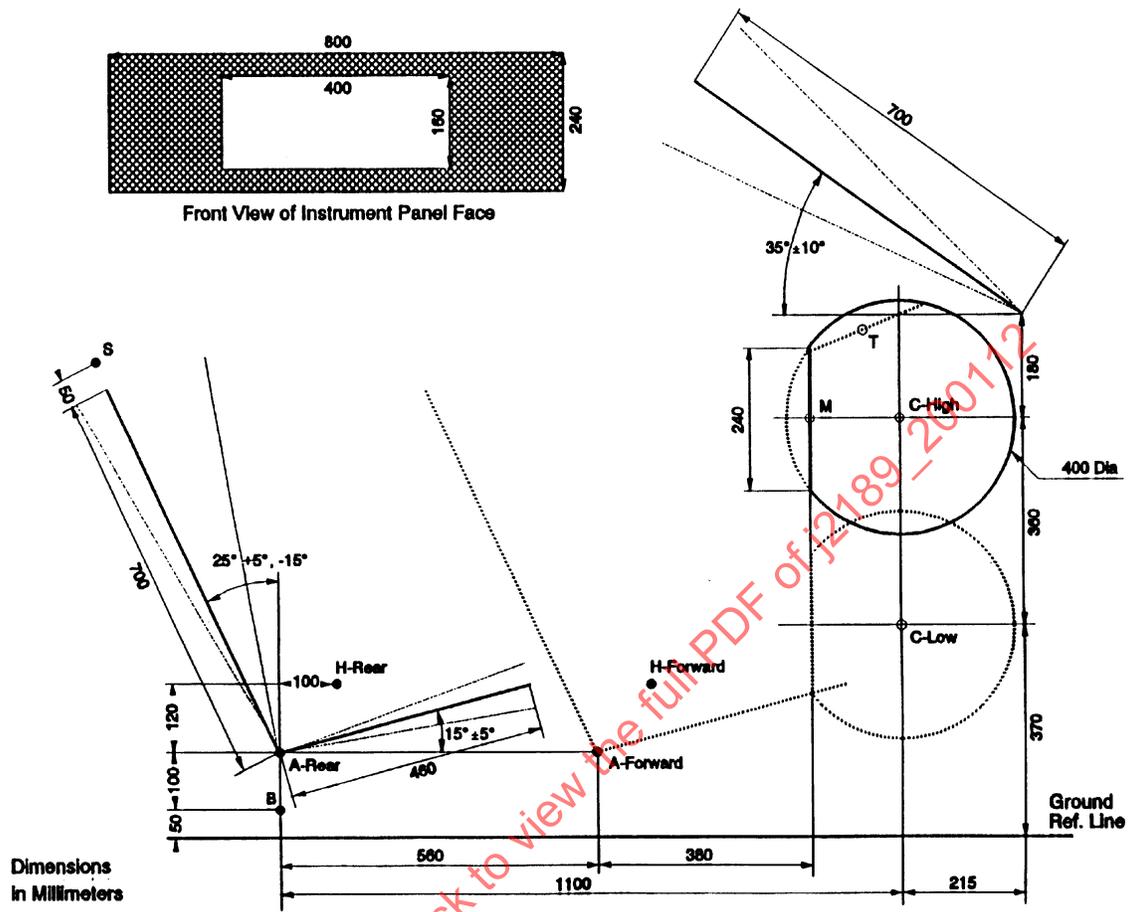


FIGURE 1—CRABI TEST FIXTURE

Definition of points in Figure 1:

- A—Intersection of back and bottom cushions
- B—Lap belt anchorage
- C—Center of instrument panel rotation
- H—Estimated H-point of fixture seat
- M—Center of airbag deployment at 0 degrees (mid-mount)
- S—Shoulder belt anchorage
- T—Center of airbag deployment at 70 degrees (top-mount)

- 7.1 Test Set-Up**—Using a vehicle, a vehicle buck, the CRABI Fixture (see Figure 1), or another fixture simulating a particular vehicle/airbag geometry, mount the airbag to the instrument panel, or simulation thereof, in a manner at least as rigid as an actual vehicle mount.

When using a vehicle buck or fixture, use all hardware that might affect how or in what direction the airbag is likely to deploy. Also use any surrounding hardware, such as the windshield or simulation thereof, that might affect the airbag's deployment direction, velocity, pattern of deployment, or shape. Mount the vehicle seat with the longest track available in its design position, so that it is in the same geometrical position relative to the airbag as in the actual vehicle.

For all test environments, move the seat to the position appropriate for the desired interaction under study. For example, full forward may produce the most severe interaction, while the full rear position may produce the least severe interaction, at least initially. Install and restrain the CRS and dummy according to the CRS manufacturer's instructions and vehicle owner's manual, if appropriate. CRS/dummy configurations are described in Section 9.

If the dummy and/or CRS is expected to move forward under dynamic conditions, forward repositioning may be advisable prior to airbag deployment. If so, hold the CRS/dummy in the desired position using one layer of paper masking tape. Loosening the belt and/or harness prior to forward repositioning may also be considered to more closely simulate dynamic positioning.

- 8. Dynamic Tests**—Dynamic tests, which better represent real-world crash conditions, may be conducted to further investigate CRS/airbag interactions or to compare the performance of a CRS with and without a deploying airbag.
- 8.1 Test Set-Up**—Use the same test set-up as in 7.1 for full-scale vehicle crash tests or for tests with a vehicle buck, the CRABI Fixture, or another fixture mounted on a sled, with the omission of the forward repositioning of the dummy and/or the CRS. Ensure that all surfaces are present that the CRS/dummy may contact during the impact, such as an instrument panel eyebrow or simulation thereof.
- 8.2 Generic Sled Pulses**—For sled tests, a mild-severity and a high-severity crash pulse are defined in this section. A vehicle-specific pulse may also be used as appropriate.
- 8.2.1 MILD-SEVERITY CRASH PULSE**—The mild-severity pulse is intended to be just severe enough to position the dummy and/or the CRS forward and to deploy the airbag. This pulse is a half-sine type with a 6.5 to 7 G nominal peak acceleration, a 26 km/h (16 mph) velocity change, and a 150 ms pulse duration. Typical acceleration-time and velocity-time curves are shown in Figures 2 and 3.
- 8.2.2 HIGH-SEVERITY CRASH PULSE**—The high-severity pulse is similar to that specified in FMVSS 213, with the intent that a single additional variable (the airbag) can be evaluated against known or baseline CRS performance. This pulse is a half-sine type with a 23 to 24 G nominal peak acceleration, a 48 km/h (30 mph) velocity change, and an 80 ms pulse duration. Typical acceleration-time and velocity-time curves are shown in Figures 4 and 5.
- 8.3 Simulation of Sensing Time**—For tests with an impact sled simulating a specific system, the interval between impact and airbag triggering should be similar to that of the specific system. When using one of the Generic Sled Pulses, an interval of 30 ms for the mild-severity pulse and 15 ms for the high-severity pulse are suggested, but the interval should be tuned to the particular airbag sensor system used.

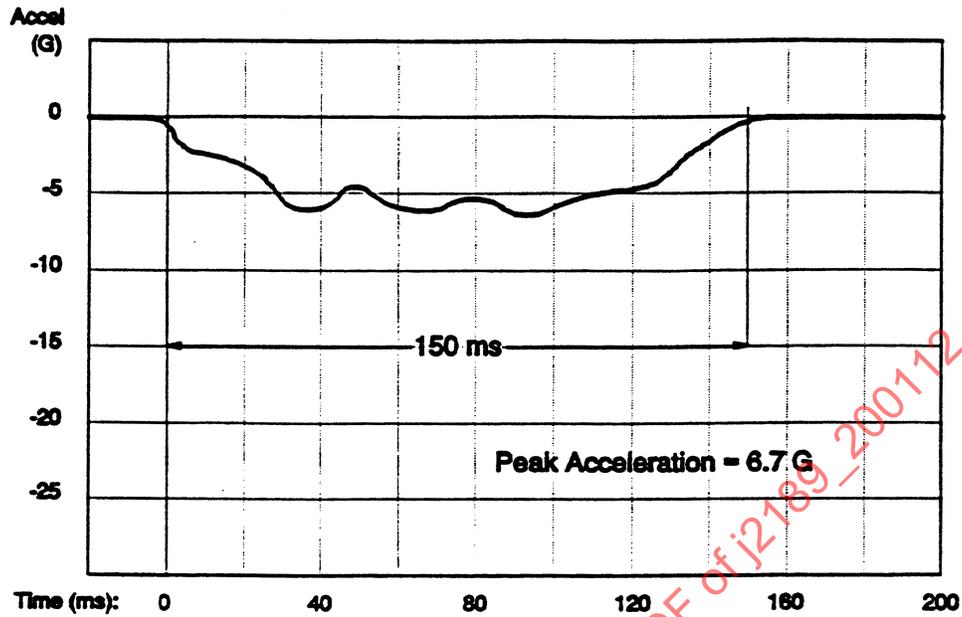


FIGURE 2—GENERIC HYGESLED PULSE FOR A MILD CRASH SEVERITY

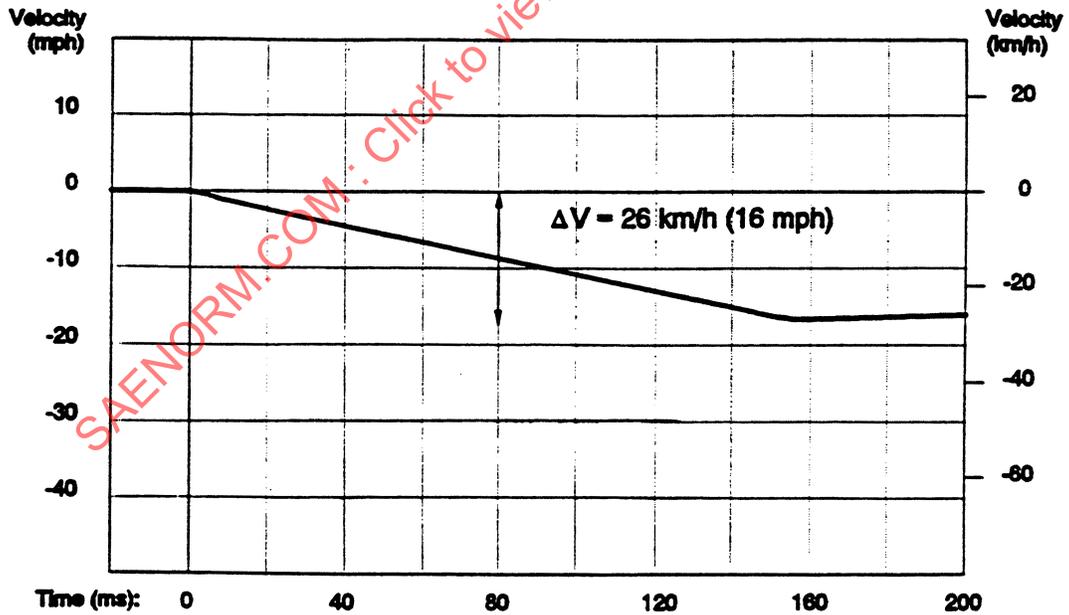


FIGURE 3—VELOCITY-TIME HISTORY OF THE GENERIC MILD-CRASH SEVERITY SLED PULSE

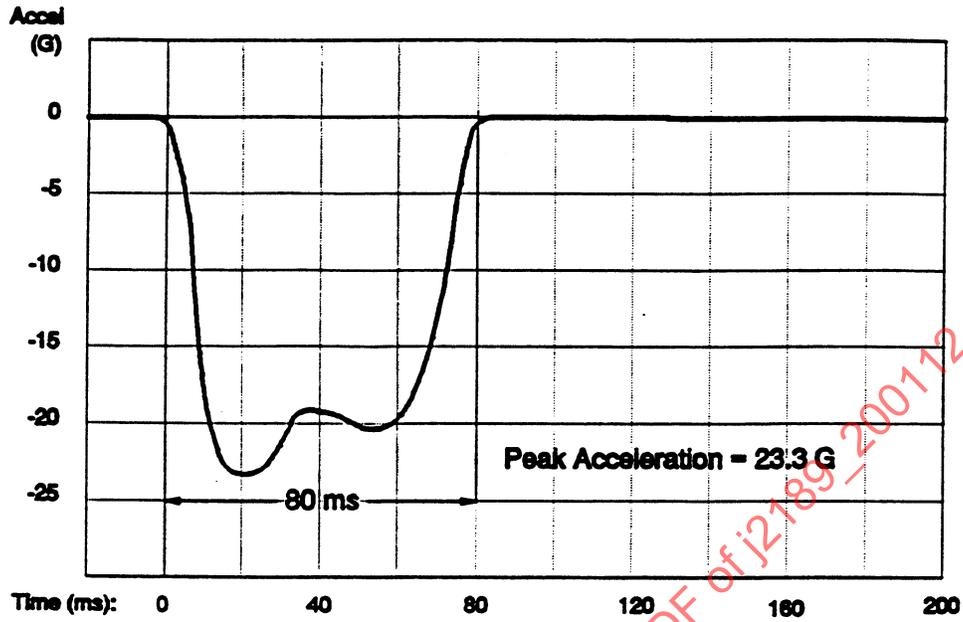


FIGURE 4—GENERIC HYGE SLED PULSE FOR A HIGH CRASH SEVERITY

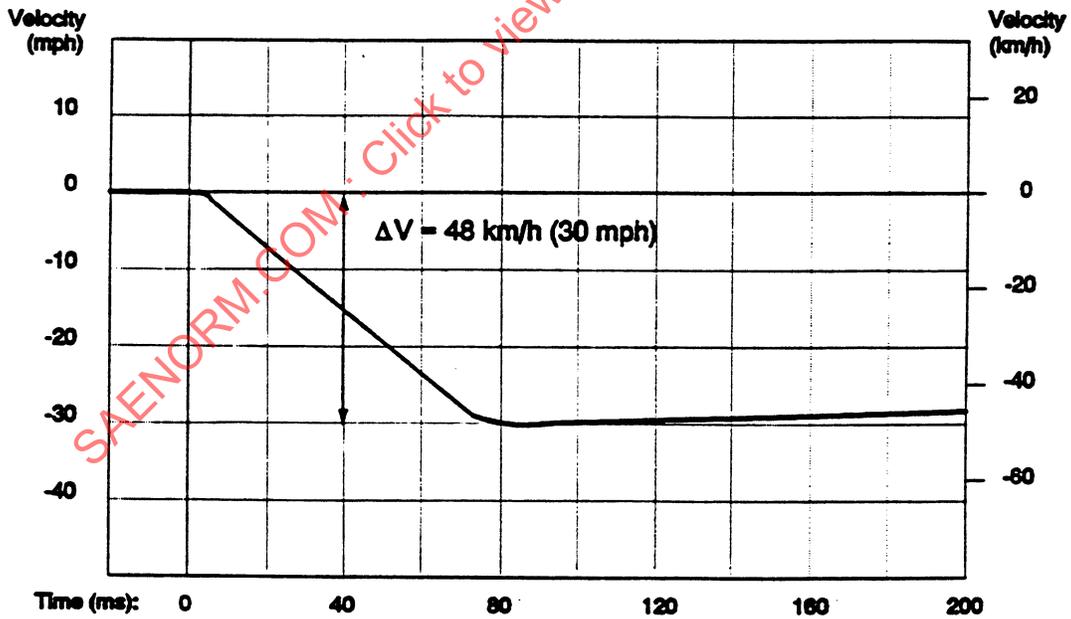


FIGURE 5—VELOCITY-TIME HISTORY OF THE GENERIC HIGH CRASH SEVERITY SLED PULSE

9. **CRS Configurations and Dummy Combinations**—Configurations of child restraint systems (CRS) and suitable dummy sizes are described in this section. Boosters, which are primarily belt-positioning and adapting devices rather than actual restraint systems, are treated separately. Some of the types of CRSs and boosters currently available in the U.S. are described in more detail by Weber (see References).

9.1 **Rear-Facing CRSs**—These are CRSs that position the child to face the rear of the vehicle. See Figure 6. They are usually used for children up to 9 months old. The CRABI 12 month would be the appropriate dummy for these CRSs. In Europe, there are rear-facing CRSs for children up to 3 years old. See Figure 7. For these CRSs, the CRABI 6, 12, and 18 month and the Hybrid III 3-year-old can be used to evaluate the airbag interactions. See Figure 7.

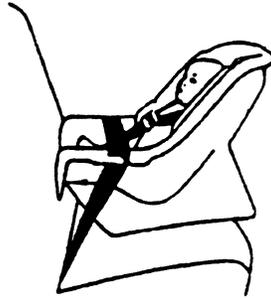


FIGURE 6—A REARWARD FACING CRS FOR CHILDREN UP TO 9 MONTHS OLD



FIGURE 7—REARWARD FACING CRS USED IN EUROPE FOR CHILDREN UP TO 3 YEARS OLD

9.2 **Laterally Positioned CRSs**—These are CRSs that position the prone or supine child perpendicular to the direction of vehicle travel. This type of CRS is used for children up to 9 months. Use the CRABI 6 month for evaluation of these CRSs. See Figure 8.

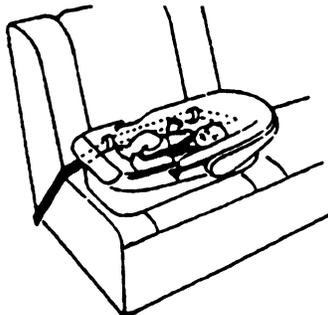


FIGURE 8—A LATERALLY POSITIONED CRS

**9.3 Forward-Facing CRSs**—These are CRSs that position the child to face the front of the vehicle. See Figure 9. Use the Hybrid III 3-Year-old to evaluate these CRSs.

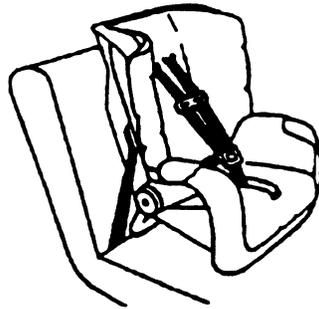


FIGURE 9—A FORWARD FACING CRS

**9.4 Boosters**—There are two different types of boosters, which are normally used with different types of belt systems, and which are associated with very different child occupant kinematics.

**9.4.1 SHIELD BOOSTER**—Anchored with a lap belt only across the front of the shield or through the base of the booster. The shoulder belt may follow the path of the lap belt or be routed behind the dummy. (Routing the shoulder belt across the dummy's chest is not recommended for this configuration.) Use with a 3-Year or 6-Year dummy. See Figure 10.



FIGURE 10—SHIELD BOOSTER

**9.4.2 BELT-POSITIONING BOOSTER**—Anchored along with the dummy with a lap and shoulder belt, using normal belt placement with the aid of belt-positioning guides. May have a high back-support structure with additional shoulder belt guides. Use with a 3-Year or 6-Year dummy. See Figure 11.



FIGURE 11—BELT-POSITIONING BOOSTER