



Transducer Calibration Verification Master Test Procedure

1 Scope

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. To provide guidelines for verifying calibration of the equipment used in noise and vibration procedures.

1.2 Foreword. Calibration verification is the process of determining the ratio of a measurable quantity (voltage) and the phenomenon it is proportional to (acceleration, force, etc.) and verifying that it is within 10% (6% for microphones) of the documented transducer calibration constant. Regularly verifying calibration of transducers increases confidence in measurement quality.

1.3 Applicability. This test procedure is appropriate for verifying calibration of the following equipment: accelerometers, microphones, intensity probes, force transducers, impact hammers, and static force rings.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

ANSI S1.11 IEC 225

2.2 GM Standards/Specifications.

None

3 Resources

3.1 Facilities. All facilities shall be free of extraneous noise and vibration sources as well as electrical noise (example: 60 Hz electromagnetic interference in the U.S.). In addition, the facility requirements that apply to the referring procedures also apply.

3.2 Equipment.

3.2.1 Test Equipment.

3.2.1.1 Data Acquisition System. A frequency domain (Fast Fourier Transform or real time filter based) capable acquisition system shall be used. The intensity probe calibration verification portion requires software that can calculate intensity from a two microphone probe. The static force calibration verification method only requires the use of a multimeter to read the output voltage of the transducer. Appendix A contains more details regarding acquisition system requirements.

3.2.1.2 Accelerometer.

3.2.1.2.1 Calibrated Standard Accelerometer. A calibrated standard accelerometer is used as a comparison to verify the calibration of the field accelerometer. The standard accelerometer shall have a current calibration date.

3.2.1.2.2 Electromagnetic/Hydraulic Shaker. A shaker is used in conjunction with a calibrated standard accelerometer in the comparison ratio calibration verification technique. The shaker shall be capable of exciting the transducer within the operating range required by the referencing procedure.

3.2.1.2.3 Elastic Cord with Fixture. An elastic cord fixed at both ends is used in the drop calibration verification technique.

3.2.1.2.4 Accelerometer Calibrator. A mechanical accelerometer calibrator that provides a precisely defined vibration level, using the data acquisition system, a calibration ratio in volts per engineering unit (or engineering units per volt) can be verified. The calibrator shall have a current calibration date.

3.2.1.3 Microphone/Intensity Probe.

3.2.1.3.1 Microphone Calibrator. A mechanical microphone calibrator/piston phone that provides a precisely defined sound pressure level to which, using the data acquisition system, a calibration factor in engineering units per volt can be verified, such as a sound level calibrator or a piston phone. The calibrator shall have a current calibration date.

Note: Intensity probe calibration verification requires a 250 Hz piston phone.

3.2.1.3.2 Intensity Probe Calibration Chamber. A calibration chamber is used in conjunction with a

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piston phone in the intensity probe calibration verification technique. The calibration chamber shall be compatible with the acquisition system, intensity probe and piston phone. Appropriate attachments such as dummy microphones are also required.

3.2.1.4 Force Transducer/Impact Hammer.

3.2.1.4.1 Calibration Mass. A known mass is used in conjunction with a calibrated accelerometer in the force ratio calibration verification technique. The mass shall be appropriately sized to allow the force transducer/impact hammer to operate within the range required by the referencing procedure.

3.2.1.4.2 Electromagnetic/Hydraulic Shaker. A shaker is used to excite the known mass, mounted force transducer, and accelerometer for the ratio calibration verification technique. The shaker shall be capable of exciting the transducer within the operating range required by the referencing procedure.

3.2.1.5 Static Force Rings.

3.2.1.5.1 Certified Mass Set. A set of known certified masses and attachment hardware for loading the force transducer from 0 N to 500 N in a minimum of two increments.

3.3 Test Vehicle/Test Piece. Not applicable.

3.4 Test Time. Variable (depending on Transducer).

Calendar time: variable days

Test hours: variable hours

Coordination hours: variable hours

3.5 Test Required Information. Calibration verification shall be performed immediately prior to a measurement session. Exceptions may be specified by the referencing procedure.

Note: It is also good measurement practice to verify calibration of the equipment immediately following a measurement session.

Note: The transducer manufacturer or outside test lab supplied calibration values may be implemented as the primary source of calibration values as specified by the referencing procedure.

3.6 Personnel/Skills. At least one technician or engineer skilled in noise and vibration data acquisition, analysis, equipment use, and test setup is required.

4 Procedure

4.1 Preparation.

4.1.1 Boundary Conditions.

4.1.1.1 Free-Free Mounting. In this condition, the test piece has **no constraints**. This is not achievable realistically, so they are approximated by using compliant springs. For ratio calibration verification using a known mass, the free-free mounted mass rigid body natural frequency should be a factor of 10 lower than the lowest frequency of interest.

Note: This requirement is only in the direction of interest.

A free-free boundary condition in lab can include but is not limited to the following suggestions:

Note: Natural frequencies of test fixtures and free-free components can be evaluated by making driving point measurements in the direction of interest.

4.1.1.1.1 Bungee or String Mounting. Hanging the mass from bungee cords or string to allow the free-free condition in the direction of excitation. The test piece shall be secured appropriately and the loading limits shall not be exceeded.

4.1.1.1.2 Air Bearing. For shaker excitation applications, a mass suspended by compressed air allows the free-free condition along the axis of excitation.

4.1.1.1.3 Mounting on Low Stiffness Material. For high frequency (50 Hz to 800 Hz) testing, the mass may be placed on foam or similar material to meet the 1:10 requirement.

4.2 Conditions.

4.2.1 Environmental Conditions. The ambient temperature should be between 18 °C and 29 °C and temperatures should not vary more than 6 °C during the given test unless otherwise specified.

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.3 Instructions. This section covers the calibration verification data acquisition and initial processing. For details of acquisition/processing parameters and measurement practices that are not defined here, refer to the referencing procedures. For example, correct impact hammer technique is defined in the referencing procedure.

The following acquisition parameters are recommended but may vary depending on the specific type of transducer and type of calibration verification being performed. Deviations from these parameters are called out in the specific section.

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Calibration Verification Acquisition and Processing Parameters:

- Flat Top Window
- AC Coupled (1 Hz high pass filter)
- 6 Averages (minimum)
- Enable overload detection
- Set internal calibration values to unity or off

Note: For sinusoidal amplitude calibration, a flat top window minimizes potential amplitude degradation due to leakage.

Note: The number of averages used may also vary depending on the number needed to obtain a consistent measurement.

4.3.1 Accelerometer. There are three methods of verifying the calibration of accelerometers that can be utilized depending on equipment available.

4.3.1.1 Ratio Calibration Verification Using a Standard Accelerometer. Attach the accelerometer to the calibrated standard and the electromagnetic shaker using the appropriate adhesive (see Appendix F). The accelerometers shall also be connected to the analyzer noting the specific channels used. Appendix B displays the setup for this procedure.

Using the shaker apply an amplitude at a specific frequency to both the calibrated standard accelerometer and the accelerometer to be verified. Acquire the data. Observe the voltage amplitude spectrum of both accelerometers. Repeat the measurement. If the data quality is judged to be adequate, then record the amplitudes at the frequency of excitation and any remarks on the test documentation form.

4.3.1.2 Absolute Calibration Verification Using Accelerometer Drop Calibration. Attach the accelerometer to the elastic cord with its fixture. The accelerometer shall also be connected to the analyzer noting the specific channels used. Appendix B displays the setup and execution for this procedure.

Vertically strike the elastic cord, applying gravity, a known acceleration, to the accelerometer. Acquire the time history of the response, triggering off the accelerometer drop. Observe the voltage amplitude change of the accelerometer from rest. Repeat the measurement. If the data quality is judged to be adequate, then record this amplitude of the change in voltage from rest to peak level and any remarks on the test documentation form.

4.3.1.3 Absolute Calibration Verification Using an Accelerometer Calibrator. Attach the accelerometer to the mechanical calibrator using

the appropriate adhesive (see Appendix F). The accelerometer shall also be connected to the analyzer noting the specific channels used. Appendix B displays the setup for this procedure.

Excite the accelerometer at a fixed level of acceleration and frequency using the accelerometer calibrator. Acquire the data. Observe the rms scaled voltage linear amplitude spectrum of the accelerometer. Repeat the measurement. If the data quality is judged to be adequate, then record the amplitude at the frequency of excitation, the known level and any remarks on the test documentation form.

4.3.2 Microphone.

4.3.2.1 Absolute Calibration Verification Using a Microphone Calibrator. Attach the microphone calibrator to the microphone. The microphone shall also be connected to the acquisition system noting the specific channels used and the excitation amplitude and frequency of the calibrator.

Apply an acoustic field of known amplitude and frequency to the microphone using the calibrator. Acquire the data. Observe the rms voltage linear amplitude spectrum of the microphone. Repeat the measurement. If the data quality is judged to be adequate, then record the amplitude at the frequency of excitation, the known level and any remarks on the test documentation form.

4.3.3 Intensity Probe Verification. As specified in 3.2.1.1 calibration verification of the intensity probe requires an analyzer with intensity processing software to calculate intensity from the two microphone probe.

Complete all steps of each of the following three sections, including calculations and data interpretation (Section 5), before proceeding to the next section.

4.3.3.1 Absolute Pressure Calibration Verification. Attach the piston phone to the calibration chamber. Place the two microphones in the upper two ports (ports 1 and 2) of the chamber and install a dummy microphone in the lower port (port 3). The calibration chamber setup is displayed below and in Appendix D.

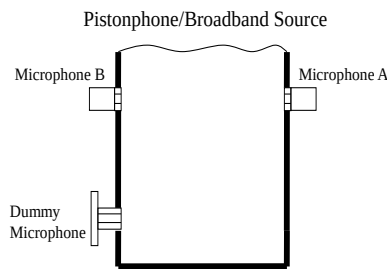
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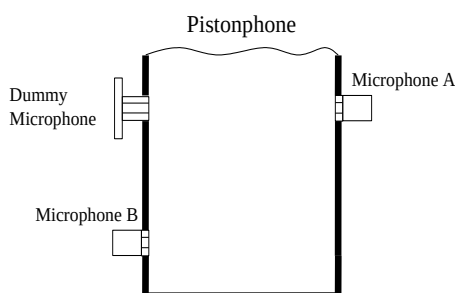
Figure 1: Absolute Pressure and Pressure-Residual Intensity Index Calibration Chamber Test Setup



Using the piston phone, apply an acoustic field of known amplitude at 250 Hz to calibration chamber and subsequently the microphone pair. Acquire the data. Observe the voltage linear amplitude spectrum of the microphones. Repeat the measurement. If the data quality is judged to be adequate, then record the voltage amplitude for each microphone at the frequency of excitation (250 Hz), reference excitation level, and any remarks on a test documentation form.

4.3.3.2 Absolute Phase (Intensity) Calibration Verification. Attach the piston phone to the calibration chamber. Place microphone B (port 3) in the lower port, microphone A (port 1) in the upper port opposite microphone B, and a dummy microphone in the remaining port (port 2) of the calibration chamber. The calibration chamber setup is displayed below and in Appendix D.

Figure 2: Phase Calibration Chamber Test Setup



Set up the acquisition system to acquire and process mean intensity data for 16 s and enter correct pressure calibration values from the previous section. The intensity signal shall be linearly weighted. For other parameters refer to the referencing procedure for how to make intensity measurements.

Using the piston phone, apply an acoustic field of known amplitude at 250 Hz to the calibration chamber. Acquire data. If the data quality is judged to be adequate, note apparent intensity level, phase calibration verification parameters and any remarks on a test documentation form.

4.3.3.3 Pressure Residual Intensity Index Verification. Attach the broadband noise source to the calibration chamber. Place the two microphones into the upper two ports (ports 1 and 2) of the chamber and install a dummy microphone into the lower port (port 3). The calibration chamber setup is displayed in 4.3.3.1 and in Appendix D.

Set up the acquisition system to acquire and process the data using the calibration verification equipment and software manufacturer's specifications and other relevant information from the referencing procedure. Apply the broadband input to the calibration chamber using the source. Acquire data. If the data quality is judged to be adequate, note apparent PI_{residual} index and any remarks on a test documentation form.

4.3.4 Force Transducer/Impact Hammer.

4.3.4.1 Force Transducer Ratio Calibration Verification (Using Shaker Excitation). Attach the calibrated accelerometer, force transducer, and shaker to the known free-free mounted mass. The force transducer and accelerometer should be mounted in line. Appendix E displays the setup.

The cable for the input force shall be connected to the first channel of the acquisition system with the accelerometer cable(s) attached to the subsequent channel(s).

Using the shaker, excite the system within the measurement frequency range of interest (frequency and amplitude). Excitation can either be broadband (e.g., burst random) or single frequency (sinusoidal).

Note: Use of a flat top window is recommended to minimize amplitude degradation (due to leakage). Refer to the referencing procedure details on minimizing leakage.

Acquire the data. If the data quality is judged to be adequate, save the acceleration Frequency Response Function (FRF) trace and record any remarks on the test documentation form.

Note: For broadband excitation, the amplitude of the FRF shall not vary by more than 1.0 dB ($Re: 1.0 (m/s^2)/V$) across the frequency range of interest.

4.3.4.2 Impact Hammer Ratio Calibration Verification. Attach the calibrated accelerometer

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to the known free-free mounted mass. Appendix E displays the test setup.

The cable for the impact hammer shall be connected to the first channel of the acquisition system with the accelerometer cable(s) attached to the subsequent channel(s).

Using the impact hammer and correct technique, as described in the referencing procedure, excite the mass on the end opposite to and in line with the accelerometer. The frequency range of excitation shall be the frequency range of interest at amplitude within the operating range of the test the calibration verification is performed for.

Note: Only uniform windows shall be used.

Acquire the data. If the data quality is judged to be adequate, save the accelerance FRF trace and record any remarks on the test documentation form.

Note: The amplitude of the FRF shall not vary by more than 1.0 dB (Re: $1.0 \text{ (m/s}^2\text{)/V}$) across the frequency range of interest.

4.3.5 Static Force Ring.

4.3.5.1 Absolute Calibration Verification. The following procedure describes the minimum number of steps to verify the calibration of a strain gage based static force ring. More increments or higher force levels may be used as appropriate.

Hang force ring from a fixed structure. Set up the signal conditioning and zero the transducer. Attach mass loading plate to the bottom of the transducer and note the force level applied.

Apply 200 N to 250 N of force to plate using a set of certified masses. Note the amount of force applied and the level readout of the transducer.

Apply a second 200 N to 250 N of force (for a total of 400 N to 500 N) to plate using the set of certified masses. Note the amount of force applied and the force level readout of the transducer as well as any remarks.

5 Data

5.1 Calculations. The following calculations may be automatically performed by the acquisition system software through their specific calibration program(s).

5.1.1 Accelerometer.

5.1.1.1 Verification Using a Calibrated Standard Accelerometer. Using the amplitude values obtained previously for the standard accelerometer, V_c , and the unknown accelerometer, V_{acc} , the calibration value of the standard accelerometer, S_c , and the equation

given below, the calibration factor of the accelerometer shall be calculated and verified.

$$S_{acc} = S_c * (V_c / V_{acc})$$

Note: Units on the calibration constant, S_{acc} , are $V/(m/s^2)$.

Details behind this equation are given in Appendix B.

5.1.1.2 Verification Using the Accelerometer Drop Calibration Method. Using the response amplitude value obtained previously, V_{acc} , the acceleration in a 9.81 m/s^2 field, and the equation given below, the calibration of the accelerometer shall be calculated and verified.

$$S_{acc} = V_{acc} / 9.81 \text{ m/s}^2$$

Note: Units on the calibration constant, S_{acc} , are $V/(m/s^2)$.

Details behind this equation are given in Appendix B.

5.1.1.3 Verification Using an Accelerometer Calibrator. Using the response amplitude value obtained previously, V_{rms} , the known excitation level, a_{rms} , and the equation given below, the calibration of the accelerometer shall be calculated and verified.

$$S_{acc} = V_{rms} / a_{rms}$$

Note: Units on the calibration constant, S_{acc} , are $V/(m/s^2)$.

Details behind this equation are given in Appendix B.

5.1.2 Microphone.

5.1.2.1 Verification Using a Microphone Calibrator. Using the response amplitude value obtained previously, V_{rms} , the known excitation level, p_{rms} , and the equation given below, the calibration of the microphone shall be calculated and verified.

$$S_{mic} = V_{rms} / p_{rms}$$

Note: Units on the calibration constant, S_{mic} , are V/Pa .

Details behind this equation are given in Appendix C.

5.1.3 Intensity Probe.

5.1.3.1 Pressure Calibration Verification. Correct the reference calibration level for atmospheric pressure using the correction value specified listed on the barometer supplied by the manufacturer of the calibration chamber. For example, if the reference calibration is 118 dB (reference $20 \times 10^{-6} \text{ Pa}$) and the table says to correct the calibration value by -0.3 dB then the calibration level would be:

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