

Performance Specifications for Anthropomorphic Test Device Transducers

1. **Scope**—This SAE Information Report defines the minimum performance specifications for accelerometers, load cells, and angular position transducers used within Anthropomorphic Test Devices (ATDs) when performing impact tests per SAE J211, "Instrumentation for Impact Test". This report does not define methodology and equipment for performing verification tests of the transducers. It is intended that any agency proposing to conduct tests in accordance with SAE J211 should be able to demonstrate that the transducers they use would meet the performance requirements specified in this information report.
 - 1.1 **Purpose**—The purpose of this information report is to provide guidelines for choosing accelerometers, load cells, and angular position transducers for use in impact testing. The aim is to provide uniformity in transducer measurements, and provide a basis for meaningful comparisons of test results from different sources.
 - 1.2 **Field of Application**—The transducer specifications defined in this information report apply in particular to those transducers used within ATDs, and whose outputs are used to calculate various injury estimates. The transducer specifications also apply to sensors used for the calibration of ATDs.
2. **References**
 - 2.1 **Applicable Publications**—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, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J211-1—Instrumentation for Impact Test—Part 1: Electronic Instrumentation
SAE J1733—Sign Convention for Vehicle Crash Testing
 - 2.1.2 **NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION (NHTSA) PUBLICATIONS**—Available from NHTSA, web site: www.nhtsa.dot.gov.

Code of Federal Regulations, Title 49, part 572 (CFR part 572)
NHTSA Docket, Notice of Proposed Rule Making (Proposed Amendments to CFR part 572).
 - 2.1.3 **MILITARY SPECIFICATIONS**—Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robins Avenue, Philadelphia, PA 19111-5094.

MIL-PRF-39023B (1 February 1999)—General Specification for Precision Nonwire-wound Resistors
MIL-STD 45662A (1 August 1988)—Calibration System Requirements

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2.1.4 ANSI STANDARDS—Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002.

ANSI/NCSL Z540-1-1994—Calibration Laboratories and Measuring and Test Equipment – General Requirements

3. Definitions

3.1 Load Cell Definitions

- 3.1.1 CHANNEL FREQUENCY CLASS (CFC)—The channel frequency class is designated by a number indicating that the channel frequency response lies within limits specified by Figure 1 of SAE J211-1 (this must be defined to calculate free air resonance).
- 3.1.2 COMPENSATED TEMPERATURE RANGE—The range of temperature over which the transducer is compensated to maintain output and zero balance within specified limits ($20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$).
- 3.1.3 CROSSTALK—Effect on the reading of an unloaded transducer axis when a load equal to the full-scale capacity of a secondary axis is applied to that secondary axis. Expressed as a percentage of full-scale capacity of the unloaded axis.
- 3.1.4 DEFLECTION AT FULL SCALE APPLIED LOAD—Maximum linear deflection of a load cell in the direction of the applied full scale load for that axis.
- 3.1.5 DEFLECTION AT FULL SCALE APPLIED MOMENT—Maximum angular deflection of a load cell in the direction of the applied full scale moment for that axis.
- 3.1.6 FREE AIR RESONANCE—The frequency at which a transducer resonates, when suspended freely in air by a single wire and impacted with a hard surfaced body. This test shall be done while monitoring the channel output to insure each channel's fundamental output frequency shall be equal to or greater than the specified frequency.
- 3.1.7 FULL SCALE CAPACITY—Full scale capacity refers to the capacity defined in CFR part 572. This must be defined for calculating other parameters in these specifications.
- 3.1.8 HYSTERESIS (% OF FULL SCALE CAPACITY)—The maximum deviation between ascending and descending output readings taken at the same load point, expressed as a percentage of full scale capacity. Refer to Figure 1 for graphical representation.
- 3.1.9 NON-LINEARITY (% OF FULL SCALE CAPACITY)—The maximum deviation of a transducer output reading from the terminal line, expressed as a percentage of full scale capacity (the terminal line is defined as a straight line connecting a transducer zero load reading and its full scale reading). Refer to Figure 1 for graphical representation.
- 3.1.10 TEMPERATURE EFFECTS ON OUTPUT—The change in output due to a change in transducer temperature, expressed as a percentage of reading per degree Celsius change. Refer to Figure 1 for graphical representation.
- 3.1.11 TEMPERATURE EFFECTS ON ZERO BALANCE—The change in zero balance due to a change in transducer temperature, expressed as a percentage of full scale capacity per degree Celsius change. Refer to Figure 1 for graphical representation.
- 3.1.12 TERMINAL LINE—A theoretical straight line connecting a transducer zero load reading and its full scale reading. Refer to Figure 1 for graphical representation.

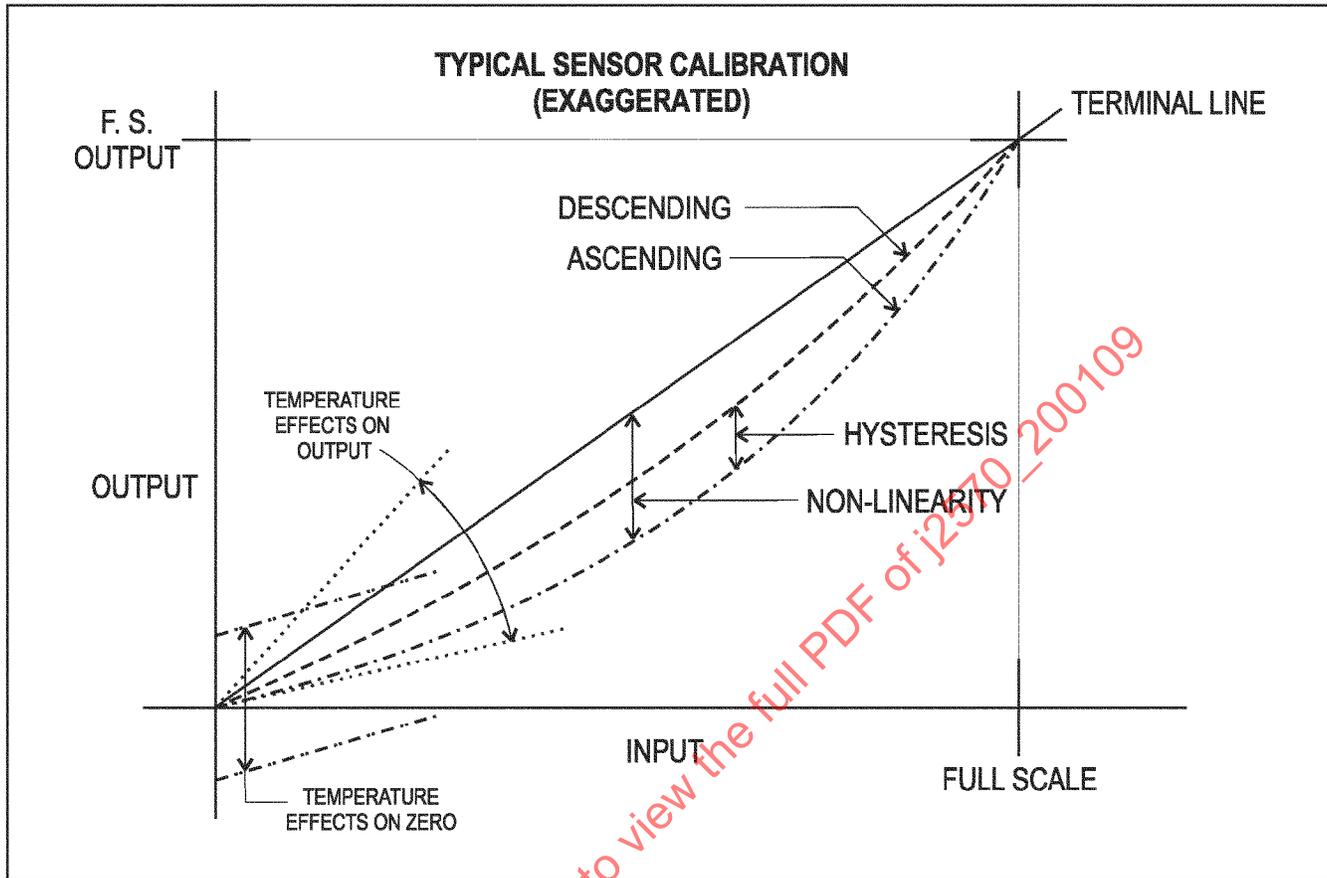


FIGURE 1—TYPICAL SENSOR CALIBRATION CURVES

3.2 Accelerometer Definitions

- 3.2.1 **COMPENSATED TEMPERATURE RANGE**—The range of temperature over which the transducer is compensated to maintain output and zero balance within specified limits ($20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$).
- 3.2.2 **DAMPING RATIO**—The ratio of a transducer output vs. input when excited by a sinusoidal input near the point of resonance. A reasonably accurate calculation for damping ratio is a ratio of measured sensitivity at near DC versus 2 times the measured sensitivity at resonance. This assumes that resonance is defined at the 90-degree phase shift point.
- 3.2.3 **FREQUENCY RESPONSE**—The range of frequencies over which the transducer output voltage (sensitivity) will follow the sinusoidally varying mechanical input within specified limits. The difference in sensitivity at any frequency relative to the sensitivity at 100 Hz is specified as a percentage of the sensitivity measured at 100Hz.
- 3.2.4 **FULL SCALE RANGE**—Full scale range as is listed in CFR part 572, or in the appropriate NPRM. This must be defined for calculating other parameters in these specifications.
- 3.2.5 **NON-LINEARITY (% OF READING)**—The maximum deviation of a transducer output reading from the terminal line, expressed as a percentage of full scale range (the terminal line is defined as a straight line connecting a transducer zero load reading and its full scale reading). Refer to Figure 1 for graphical representation.

- 3.2.6 RESONANT FREQUENCY—The resonant frequency is the frequency at which the voltage output (sensitivity) of an accelerometer lags the mechanical input by a phase angle of 90 degrees. For undamped accelerometers it may alternately be defined as the frequency at which the response (sensitivity) of an accelerometer is at its maximum output.
- 3.2.7 TEMPERATURE EFFECTS ON OUTPUT—The change in output due to a change in transducer temperature, expressed as a percentage of reading per degree Celsius change. Refer to Figure 1 for graphical representation.
- 3.2.8 TEMPERATURE EFFECTS ON ZERO BALANCE—The change in zero balance due to a change in transducer temperature, expressed as a percentage of full scale range per degree Celsius change. Refer to Figure 1 for graphical representation.
- 3.2.9 TERMINAL LINE—A theoretical straight line connecting a transducer's zero load reading and its full scale reading. Refer to Figure 1 for graphical representation.
- 3.2.10 TRANSVERSE SENSITIVITY—The output of the sensitive axis due to any acceleration applied orthogonally to that axis, specified as a percentage of applied acceleration.
- 3.2.11 ZERO REPEATABILITY—When any shock pulse is applied in the primary direction and within the specified range of an accelerometer, the zero output should return to its initial value.

3.3 Angular Displacement Transducer Definitions

- 3.3.1 COMPENSATED TEMPERATURE RANGE—The range of temperature over which the transducer is compensated to maintain rated output and zero balance within specified limits.
- 3.3.2 MINIMUM ELECTRICAL ANGLE—The specified shaft travel over which the functional characteristic extends between defined output ratio limits, as determined from the index point.
- 3.3.3 MINIMUM ROTATIONAL SPEED—The minimum rotational speed at which the transducer must operate while maintaining its specified performance.
- 3.3.4 NON-LINEARITY—The maximum deviation, expressed in degrees, of the actual functional characteristic from a fully defined straight reference line.
- 3.3.5 OUTPUT SMOOTHNESS—A measurement of any spurious variation in the electrical output that is not present in the input, expressed in degrees.
- 3.3.6 SHAFT END PLAY—The total axial excursion of the shaft, measured at the end of the shaft with a specified axial load supplied alternately in opposite directions, expressed in inches.
- 3.3.7 SHAFT RADIAL PLAY—The total radial excursion of the shaft, measured at a specified distance from the front surface of the unit, expressed in inches. A specified radial load is applied alternately in opposite directions at a specific point.
- 3.3.8 SHAFT RUN-OUT—The eccentricity of the shaft diameter with respect to the rotational axis of the shaft, measured at a specified distance from the end of the shaft, with a specified radial load applied to the shaft.
- 3.3.9 SHOCK DISCONTINUITY—The maximum period of time that the transducer may experience any electrical output discontinuity caused by subjecting the transducer to a 100 g, half sine pulse of 11 ms duration in any direction.

- 3.3.10 STARTING/RUNNING TORQUE—The maximum moment in the clockwise and counterclockwise directions required to initiate or maintain shaft rotation anywhere in the total mechanical travel of the transducer.
- 3.3.11 TERMINAL LINE—A theoretical straight line connecting a transducer zero load reading and its full scale reading. Refer to Figure 1 for graphical representation.
- 3.3.12 TEMPERATURE EFFECTS ON OUTPUT—The change in output due to a change in transducer temperature, expressed as a percentage of reading per degree Celsius change.
- 3.3.13 TEMPERATURE EFFECTS WITH NO ROTATION—The change in output with no rotation due to a change in transducer temperature, expressed in degrees.

4. Performance Specifications

4.1 Load Cell Performance Specifications

- 4.1.1 CROSSTALK (ABSOLUTE VALUE)— $\leq 5.0\%$
- 4.1.2 COMPENSATED TEMPERATURE RANGE— $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$
- 4.1.3 DIMENSIONS AND MECHANICAL CONFIGURATION—Refer to CFR part 572 or NHTSA Docket. If not defined by CFR part 572 or NHTSA Docket, then user defined.
- 4.1.4 FREE AIR RESONANCE—Free air resonance must be at least 5 times the amount of the Channel Filter Class (CFC) in CFR part 572. If not defined by CFR part 572, refer to the CFC as defined by SAE J211.

EXAMPLE—For Femur Force Measurements, CFR part 572 defines the Channel Filter Class (CFC) as Class 600. Therefore, free air resonance for the Femur Load Cell must be at least (5)* (600) or 3000 Hz.
- 4.1.5 FULL SCALE RANGE—Refer to CFR part 572 or NHTSA Docket. If not defined by CFR part 572 or NHTSA Docket, then user defined.
- 4.1.6 HYSTERESIS (% OF FULL SCALE CAPACITY [ABSOLUTE VALUE])— $\leq 1.0\%$
- 4.1.7 MAXIMUM DEFLECTION AT FULL SCALE APPLIED LOAD— $\leq 0.254\text{ mm}$
- 4.1.8 MAXIMUM ROTATION AT FULL SCALE APPLIED MOMENT— $\leq 0.5\text{ degrees}$
- 4.1.9 NON-LINEARITY (% OF FULL SCALE CAPACITY [ABSOLUTE VALUE])— $\leq 1.0\%$
- 4.1.10 REGULATED OR PROPOSED APPLICATION—Refer to CFR part 572 or NHTSA Docket.
- 4.1.11 TEMPERATURE EFFECTS ON OUTPUT (% READING [ABSOLUTE VALUE])— $\leq 0.05\%$ of Reading per $^{\circ}\text{C}$
- 4.1.12 TEMPERATURE EFFECTS ON ZERO BALANCE (% FULL SCALE CAPACITY [ABSOLUTE VALUE])— $\leq 0.05\%$ of Full Scale per $^{\circ}\text{C}$

NOTE 1—If a testing lab uses or a manufacturer builds a device that requires an adapter to correctly position or mount the transducer (to comply with CFR part 572), all specifications must be met with the adapter attached to the transducer.

4.2 Accelerometer Performance Specifications

- 4.2.1 COMPENSATED TEMPERATURE RANGE— $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$
- 4.2.2 DAMPING RATIO— ≤ 0.05
- 4.2.3 DIMENSIONS AND MECHANICAL CONFIGURATION—Refer to CFR part 572 or NHTSA Docket. If not defined by CFR part 572 or NHTSA Docket, then user defined.
- 4.2.4 FREQUENCY RESPONSE—0 to 2kHz $\pm 2.5\%$, and 0 to 4kHz $\pm 4\%$
- 4.2.5 NON-LINEARITY (% OF READING [ABSOLUTE VALUE])— $\leq 1.0\%$
- 4.2.6 REGULATED OR PROPOSED APPLICATION—Refer to CFR part 572 or NHTSA Docket.
- 4.2.7 RESONANT FREQUENCY— $\geq 20\text{ kHz}$
- 4.2.8 SEISMIC MASS LOCATION—Refer to CFR part 572 or NHTSA Docket. If not defined by CFR part 572 or NHTSA Docket, then user defined.
- 4.2.9 TEMPERATURE EFFECTS ON OUTPUT (ABSOLUTE VALUE)— $\leq 0.1\%$ Reading per $^{\circ}\text{C}$
- 4.2.10 TEMPERATURE EFFECTS ON ZERO BALANCE (ABSOLUTE VALUE)— $\leq 0.25\%$ Full-Scale per $^{\circ}\text{C}$
- 4.2.11 TRANSVERSE SENSITIVITY (ABSOLUTE VALUE)— $\leq 1.0\%$
- 4.2.12 ZERO REPEATABILITY (ABSOLUTE VALUE)— $\leq 0.2\text{ g}$

NOTE 1—If a testing lab uses or a manufacturer builds a device that requires an adapter to correctly position or mount the transducer (to comply with CFR part 572), all specifications must be met with the adapter attached to the transducer.

NOTE 2—With no change in the temperature environment and a warm up time of 2 min, output should be stable within $\pm 0.2\text{ g}$.

4.3 Angular Displacement Transducer Specifications

- 4.3.1 COMPENSATED TEMPERATURE RANGE— $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$
- 4.3.2 DIMENSIONS AND MECHANICAL CONFIGURATION—Refer to CFR part 572 or NHTSA Docket. If not defined by CFR part 572 or NHTSA Docket, then user defined.
- 4.3.3 ELECTRICAL ANGLE (FOR CHEST MEASUREMENTS; OTHERWISE, AS DEFINED BY APPLICATION)— $>45\text{ degrees}$
- 4.3.4 ROTATIONAL SPEED— $\geq 9600\text{ degrees per second}$
- 4.3.5 NON-LINEARITY (ABSOLUTE VALUE)— $\leq 0.5\text{ degrees}$
- 4.3.6 OUTPUT SMOOTHNESS (ABSOLUTE VALUE)— $\leq 0.25\text{ degrees}$
- 4.3.7 REGULATED OR PROPOSED APPLICATION—Refer to CFR part 572 or NHTSA Docket.
- 4.3.8 SHOCK DISCONTINUITY (100 G HALF SINE PULSE FOR MINIMUM OF 11 MS)— $\leq 100\text{ }\mu\text{s}$