
Standard Method of Test for Determining the Influence of Road Surfaces on Vehicle Noise Using the Statistical Isolated Pass-By (SIP) Method

AASHTO Designation: T 389-22¹

Technically Revised: 2022

Technical Subcommittee: 5a, Pavement Measurement



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1. SCOPE

- 1.1. This test method describes a procedure for measuring the influence of road surfaces on highway traffic noise. The Statistical Isolated Pass-By (SIP) Method provides a quantitative measure of the sound pressure level at locations adjacent to a roadway. The SIP method allows for the comparison of vehicle noise on roadways of varying surfaces and across studies by comparing measured sound levels to a reference noise curve.
- 1.2. Measurements capture the sound pressure level from isolated vehicles in existing traffic. The SIP method is to be applied on roadways where measuring sound levels from single-vehicle pass-by events is possible without contamination from sound from other vehicles.
- 1.3. This standard is intended for use by acoustic professionals. Competency with acoustical measurement and analysis techniques is assumed.
- 1.4. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*
- 1.5. *The quality of the results produced by this standard are dependent on the competence of the personnel performing the procedure and the capability, calibration, and maintenance of the equipment used. Agencies that meet the criteria of R 18 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with R 18 alone does not completely assure reliable results. Reliable results depend on many factors; following the suggestions of R 18 or some similar acceptable guideline provides a means of evaluating and controlling some of those factors.*

2. REFERENCED DOCUMENTS

- 2.1. AASHTO Standards:
 - M 339M/M 339, Thermometers Used in the Testing of Construction Materials
 - R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
 - T 360, Measurement of Tire/Pavement Noise Using the On-Board Sound Intensity (OBSI) Method

- < [T 390](#), Determining the Influence of Road Surfaces on Traffic Noise Using the Continuous-Flow Traffic Time-Integrated Method (CTIM)

2.2. *ASTM Standards:*

- < [E230/E230M](#), Standard Specification for Temperature Electromotive Force (emf) Tables for Standardized Thermocouples
- < [F2493](#), Standard Specification for P225/60R16 97S Radial Standard Reference Test Tire

2.3. *FHWA Reports:*

- < FHWA-PD-96-008, Development of National Reference Energy Mean Emission Levels for the FHWA Traffic Noise Model (FHWA TNM®), Version 1.0
- < FHWA-PD-96-009, FHWA Traffic Noise Model (FHWA TNM®): User's Guide, TNM® Version 2.5 Addendum, April 2004
- < FHWA-PD-96-010, FHWA Traffic Noise Model (FHWA TNM®), Version 1.0: Technical Manual, 2004, update sheets available from FHWA
- < FHWA-PD-96-046, *Measurement of Highway-Related Noise*, Section 4: Existing-Noise Measurements in the Vicinity of Highways

2.4. *International Electrotechnical Commission Standards:*

- < IEC 60584 1: 2013 Thermocouples Part 1: EMF Specifications and Tolerances
- < IEC 60942: 2003, Electroacoustics—Sound Calibrators
- < IEC 61260: 1995, Electroacoustics—Octave-Band and Fractional-Octave-Band Filters
- < IEC 61672-1: 2002, Electroacoustics—Sound Level Meters—Part 1: Specifications

2.5. *ANSI Standard:*

- < S1.42: 2001 (R2006), American National Standard Design Response of Weighting Networks for Acoustical Measurements

3. TERMINOLOGY

3.1. *Definitions:*

- 3.1.1. *Continuous-Flow Traffic Time-Integrated Method (CTIM)*—a test method for measuring the influence of road surfaces on highway traffic noise. The CTIM method captures the sound from existing traffic for all vehicles on all roadway lanes and includes propagation effects over the roadway pavement and adjacent terrain to the nearby measurement location.
- 3.1.2. *data set*—the data collected to determine the reported Statistical Isolated Pass-By index (SIPI).
- 3.1.3. *designated speed*—the average of all pass-by vehicle speeds for a single vehicle category.
- 3.1.4. *maximum sound level*—the highest sound pressure level recorded by the measuring instrument during a vehicle pass-by, using the A-weighted frequency network and a fast sound level meter response time (0.125-s exponential average).
- 3.1.5. *measured vehicle sound level, L_{veh}* —the sound level determined at the designated speed from a regression line of the maximum A-weighted sound pressure level versus the logarithm of vehicle speed, calculated for each vehicle category for the measured data for a single microphone position [either 25 ft or 50 ft (7.6 m or 15.2 m) from the center of the travel lane] for a single pavement type.

- 3.1.6. *measurement period*—a period of time over which measurements are made during one site visit. A data set may combine one or more consecutive measurement periods to capture enough data to properly represent the site.
- 3.1.7. *on-board sound intensity (OBSI) method*—a measurement procedure to evaluate the tire/pavement noise component resulting from the interaction of an [ASTM F2493](#), Standard Reference Test Tire (SRTT) on a pavement surface. Sound intensity measurements are taken at defined locations near the tire/pavement interface.
- 3.1.8. *powertrain noise*—the noise generated from the powertrain, including the vehicle engine, exhaust system, air intake, fans, transmission, differential, and axles.
- 3.1.9. *reference noise curve*—the reference noise curve is extracted from the portion of the Reference Energy Mean Emission Level (REMEL) curve that is primarily attributed to tire/pavement noise (FHWA-PD-96-008). The reference noise curve is defined as $A \times \log_{10}(\text{speed in mph}) + B$. The coefficients for each vehicle category are shown in Table 1 for the 50-ft (15.2-m) position (extracted from FHWA-PD-96-008, Section 7.4) and in Table 2 for the 25-ft (7.6-m) position [calculated by shifting the 50-ft (15.2-m) curve up by 6 dB]. For data measured at the 50-ft (15.2-m) position, the $L_{veh,ref}$ shall be extracted from the 50-ft (15.2-m) reference curve for comparison. For data measured at the 25-ft (7.6-m) position, the $L_{veh,ref}$ shall be extracted from the 25-ft (7.6-m) reference curve for comparison. (The measurement positions are described in more detail in Section 10.)

Table 1—Reference Noise Curve Parameters for Position of Microphone—50 ft (15.2 m) from the Center of the Lane, 12 ft (3.7 m) above the Roadway Plane

Reference Curve Coefficients for Reference Pavement	Automobiles	Medium Trucks	Heavy Trucks	Buses	Motorcycles
A	41.740807	33.918713	35.879850	23.479530	41.022542
B	0.223836	19.495961	20.306023	38.006238	7.333072

Table 2—Reference Noise Curve Parameters for Position of Microphone—25 ft (7.6 m) from the Center of the Lane, 5 ft (1.5 m) above the Roadway Plane

Reference Curve Coefficients for Reference Pavement	Automobiles	Medium Trucks	Heavy Trucks	Buses	Motorcycles
A	41.740807	33.918713	35.879850	23.479530	41.022542
B	6.223836	25.495961	26.306023	44.006238	13.333072

- 3.1.10. *reference surface*—the reference surface is defined as the average pavement type from the FHWA Traffic Noise Model (FHWA TNM®) (FHWA-PD-96-009, FHWA-PD-96-010), measured in the Reference Energy Mean Emission Level (REMEL) study (FHWA-PD-96-008). All results shall be compared to the Reference Noise Curve based on the average pavement [(dense-graded asphaltic concrete (DGAC) and portland cement concrete (PCC) combined] found in the TNM vehicle noise emission level database [REMELs (FHWA-PD-96-008)]. See Section 3.1.9 for reference curve coefficients.
- 3.1.11. *reference vehicle sound level, $L_{veh,ref}$* —the sound level determined at the designated speed from the reference noise curve.
- 3.1.12. *regression uncertainty*—the uncertainty in the location of the true regression line for the linear regression analysis of sound level data as a function of speed. The procedure for calculating regression uncertainty is found in Section 14.1.4.

3.1.13. *statistical isolated pass-by index (SIPI)*—SIPI is defined as:

$$\text{SIPI} = L_{veh} - L_{veh,ref}$$

where L_{veh} is the measured vehicle sound level and $L_{veh,ref}$ is the reference vehicle sound level. The SIPI is the difference between sound levels representing two sets of data: (1) measured data for a single pavement type and single vehicle category, and (2) data representing the reference pavement and a single vehicle category. The SIPI can be used for the comparison of different pavements, for the assessment of the acoustical characteristics of a pavement over time, or for other comparison uses not specified. The procedure for calculating SIPI is found in Section 14.1.

3.1.14. *statistical isolated pass-by (SIP) method*—the measurement procedure designed to evaluate vehicle noise generated on different road surfaces by measuring the sound pressure level from isolated vehicles in existing traffic. The measurements are taken from a large number of vehicles operating normally on the road. Results obtained using this procedure are compared to reference vehicle sound levels.

3.1.15. *tire/pavement noise*—the sound generated by the interaction of the tire with the pavement surface as it traverses the pavement.

3.1.16. *traffic noise*—the overall noise emitted by multiple vehicles running over the road being evaluated.

3.1.17. *vehicle category*—consists of vehicles that have certain common features easy to identify in the traffic stream, such as the number of axles and the size. The common features are assumed to correspond to similarities in their sound emission when driven under the same operating conditions. The vehicle categories in Table 3 are considered to be sufficient for description of the noise characteristics of road surfaces and are used in the SIP method.

Table 3—Vehicle Categories

Vehicle Category	Number of Axles, Number of Tires, Gross Vehicle Weight (examples)
Automobiles	2 axles, 4 tires, and generally <9,900 lb (4500 kg) (designated primarily for transportation of 9 or fewer passengers or for transportation of cargo—cars, pickup trucks, and sports utility vehicles)
Medium trucks	2 axles, more than 4 tires, and generally >9,900 lb (4500 kg) and <26,400 lb (12 000 kg)
Heavy trucks	3 or more axles and generally >26,400 lb (12 000 kg)
Buses	2 or 3 axles (designated for transportation of 9 or more passengers)
Motorcycles	2 or 3 tires (with an open-air driver and/or passenger compartment)

Notes:

1. The definitions for these vehicle categories are intended for U.S. applications, including the FHWA Traffic Noise Model (FHWA-PD-96-009, FHWA-PD-96-010) and its vehicle noise emission database (FHWA-PD-96-008). The vehicle category definitions can be found in those references as well as the FHWA highway noise measurement manual (FHWA-PD-96-046).

2. Only vehicles that clearly fall within any of the types described in this section shall be measured. Where there is any doubt in classifying a vehicle, the measurement for that vehicle shall be discarded from the study.

3.1.18. *vehicle noise*—the total noise from a vehicle, including a combination of noise generated by the tire/road interaction (tire/pavement noise), air turbulence, and the powertrain.

4. SUMMARY OF TEST METHOD

4.1. *Measuring the Sound Level*—In the SIP method, the maximum A-weighted sound pressure levels of a statistically significant number of individual vehicle pass-bys are measured at a specified roadside location together with the vehicle speeds. Each measured vehicle is classified into one of five categories: automobiles, medium trucks, heavy trucks, buses, and motorcycles. At a minimum, the automobile and heavy truck categories should be evaluated in order to determine the influence of each roadway surface (the other vehicle categories are optional).

- 4.2. *Analysis of Data*—Each individual pass-by level, together with its vehicle speed, is recorded, and a linear regression of the maximum A-weighted sound pressure level versus the logarithm of the speed is calculated for each vehicle category. From this regression line, the measured vehicle sound level, L_{veh} , and regression uncertainty are determined at the designated speed. The measured sound level is called the measured vehicle sound level, L_{veh} . For each roadway surface or pavement type, the L_{veh} is calculated for each vehicle category.
- 4.3. *Comparison of Data to Reference*—The L_{veh} value is compared to the Reference Vehicle Sound Level, $L_{veh,ref}$ using the reference surface, both at the designated speed. The difference between the two values is calculated and reported as the Statistical Isolated Pass-by Index (SIPI).
- 4.4. The method is detailed below, and additional SIP considerations are available in a memorandum to FHWA dated April 20, 2017, “Additional Considerations for AASHTO Standard Methods of Test [TP 98](#) (SIP) and [TP 99](#) (CTIM).”² The memorandum is available at: http://downloads.transportation.org/TP98-TP99/SIP_CTIM_Considerations_Memo.pdf

5. SIGNIFICANCE AND USE

- 5.1. This test method provides an objective measure of the influence of road surfaces on vehicle noise at locations adjacent to a roadway and allows for the comparison of vehicle noise on roadways of varying surfaces by comparing measured sound levels to those representing the tire/pavement noise for a reference surface, thus allowing comparison of results across studies.
- 5.2. Use of this method, in conjunction with other measurement methods, will increase the understanding of the influence of pavement on noise and eventually be applicable to pavement design and selection.
- 5.3. The SIP procedure reports broadband A-weighted maximum sound pressure levels. While it is possible to measure one-third octave band levels in conjunction with the broadband levels, methods to analyze the one-third octave band data are not included in this procedure.
- 5.4. In situations where it is not possible to measure single vehicle pass-by events without contamination from other vehicles, [T 390](#), Determining the Influence of Road Surfaces on Traffic Noise Using the Continuous-Flow Traffic Time-Integrated Method (CTIM), or another method that allows for measuring continuously flowing traffic should be applied. The appropriate measurement technique should be selected based on site and traffic conditions. The SIP method is preferred over [T 390](#) due to its ability to compare results across sites and/or studies.
- 5.5. The SIP test method may be used in conjunction with the on-board sound intensity (OBSI) method described in AASHTO [T 360](#) that measures the tire/pavement component of vehicle noise exclusively.

6. APPARATUS

- 6.1. *Sound Level Instrumentation*—The sound level meter (or equivalent measuring system) shall meet the requirements of a Class 1 instrument according to IEC 61672-1.
- Note 1**—It is recommended to use a pressure response/random incidence microphone at grazing incidence (i.e., vertical orientation); see Figure 1.

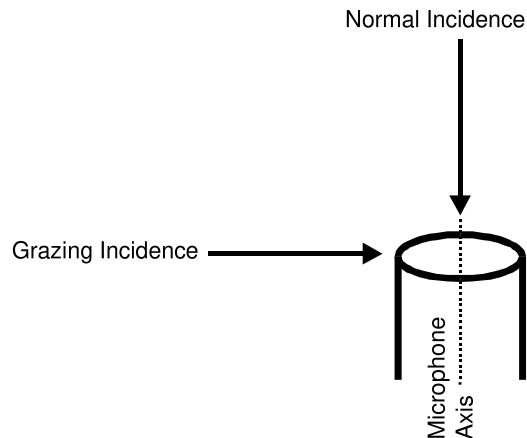


Figure 1—Illustration of Directions for Microphone Orientation

- 6.2. *Windscreens*—A windscreen that does not detectably influence the measured sound levels shall be used.
- 6.3. *Frequency Analysis Instrumentation*—Frequency analysis of the measured sound using one-third octave band resolution is recommended, but not mandatory. The frequency range of 50 to 10 000 Hz (center frequencies of one-third octave bands) shall be covered. The one-third octave band filters shall conform to IEC 61260.
- 6.4. *Calibration Instrumentation*—The calibration device used shall meet the requirements of a Class 1 instrument according to IEC 60942. (Note that some calibrators require correction for environmental conditions. The manufacturer's specifications should be consulted.)
- 6.5. *Vehicle Speed Measurement Instrumentation*—The vehicle speed shall be measured using a measuring instrument with an accuracy of ± 1 mph (± 1.6 km/h). A list of measuring devices/methods is found in *Measurement of Highway-Related Noise* (FHWA-PD-96-046) and includes radar gun, stopwatch, light sensors, and pneumatic lines. Care must be taken to avoid interfering with the pass-by sound level measurements, including actions that could influence driver behavior and/or generating any intrusive noise caused by a measurement device.
- 6.6. *Temperature Measurement Instrumentation*—The air temperature measuring instrument(s) shall meet the requirements of [M 339M/M 339](#) and be capable of measuring temperature between 40 and 100°F (4 and 38°C) with an accuracy of $\pm 2^\circ\text{F}$ ($\pm 1.2^\circ\text{C}$). Meters using an infrared technique shall not be used for air temperature measurements (see Note 2).
- Note 2**—Thermometer types suitable for use include IEC 60584 thermocouple thermometer Type J or K, Class 1; or [ASTM E230/E230M](#) thermocouple thermometer, Type J or K, Class Special.
- Wind Measurement Instrumentation*—The wind speed measuring instrument(s) shall have an accuracy of ± 2 mph (± 0.9 m/s). The wind direction-measuring instrument(s) shall have an accuracy of ± 10 degrees.

7. SELECTION OF TEST SITES

- 7.1. *The following considerations apply for site selection:*
- 7.1.1. Each road test section shall extend at least 100 ft (30.5 m) on both roadway up- and down-stream directions from the microphone location.