Hybrid III Family Chest Potentiometer Calibration Procedure

RATIONALE

SAE J2517 has been revised to replace references to Engineering Aids 25 and 26 with references to SAE J2860 and SAE J2862 where applicable. Also added references to SAE J2858.

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1. SCOPE AND PURPOSE

This procedure establishes a recommended practice for establishing the sensitivity of the chest displacement potentiometer assembly used in the Hybrid III family of Anthropomorphic Test Devices (ATDs, or crash dummies). This potentiometer assembly is used in the Hybrid III family to measure the linear displacement of the sternum relative to the spine (referred to as chest compression). An inherent nonlinearity exists in this measurement because a rotary potentiometer is being used to measure a generally linear displacement. As the chest cavity is compressed the potentiometer rotates, however the relationship between the compression and the potentiometer rotation (and voltage output) is nonlinear.

Crash testing facilities have in the past used a variety of techniques to calibrate the chest potentiometer, that is to establish a sensitivity value (mm/(volt/volt) or mm/(mvolt/volt)). These sensitivity values are used to convert recorded voltage measurements to engineering units, in this case chest compression in mm. Some of these techniques intended to correct for the nonlinearity and others did not. Of those that did correct for the nonlinearity, there was a variation in techniques used. This variation in calibration procedures was in part identified by the SAE Dummy Testing Equipment Committee (DTEC) and led to overall variability in chest compression measurements between laboratories.

The intent of this recommended practice is to minimize the variations in chest deflection measurements between crash testing laboratories. Before this procedure was written, a round robin showed variations for the Small Female of 10% among eight labs for the chest pot sensitivity value. A follow-up round robin of this procedure showed a worst case variation of 2.7% among 10 labs, with a standard deviation of 0.9%. The initial version of SAE J2517 released in May 2000 attempted to fix this problem by recommending a two-point calibration which was not intended to correct for the nonlinearity (which, for example, is as large as 3% for the Small Female but is small near the peak). It also did not require the measurement of a starting position of the potentiometer before each crash test, thus it did not correct for the difference in starting chest geometry between a subject dummy and its design intent. It was intended to be a simple and reproducible calibration procedure which crash test facilities could easily adopt with little or no modifications to their facilities. In practice, most laboratories did not adopt the procedure since it did not correct for the nonlinearities.

Recent attempts to reduce dummy-to-dummy and lab-to-lab variations at lower deflection levels (around 25 mm) have renewed interest in adopting a calibration procedure to correct for the nonlinearity of the measurement system. This current revision of this procedure uses a multipoint calibration with a third order regression to correct for the nonlinearities of the system with a standardized method. It requires changes in the calibration method of the transducer, the data collection procedures when used in a dummy, and the processing procedures after test data is collected. Following this standardized methodology will minimize linearity errors as well as lab-to-lab variations.

2. REFERENCES

2.1   Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1   SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

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

SAE J2570   Performance Specifications for Anthropomorphic Test Device Transducers

SAE J2706   Hybrid III Six-Year-Old Child Dummy User's Manual

SAE J2856   User's Manual for the 50th Percentile Male Hybrid III Test Dummy

SAE J2857   Hybrid III 3-Year-Old Child Dummy User's Manual

SAE J2858   Hybrid III Ten-Year-Old Child Dummy User's Manual

SAE J2860   User's Manual for the Large Male Hybrid III Test Dummy

SAE J2862   User's Manual for the Small Adult Female Hybrid III Test Dummy

2.2   Related Publication

The following publication is provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1   Federal Publication

Available from the Superintendent of Documents, U.S. Government Printing Office, Mail Stop: SSOP, Washington, DC 20402-9320.

Federal Safety Standards, Motor Vehicle Regulation No. 572, Test Dummies Specifications - Anthropomorphic Test Dummy for Applicable Test Procedures
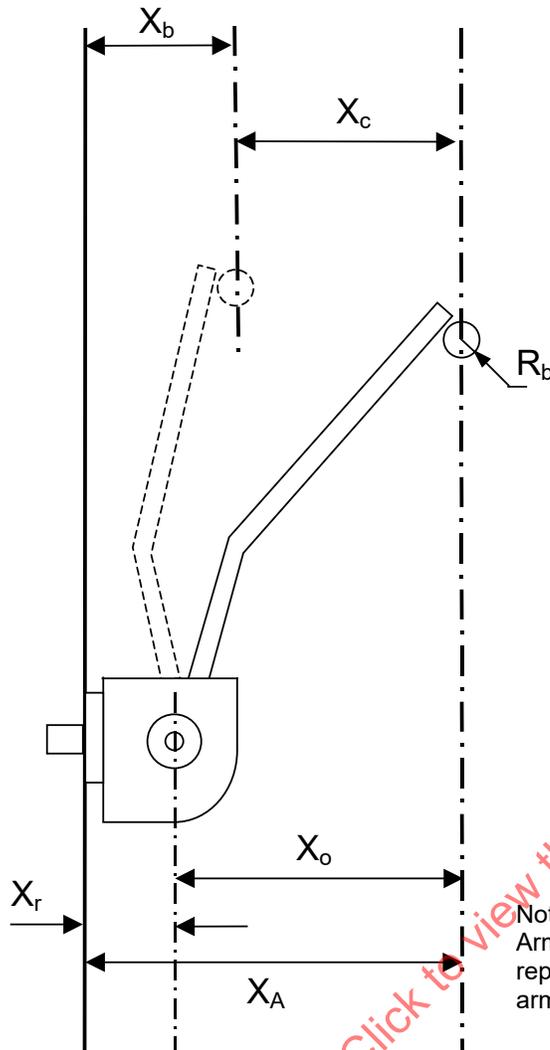
3.   CALIBRATION PROCEDURE
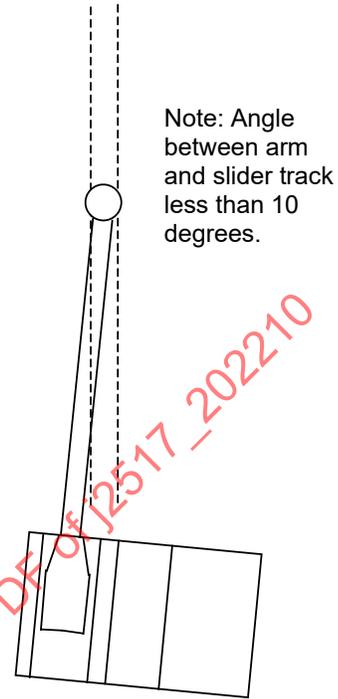
3.1   Chest Potentiometer Assembly

The chest potentiometer assembly consists of the potentiometer, potentiometer bracket, arm connector, and arm. These components will be treated as an assembly during the calibration process. The assembly should be removed from the dummy as described in SAE J2856, J2706, J2857, J2858, J2860, and J2862. Next it should be placed in a fixture as described in 3.2, calibrated as described in 3.3, and replaced in the dummy. There should be no mechanical adjustments or disassembly of the potentiometer assembly once the calibration is completed. Any adjustments to the assembly would require re-calibration.

3.2   Calibration Fixture

The potentiometer assembly is placed in a calibration fixture that duplicates the nominal design position of arm, which is referenced as X_o in Figure 1. (This starting position represents the design position of the uncompressed chest.) The fixture should also be capable of stroking the arm relative to the potentiometer a distance of X_c as listed in Table 2. (This represents a position of the sternum when the chest is compressed.) The fixture does not need to be of a specific design, it simply needs to duplicate the position of the potentiometer at the points referenced in Table 2. As shown in Figure 2, the rotational position of the arm assembly about the longitudinal (fore-aft in dummy) axis is not critical. The potentiometer can either be installed in the fixture with the arm parallel to the slider track, or at a slight angle as installed in the dummy. (This angle between the slider track and arm should be less than 10 degrees, however.)

X_b

X_c

R_b

Note: Angle between arm and slider track less than 10 degrees.

X_o

X_r

Note: Drawing not to scale. Arm shape shown represents adult dummy arm.

X_A

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Figure 1 - Calibration fixture side view

Figure 2 - Calibration fixture front view

NOTE: The dimensions given are to the center of the ball. If a fixture is used that goes to the edge of the ball, the ball radius R_b must be added to X_a to get the starting position.

Table 1 - Calibration setup dimensions

Dummy Type	Initial Position X_o, (mm)	Reference Dimension X_a (mm)	Reference Dimension X_b (mm)	Reference Dimension X_r (mm)	Ball Radius R_b (mm)
3 year old Hybrid III	40	50	15	10	3.2
6 year old Hybrid III	44	54	12	10	3.2
10 year old Hybrid III	62	72	26	10	3.2
Small female Hybrid III	67	81	27	14	4.8
50th percentile male Hybrid III	70	84	16	14	4.8
Large adult male Hybrid III	94	108	37	14	4.8

Table 2 - Calibration points

Dummy Type	Calibration Points, X_c (mm)
3 year old Hybrid III	-6, -3, 0, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, 36, 39
6 year old Hybrid III	-8, -4, 0, 4, 8, 12, 16, 20, 24, 28, 32, 36, 40, 44, 48
10 year old Hybrid III	-8, -4, 0, 4, 8, 12, 16, 20, 24, 28, 32, 36, 40, 42, 46, 50
Small Female Hybrid III	-10, -5, 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55,60
50th percentile male Hybrid III	-10, -5, 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75
Large adult male Hybrid III	-10, -5, 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80

3.3   Calibration Procedure

At the initial position, X_o, loosen the set screw locking the pot shaft to the arm coupling and adjust the pot so that the output reading is 0.0 V (±2.5 mV/V). Tighten the set screw to lock the pot shaft to the coupling and recheck the V_o output level.

Set the fixture to each of the calibration points, X_c, shown in Table 2 within ±0.25 mm. Take a sensor output reading (S) at each of the Displacements (D) for the X_c calibration points listed in Table 2. Record the actual displacement values (D) in mm and the sensor output readings (S) in mV/V.

Complete a third order regression through the calibration data to relate the sensor output readings S (mV/V) to the displacement values D (mm) according to the following equation:

$$D = A*S^3 + B*S^2 + C*S + M \qquad \text{(Eq. 1)}$$

where:

D = actual displacement in mm

S = sensor output reading in mV/V

A, B, C, and M = calibration coefficients

From the regression analyses determine values for A, B, C, and M. These are the calibration coefficients that will be stored for the sensor and used to convert test data to engineering units. A sample of a calibration dataset is located in Appendix A of this procedure.