

Development of the J2825 On-Highway Motorcycle Sound Test Procedure

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ABSTRACT

In response to a growing need for a practical and technically valid method for measuring exhaust sound pressure levels (SPL) of on-highway motorcycles, the SAE Motorcycle Technical Steering Committee has developed Surface Vehicle Recommended Practice J2825¹, "Measurement of Exhaust Sound Pressure Levels of Stationary On-Highway Motorcycles," which includes a new stationary sound test procedure and recommendations for limit values. Key goals of the development process included: minimal equipment requirements, ease of implementation by non-technical personnel, and consistency with the federal EPA requirements; in particular, vehicles compliant with the EPA requirements should not fail when assessed using J2825.

Development of the recommended practice involved a comprehensive field study of 25 motorcycles and 76 different exhaust systems, ranging from relatively quiet OEM systems to unbaffled, aftermarket exhaust systems. For the various motorcycle/exhaust system configurations, SPL measurements were made using the EPA pass-by procedure and several different stationary measurement methods. Correlations between the results obtained by these different methods were studied for the entire subject group (combinations of motorcycle and exhaust system) as well as for sub-groups based on motorcycle engine configuration.

Of the stationary measurement methods explored; the most reliable results were obtained when the SPL was measured 20 inches from the tailpipe outlet. On the basis of engine configuration, stationary test results were correlated with results measured using the wide-open throttle, EPA pass-by procedure. For four-cylinder motorcycles, the best correlation was obtained at 5000 rpm; for all other engine types the best correlation was obtained at 2000 rpm. Satisfactory results were also obtained using idle SPL measurement.

INTRODUCTION

Noise standards for highway motorcycles adopted by the U.S. Environmental Protection Agency (EPA)² are based on a test procedure that measures the sound level from a distance of 15 meters (49.2 feet) as the vehicle is accelerating at wide open throttle, usually in second gear, to a maximum engine speed of 55 to 95% (depending on engine displacement) of rated engine speed. (Motorcycles with engines larger than 675 cc are accelerated to 55% of rated engine speed; higher engine speeds are required for motorcycles with smaller engines.) Sound levels measured using this wide open throttle, "pass-by" test procedure are considered representative of what the public would be exposed to at a distance of 15 meters" when a motorcycle is rapidly accelerated under wide open throttle conditions. This emulates moderately high acceleration such as may be required to merge onto a freeway. For 1986 and

newer motorcycles, the maximum allowable sound level is 80 decibels, A-scale (dBA). This standard applies to both original equipment manufacturer (OEM) exhaust systems and aftermarket exhaust systems.

Motorcycles meeting the federal noise standard are essentially as quiet as new passenger cars. However, for various reasons, not all motorcycles operating in customer service are in compliance with the standard. Unfortunately, determining whether a motorcycle in customer service complies with federal noise standards would require taking the vehicle to a test facility, compliant with EPA test site requirements, where it could be measured under carefully controlled conditions with no other vehicles operating in the immediate vicinity. The official pass-by test procedure is therefore impractical for enforcement of noise standards in customer service.

The Motorcycle Sound Working Group, under the auspices of the American Motorcyclist Association (AMA), published a document in 2004 entitled "Sound Advice."³ Members of the Working Group with an interest in on-highway motorcycles included AMA staff and representatives of the Motorcycle Industry Council (MIC), Harley-Davidson (H-D), FMF Racing, ABATE, and the Motorcycle Riders Foundation. Sound Advice addresses the point that "Of the myriad issues facing motorcyclists today, excessive motorcycle sound has become the single greatest threat to American motorcycling's future." The document points out that excessive motorcycle sound has resulted in restrictions on motorcycle dealership expansion and bans or restrictions on motorcycle use. The document notes that enforcement of regulations governing the noise level of motorcycles is "complicated by the fact that there is no reliable way to correlate sound levels between the EPA's pass-by testing method and various stationary testing methods used by local enforcement agencies." It is also noted that "This creates a dilemma for local governments and enforcement agencies because federal law prohibits state and local governments from enacting standards that are more stringent than federal law." Despite the concerns about correlation noted in Sound Advice, many states have adopted noise standards for motorcycles that use a "stationary" sound test procedure.

In 1980, the Motorcycle Committee of the Society of Automotive Engineers (SAE), with support from the MIC, developed a stationary measurement procedure targeted for off-highway motorcycles. In support of the procedure development, extensive measurements were made of off-highway and dual purpose motorcycles, using a number of candidate procedures. The procedure that resulted from this research, SAE J1287⁴ "Measurement of Exhaust Sound Levels of Stationary Motorcycles," was based on comparison and correlation of the results obtained using various methods with those obtained using the EPA procedure. As illustrated

in [Figure 1](#), the procedure involves measuring the sound pressure level 20 inches from the tailpipe of the motorcycle while the engine is running at 50% of rated engine speed with the transmission in neutral. While this procedure is commonly used in off-highway situations, no state currently specifies J1287 for on-highway motorcycle sound testing.

Enforcement of noise standards based on SAE J1287 for off-highway motorcycles is facilitated by the publication of test speeds for all popular off-highway and dual purpose motorcycle models by MIC. Vibrating reed tachometers, which can provide an accurate indication of engine speed for single cylinder engines typically used off-highway, are used for engine speed measurement.

Testing has determined that off-highway motorcycles with OEM exhaust systems can meet a limit of 96 dBA on the SAE J1287 test. However, for multi-cylinder on-highway motorcycles with balance shafts, speed measurement using simple, vibrating reed tachometers is not reliable. In addition, data regarding rated engine speeds are often not published by manufacturers and have not been compiled by MIC or any other organization. There is also no analysis documenting a stationary noise standard that will not falsely fail highway motorcycles that meet the federal pass-by noise standards; hence the interest in developing a simplified stationary highway motorcycle sound test procedure.

During 2006, with support from the MIC, the SAE Motorcycle Technical Committee initiated work on the development of a new sound test procedure for highway motorcycles by developing an overall scope of work for the project. Seven specific tasks were identified: (1) Literature Review; (2) Development of a Field Testing Protocol; (3) Selection of Motorcycles and Aftermarket Exhaust Systems; (4) Field Testing; (5) Data Analysis and Reporting; (6) Validation Testing; and (7) Event Field Testing.

LITERATURE REVIEW

The literature review task uncovered a wide range of opinions regarding the feasibility of using a stationary test procedure to identify motorcycles with excessively loud exhaust systems without falsely failing vehicles that meet EPA noise standards. At one end of the spectrum, a joint Forest Service/MIC correlation study published in 1993⁵ indicated "no apparent linear correlation" between the EPA drive-by test procedure and the SAE J1287 "20 inch test." This finding is consistent with, if not the source of, a statement in Sound Advice that "there is no reliable way to correlate sound levels between the EPA's pass-by testing method and various stationary testing methods." However, there were only eight motorcycles used in the Forest Service/MIC test program and most of them had relatively quiet exhaust systems. As described below, earlier studies dealing with a wider range of

- 20" from muffler while motorcycle is stationary and engine at steady, test RPM (50% of rated speed).
- Fairly quick, easy, economical field test for single cylinder motorcycles that can have rpm measured with vibrating reed tachometer.
- MIC publishes test speeds for off-highway models.
- Test speed information not available for many highway motorcycles.

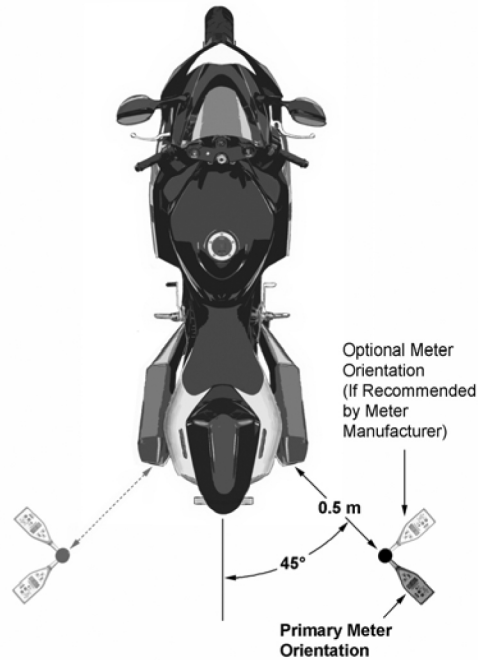


Figure 1. J1287 Stationary Sound Test Procedure

motorcycles concluded that there was greater potential for a stationary test.

Evidence of the correlation between a stationary test like J1287 and the EPA pass-by test can be found in the much older correlation study performed for MIC by McDonnell Douglas in 1975.⁶ One of the objectives of that study was “to evaluate various test methodologies as candidates for a stationary vehicle noise test for motorcycles, with application to in-service enforcement against excessively noisy modified or deteriorated exhaust systems...” There were 200 motorcycles included in the program. Pass-by sound level testing was conducted using the SAE J33 1a and J47 test procedures. (The J33 1a test procedure is similar to the procedure specified by EPA for determining compliance with federal noise standards.) The range of stationary tests conducted included sound level measured 0.5 meters from the tailpipe with the engine running in neutral at 50% of rated speed, which is essentially the same as what subsequently became J1287.

Although the correlation between the pass-by test and a J1287-type test was weak, the correlation coefficient (r) was 0.55, which is substantially better than the correlation indicated in the subsequent Forest Service/MIC program. The McDonnell Douglas report concluded that a stationary test similar to what is now J1287, “has potential for use as an in-service noise enforcement test method with an ISO test standard of 102 dBA being selected to pass all motorcycles meeting a J33 1a level of 86 dBA.” Based on Figure 7 of the report, 102 dBA would pass all motorcycles meeting a pass-

by limit of 83 dBA, which, coincidentally, was the standard that became applicable to on-highway motorcycles for model years 1983-1985. A 102 dBA limit for the stationary test was supported by the fact that (a) 102 dBA was the highest noise level measured at 0.5 m and 50% of rated engine speed for a motorcycle at or below 83 dBA on the pass-by test and (b) five out of five motorcycles that exceeded 102 dBA on the stationary test also exceeded 83 dBA on the pass-by test.

Despite the fact that the correlation was not “good,” the data in the McDonnell Douglas report indicate that motorcycles in excess of 102 dBA on a J1287-type test would be expected to fail an 83 dBA pass-by test. This finding is significant because vehicles with unbaffled pipes are much louder than 102 dBA on the J1287 test. In other words, motorcycles with unbaffled pipes will fail a 102 dBA limit when tested using J1287, while vehicles that can pass an 83 dBA pass-by test will pass.

At a meeting between representatives of MIC and the SAE Motorcycle Technical Committee in 2006, a summary of data collected by the German authority KBA was presented, showing the same weak correlation between stationary and pass-by sound levels as demonstrated in the McDonnell Douglas study described above. By extrapolating the KBA data, it was hypothesized that a stationary test standard in the range of 100 - 105 dBA might be effective in identifying motorcycles with the highest pass-by sound levels with a relatively low failure of motorcycles measured at 80 dBA or lower on the pass-by test. This finding is consistent with the finding of the McDonnell Douglas study.

The studies summarized above indicate that there is some degree of correlation between relatively simple stationary tests and pass-by tests similar to the test used by EPA to certify new motorcycles.

FIELD TESTING PROTOCOL

The first element of the field testing protocol involved a simple pre-test evaluation of each motorcycle/exhaust system combination to ensure the vehicle was free from misfires, backfires, or any significant driveability problems.

STATIONARY TESTING

Stationary test procedures used during field testing included idle, 50% of rated speed (per J1287), an alternative to the constant speed J1287 test that involved slowly increasing engine speed to 50% of rated speed, a matrix of alternative engine speeds ranging from 2,000 to 6,500 rpm, and a “throttle blip” test. The alternative test involving a slowly increasing engine speed was evaluated for use with motorcycles that are unable to maintain 50% of rated speed under no-load conditions. The “throttle blip” test involved rapidly opening and closing the throttle in a manner that resulted in the peak engine speed reaching 50% of rated speed.

In addition to the standard 20 inch test distance, it was decided to conduct a series of tests with alternative measurement distances. All types of stationary testing were planned to be conducted on warmed up vehicles under conditions that comply with SAE J1287 requirements for “Test Site” (e.g., distance from buildings, proximity of people, ambient sound level, and wind speed). It was decided that the vehicle warm-up would be done for at least 3 minutes with the vehicle in a restraining fixture. A cooling fan was always utilized to insure uniform engine and exhaust system temperatures, this is necessary to avoid overheating during the research testing.

PASS-BY TESTING

The field testing protocol called for pass-by testing performed using the official EPA testing procedure described in Appendix I-1 to Subparts D and E of Title 40, Code of Federal Regulations, Part 205 (40CFR205). The test involves measuring the sound level of a motorcycle at a distance of 15 meters as it accelerates at wide open throttle from an initial engine speed to the point where the throttle is closed (“closing rpm”). As described below, the initial rpm and closing rpm are defined as a function of engine displacement. [Figure 2](#), extracted from the CFR, shows how the closing rpm varies with engine size.

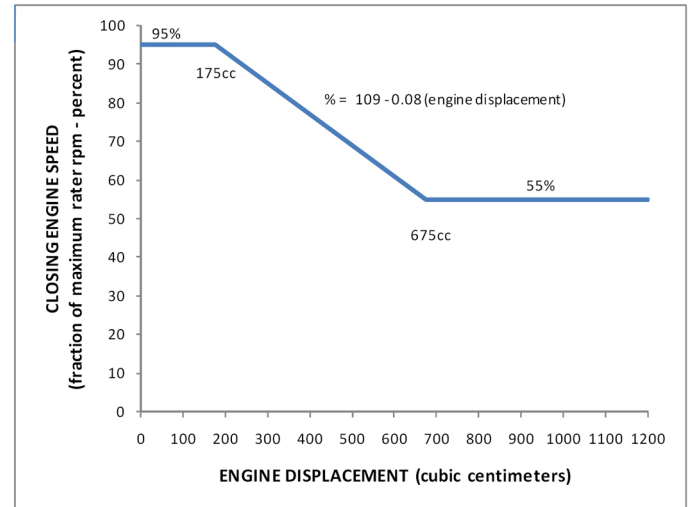


Figure 2. Closing RPM vs. Engine Size for Pass-by Testing

One complication of the pass-by test procedure is that the “acceleration point” is vehicle specific and must be determined by trial and error. A detailed, step-by-step procedure was used to determine the acceleration point for each vehicle and to determine the proper gear. (Second gear is the default gear for the EPA pass-by test; however, a higher gear is required if the distance covered during the acceleration in second gear is less than 10 meters.) [Figure 3](#), extracted from the CFR, shows the layout of the course for pass-by testing.

TEST VEHICLES AND EXHAUST SYSTEMS

TEST VEHICLES

The original statement of work called for the selection of approximately 30 high-volume motorcycle models representing a wide range of on-highway motorcycles in terms of engine/exhaust configurations. The original objective was to select approximately 6 sport models, 6 cruiser models, 6 standard models, 6 touring/sport touring models, and 6 dual sport models. At least 5 of the cruiser models and 5 of the sport models were to be selected based on the likelihood they would be retrofitted with aftermarket exhaust systems in customer service.

The first step in the vehicle selection process involved the compilation of sales data obtained by MIC for 2001 through 2006. [Table 1](#) shows the distribution of highway motorcycle sales by category for this period of time. Based on the distribution of sales shown in the table, combined with the relatively limited use of aftermarket exhaust systems on “dual-sport” and “standard” style motorcycles, MIC recommended reduced emphasis on dual-sports and standards and increased emphasis on cruisers.

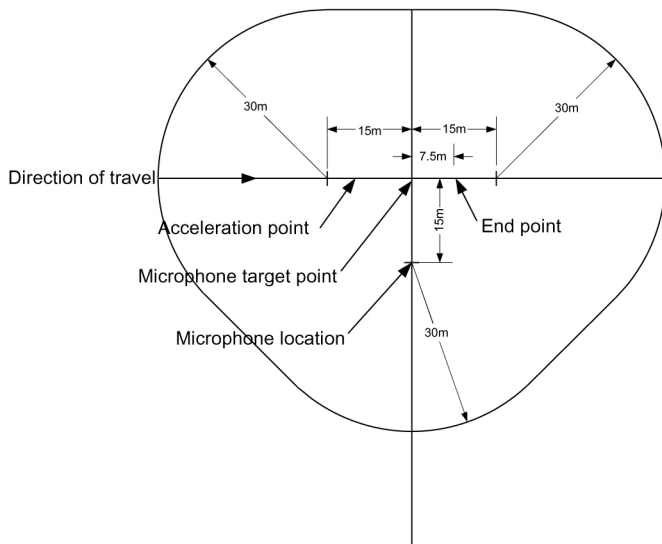


Figure 3. Course Layout for Pass-by Testing

Table 1. Highway Motorcycle Sales Fractions by Category (2001 - 2006)

Category	Sales Fraction
Cruiser	49%
Sport	28%
Touring/Sports Touring	21%
Standard	2%
Dual-Sport	3%
TOTAL	100%

Cruisers

Based on a review of detailed MIC sales data, it was apparent that H-D had almost half of the cruiser market in the 2001-2006 period. A request was made for H-D to provide several of its most popular cruiser models for testing. H-D offered to provide three cruiser models: a high production volume, air-cooled, 1200 cc V-twin ("Sportster"); a high production volume, air-cooled, 1584 cc V-Twin ("FLSTC"); and a lower production volume, water-cooled V-twin (a 1130 cc "V-Rod").

Honda had the second highest share of the cruiser market in the 2001-2006 period. Based on MIC sales data, a request was made for two specific models and Honda agreed to provide both, a 750 cc "Shadow" and a 1300 cc "VTX." Both were water-cooled V-twins.

Yamaha, Kawasaki, and Polaris were each asked to provide one of their V-twin cruisers. The models provided were an air-cooled Yamaha 1100 cc "V-Star," a water-cooled Kawasaki 1500 cc "Vulcan," and an air/oil-cooled 1634 cc "Victory Vegas."

Sports

Based on MIC sales data, Suzuki, Kawasaki, Honda, and Yamaha dominate the sport bike market. The most popular models are in the 600 cc displacement class. Each of the dominant manufacturers was asked to provide one of its 600 cc models and did so. The 600 cc models provided were a Honda "CBR 600," a Suzuki "GSX-R600," a Yamaha "YZF-R6," and a Kawasaki "Ninja ZX6." Suzuki and Yamaha were also asked to provide one of their popular 1000 cc models, a Suzuki "GSX-R1000" and a Yamaha "YZF-R1." All of the 600 and 1000 cc models were equipped with water-cooled inline 4-cylinder engines. H-D provided a 1200 cc, V-twin, air-cooled Buell "XB."

Touring/Sports Touring

Based on MIC sales data, H-D produced well over half of the motorcycles in this category from 2001 to 2006. It was therefore important to have a representative H-D model in this category. The air-cooled, 1688 cc V-twin "FL" model provided by H-D accomplished that objective. The most popular model in the Touring/Sport Touring category produced by a manufacturer other than H-D is the 1800 cc Honda "Gold Wing," which uses a "boxer" style 6-cylinder engine. Honda also provided a water-cooled "ST1300" with a V-4 engine, which is a popular Sport Touring model. Only about 20% of the Touring/Sport Touring category is produced by manufacturers other than H-D and Honda. Two represent the variety of models available: BMW provided an air/oil-cooled opposed twin ("R1200RT") and Yamaha provided a water-cooled inline 4-cylinder "FJR1300."

Standard

To represent motorcycles in the relatively small Standard category, Honda provided a "Nighthawk" 250 parallel twin and Suzuki provided a "SV650" V-twin.

Dual Sport

To represent motorcycles in the relatively small Dual Sport category, BMW provided an "R1200GS," Kawasaki provided a single cylinder "KLR650," and Suzuki provided a 1000 cc V-twin model called the "V-Strom."

Table 2 lists each of the vehicles included in the testing program.