**DEPARTMENT OF TRANSPORTATION**

**National Highway Traffic Safety Administration**

**49 CFR Parts 571 and 585**

**[Docket No. NHTSA–2016–0125]**

**RIN 2127–AK93**

# Federal Motor Vehicle Safety Standards; Minimum Sound Requirements for Hybrid and Electric Vehicles

**AGENCY:** National Highway Traffic Safety Administration (NHTSA), Department of Transportation (DOT).

**ACTION:** Final rule.

**SUMMARY:** To reduce the risk of pedestrian crashes, especially for the blind and visually-impaired, and to satisfy the mandate in the Pedestrian Safety Enhancement Act (PSEA) of 2010 this final rule establishes a new Federal motor vehicle safety standard (FMVSS) setting minimum sound requirements for hybrid and electric vehicles. This new standard requires hybrid and electric passenger cars, light trucks and vans (LTVs), and low speed vehicles (LSVs) to produce sounds meeting the requirements of this standard. This final rule applies to electric vehicles (EVs) and to those hybrid vehicles (HVs) that are capable of propulsion in any forward or reverse gear without the vehicle's internal combustion engine (ICE) operating. This standard will help to ensure that blind, visually impaired, and other pedestrians are able to detect and recognize nearby hybrid and electric vehicles, as required by the PSEA.

**DATES:** *Effective date:* This rule is effective February 13, 2017.

*Compliance date:* Initial compliance is required, in accordance with the phase-in schedule, on September 1, 2018. Full compliance is required on September 1, 2019.

*Petitions for reconsideration:* Petitions for reconsideration of this final rule must be received not later than January 30, 2017.

*Incorporation by Reference:* The incorporation by reference of certain publications listed in the standard is approved by the Director of the Federal Register as of February 13, 2017.

**ADDRESSES:** Petitions for reconsideration of this final rule must refer to the docket and notice number set forth above and be submitted to the Administrator, National Highway Traffic Safety Administration, 1200 New Jersey Avenue SE., Washington, DC 20590.

**FOR FURTHER INFORMATION CONTACT:**

For non-legal issues, Mr. Mike Pyne, Office of Crash Avoidance Standards (telephone: 202–366–4171) (fax: 202–493–2990). Mr. Pyne's mailing address is National Highway Traffic Safety Administration, NVS–123, 1200 New Jersey Avenue SE., Washington, DC 20590.

For legal issues, Mr. Thomas Healy, Office of the Chief Counsel (telephone: 202–366–2992) (fax: 202–366–3820). Mr. Healy's mailing address is National Highway Traffic Safety Administration, NCC–112, 1200 New Jersey Avenue SE., Washington, DC 20590.

**SUPPLEMENTARY INFORMATION:**

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## I. Executive Summary

The PSEA requires NHTSA to establish performance requirements for an alert sound that is recognizable as a motor vehicle in operation that allows blind and other pedestrians to detect nearby electric vehicles or hybrid vehicles operating at lower speeds. This final rule establishes FMVSS No.141, *Minimum Sound Requirements for Hybrid and Electric Vehicles,* which requires hybrid and electric passenger cars and LTVs with a gross vehicle weight rating (GVWR) of 4,536 kg (10,000 lbs.) or less and LSVs, to produce sounds meeting the requirements of this standard so both blind and sighted pedestrians can more easily detect and recognize by hearing these vehicles. Both blind and sighted pedestrians have greater difficulty detecting hybrid and electric vehicles at low speeds than vehicles with ICE engines because hybrid and electric vehicles produce measurably less sound at those speeds.[1] At higher speeds, in contrast, tire and wind noise are the primary contributors to a vehicle's noise output, so the sounds produced by hybrid and electric vehicles and ICE vehicles are similar.

Hybrid vehicles with gross vehicle weight rating (GVWR) of 4,536 kg (10,000 lbs.) or less are 1.18 times more likely than an ICE vehicle to be involved in a collision with a pedestrian and 1.51 times more likely to be involved in a collision with a pedalcyclist. NHTSA assumes that this difference in accident rates is mostly attributable to the pedestrians' inability to detect the presence of these vehicles through hearing.

To further evaluate the assumption that the difference in crash rates is mostly attributable to differences in vehicle emitted sound, the agency conducted research to see if there was a difference in the ability of pedestrians to detect approaching hybrid and electric vehicles versus ICE vehicles. The agency also conducted research to examine how the frequency composition of a sound influenced the ability of pedestrians to detect that sound in the presence of ambient noise. Section II.C provides much more information on this research and how the agency used it in the context of this rulemaking.

[1] Garay-Vega, L; Hastings, A.; Pollard, J.K.; Zuschlag, M. & Stearns, M. (2010, April). Quieter Cars and the Safety of Blind. Pedestrians: Phase 1. DOT HS 811 304. Washington, DC: National Highway Traffic Safety Administration.

*A. Summary of Requirements of the Final Rule*

On January 14, 2013, NHTSA published a notice of proposed rulemaking (NPRM) specifying minimum sound requirements for hybrid and electric vehicles.[2] The NPRM discussed three alternative means for the agency to establish requirements for, and measure compliance with, minimum levels of vehicle emitted sound. In the NPRM, the agency proposed its preferred alternative which was to establish minimum requirements for vehicle emitted sound using a psychoacoustic model. Sounds meeting the proposed requirements would contain acoustic elements designed to enhance detection and to aid pedestrians in recognizing the sound as coming from a motor vehicle. We believed that the preferred alternative placed the greatest emphasis on ensuring the vehicle emitted sounds were detectable to pedestrians. In addition to the preferred alternative, the NPRM also discussed minimum sound requirements for HVs and EVs designed to resemble sounds produced by ICE vehicles. This alternative would place a greater emphasis on recognizability than the preferred alternative. Compliance with both of these alternatives would be determined using a compliance test that measured the sound produced by the vehicle.

In order to provide an alternative that would allow the most flexibility in the types of sounds that manufacturers could choose to add to vehicles to alert pedestrians, we also discussed using human factors testing to determine whether a sound used to alert pedestrians was recognizable as a motor vehicle.

After careful consideration of all available information, including the public comments submitted in response to the NPRM,[3] the agency has decided to adopt the preferred alternative in the NPRM and many of the elements of the proposed rule. In the final rule, as proposed, the agency requires hybrid and electric vehicles to emit sound while the vehicle is stationary with the vehicle propulsion system activated. (However, in the final rule this requirement does not apply to vehicles that are parked with the propulsion system activated—see below.) Also as proposed, the agency requires hybrid and electric vehicles to emit minimum sound levels while in reverse and while the vehicle is in forward motion up to 30 km/h. The final rule also adopts the agency's proposal to conduct compliance testing outdoors.

With regard to the scope of the final rule and what level of sound to emit and when, however, the agency is adopting numerous changes to the proposal in response to additional analysis conducted by the agency and in response to comments, including the following:

- The final rule will only apply to four-wheeled hybrid and electric vehicles with a gross vehicle weight rating (GVWR) of 4,536 kg (10,000) pounds or less. The NPRM proposed that this rule would also apply to hybrid and electric vehicles with a GVWR over 4,536 kg (10,000) pounds and to electric motorcycles. We believe that we do not have enough information at this time to apply the minimum acoustic requirements of this final rule to these vehicles.
- In this final rule, the agency is reducing the number of one-third octave bands for which there are minimum requirements. The NPRM proposed that vehicles would have to emit sound meeting minimum requirements in eight one-third octave bands. To comply with this final rule, hybrid and electric vehicles will instead have to meet a requirement specifying either two or four one-third octave bands. Vehicles complying with the four-band requirement must meet minimum sound pressure levels in any four non-adjacent one-third octave bands between 315 Hz and 5000 Hz, including the one-third octave bands between 630 Hz and 1600 Hz (these bands were excluded in the NPRM). Vehicles complying with the two-band requirement must meet minimum sound pressure levels in two non-adjacent one-third octave bands between 315 Hz and 3150 Hz. For the two-band requirement, one band must be below 1000 Hz and the second band must be at or above 1000 Hz, and the two bands used to meet the two-band requirement also must meet a minimum band sum requirement.
- The NPRM proposed that the fundamental frequency of the sound emitted by a hybrid or electric vehicle must vary as the vehicle changes speed by one percent per km/h for speeds between 0 and 30 km/h to allow pedestrians to detect vehicle acceleration and deceleration. This requirement was referred to as ''pitch shifting,'' and it is not required in the final rule. Instead, the final rule assists pedestrians in detecting increases in vehicle speed by requiring vehicle-emitted sound to increase in sound pressure level by a specified amount as the vehicle's speed increases. The agency acknowledges that the concept of increasing sound pressure level with increased speed is not a direct replacement for pitch shifting, but we believe it is a reasonable alternative that will provide useful audible information to pedestrians about the operating state of nearby vehicles.
- The NPRM proposed that sound emitted by hybrid and electric vehicles must contain one tone no higher than 400 Hz and emit broadband content including each one-third octave band from 160 Hz to 5000 Hz so that sounds emitted by these vehicles would be recognizable as motor vehicles. The final rule does not adopt these proposed requirements. We believe that pedestrians will use other cues to recognize EVs and HVs such as the location of the sound source and the frequency and level changes caused by the motion of the sound.
- In order to ensure that hybrid and electric vehicles of the same make, model, and model year emit the same sound, as required by the PSEA, the NPRM proposed that vehicles of the same make, model, and model year must emit the same level of sound, within 3 dB(A), in each one-third octave band from 160 Hz to 5000 Hz. We have instead decided to ensure that EVs and HVs of the same make, model, and model year emit the same sound by requiring that all vehicles of the same make, model, and model year use the same alert system hardware and software, including specific items such as the same digital sound file where applicable, to produce sound used to meet the minimum sound requirements in today's final rule.
- The NPRM proposed that each hybrid and electric vehicle must meet minimum sound requirements anytime the vehicle's propulsion system is activated, including when the vehicle is stationary. The final rule requires each hybrid and electric vehicle to meet minimum sound requirements any time the vehicle's propulsion system is activated, including when the vehicle is stationary, unless the vehicle's gear selector is in the ''park'' position or the parking brake is applied (the latter for HVs and EVs with manual transmissions).
- The NPRM proposed a phase-in schedule that required each manufacturer of hybrid and electric vehicles to begin meeting the requirements of the final rule with 30 percent of the hybrid and electric vehicles they produce three years before the date for full compliance established in the PSEA. In the final rule, we have modified the phase-in schedule to provide additional time for compliance

[2] 78 FR 2797.

[3] ''Federal Motor Vehicle Safety Standards; Minimum Sound Requirements for Hybrid and Electric Vehicles,'' 78 FR 2798 (January 14, 2013).

for manufacturers of light vehicles; 50 percent of each manufacturer's HV and EV production must comply with this final rule one year before the date for full compliance established in the PSEA of September 1, 2019.

*B. Costs and Benefits*

As discussed in detail in Section V of this notice, the benefits of this final rule will accrue from injuries to pedestrians that will be avoided, based on the anticipated ability of this rule to reduce the pedestrian injury rate for HVs and EVs to that of ICE vehicles. As discussed in Section II.B, a traditional analysis of pedestrian fatalities is not appropriate for this rulemaking. If we assume that HVs and EVs increase their presence in the U.S. fleet to four percent of all vehicle registrations in model year 2020, a total of 2,464 injuries to pedestrians and pedalcyclists would be expected over the lifetime of the 2020 model year fleet due to the pedestrians' and pedalcyclists' inability to detect these vehicles by their sense of hearing. Taking into account the agency's estimate of detectability of vehicle alert sounds complying with this final rule, which is discussed in the Final Regulatory Impact Assessment, we estimate that the benefit of reducing the pedestrian and pedalcyclist injury rate per registered vehicle for EVs HVs to ICE vehicles when four percent of the fleet is HVs and EVs would be 2,390 fewer injured pedestrians and pedalcyclists. We do not include any quantifiable benefits in pedestrian or pedalcyclist injury reduction for EVs because we believe it is reasonable to assume that EV manufacturers would have installed alert sounds in their cars without passage of the PSEA and this proposed rule.[4] We also estimate that this rule will result in 11 fewer injured pedestrians and pedalcyclists caused by LSVs.

TABLE 1—DISCOUNTED BENEFITS FOR PASSENGER CARS AND LTVS, MY2020, 2013$

| 3% Discount | Pedestrians | | | Pedalcyclists | | | Total PED + CYC | | |
|---|---|---|---|---|---|---|---|---|---|
| | 3% Discount factor | Total monetized benefits | Total ELS | 3% Discount factor | Total monetized benefits | Total ELS | 3% Discount factor | Total monetized benefits | Total ELS |
| (PC) | 0.8024 | $132.3M | 9.70 | 0.80243 | $168.8M | 14.55 | 0.8024 | $301.1M | 24.25 |
| (LTV) | 0.7867 | 7.9M | 0.58 | 0.78673 | 9.4M | 0.80 | 0.7867 | 17.4M | 1.39 |
| Total | 0 | 140.3M | 10.29 | 0 | 178.3M | 15.35 | 0 | 318.5M | 25.64 |
| 7% Discount | 7% Discount factor | Total monetized benefits | Total ELS | 7% Discount factor | Total monetized benefits | Total ELS | 7% Discount factor | Total monetized benefits | Total ELS |
| (PC) | 0.6268 | $102.5M | 7.50 | 0.62684 | $130.5M | 11.24 | 0.6268 | $233.0M | 18.74 |
| (LTV) | 0.6077 | 6.1M | 0.45 | 0.60775 | 7.2M | 0.61 | 0.6077 | 13.3M | 1.06 |
| Total | 0 | 108.6M | 7.94 | 0 | 137.7M | 11.85 | 0 | 246.3M | 19.80 |

TABLE 2—TOTAL COSTS FOR PCS AND LTVS, MY2020, 2013$

| | Sales | Sales impacted | Fuel costs/veh | Fuel costs (total) | Avg. install costs/veh | Install costs total | Total cost/veh | Total costs |
|---|---|---|---|---|---|---|---|---|
| 3% discount: | | | | | | | | |
| (PC) | 8,000,000 | 483,462 | $4.70 | $2,272,270 | $74.36 | $35,951,512 | $79.06 | $38,223,782 |
| (LTV) | 8,000,000 | 46,428 | 5.30 | 246,067 | 71.97 | 3,341,333 | 77.27 | 3,587,400 |
| Total | 16,000,000 | 529,889 | $4.75 | $2,518,337 | $74.15 | $39,292,845 | $78.91 | $41,811,182 |
| 7% discount: | | | | | | | | |
| (PC) | 8,000,000 | 483,462 | $3.80 | $1,837,155 | $74.36 | $35,951,512 | $78.16 | $37,788,667 |
| (LTV) | 8,000,000 | 46,428 | 4.20 | 194,996 | 71.97 | 3,341,333 | 76.17 | 3,536,329 |
| Total | 16,000,000 | 529,889 | 3.84 | 2,032,151 | 74.15 | 39,292,845 | 77.99 | 41,324,996 |

TABLE 3—COSTS AND SCALED BENEFITS FOR LSVS, MY2020 [5]

| Discount rate (%) | Sales ratio LSV to light vehicle (%) | Sales | Scaled costs | Scaled injuries (undisc.) | Scaled ELS | Scaled benefits | Scaled benefits minus scaled costs |
|---|---|---|---|---|---|---|---|
| 3 | 0.47 | 2,500 | $197,264 | 11.28 | 0.1210 | $1,502,807 | $1,305,543 |
| 7 | 0.47 | 2,500 | 194,970 | 11.28 | 0.0934 | 1,161,989 | 967,019 |

[4] As further discussed in the agency's Final Regulatory Impact Analysis, due to foresight on the part of light electric vehicle manufacturers, paired with consumer expectations and style choices, light vehicle EVs are all assumed to be equipped with speaker systems. NHTSA assumes the sound alert benefits for these vehicles are attributable to the market and not the rule. This assumption makes our benefit figures conservative. On the other hand, we did not assume that electric LSVs would be voluntarily equipped with speaker systems since none of these vehicles were known to have such systems currently.

[5] Scaled benefits and costs for low-speed vehicles (LSVs) are estimated to be directly proportional to costs for light vehicles based on sales. Scaled costs include both installation costs for the system and fuel costs.

NHTSA estimates that the fuel and installation cost of adding a speaker system in order to comply with the requirements of this rule is $129.84 per vehicle for unequipped hybrid light vehicles (*i.e.,* vehicles that did not previously have any alert system components installed), and $54.99 for electric light vehicles. We estimate that for model year (MY) 2020, which is the first model year to which the requirements of this final rule will apply to the entire light vehicle fleet, this final rule will apply to 529,889 passenger cars and LTVs. The estimated costs for manufacturers of complying with this rule is $39.29M in MY 2020, and we would expect that due to the additional weight that these components add to the vehicles in which they are installed, if manufacturers make no other changes to reduce vehicle weight, these vehicles would consume an additional 2.3 more gallons of fuel over the lifetime of a passenger car and 2.5 more gallons of fuel over the lifetime of a light truck which would result in an average fuel cost of $4.75 per vehicle for over the lifetime of MY 2020 vehicles subject to the rule at the 3-percent discount rate and $3.84 per vehicle for over the lifetime of MY 2020 vehicles subject to the rule at the 7-percent discount rate.).

To more easily compare the costs and benefits of this rulemaking, we have converted pedestrian and pedalcyclist injuries avoided into equivalent lives saved. We estimate that the impact of this rule in pedestrian and pedalcyclist injury reduction in light vehicles and LSVs will be 25.76 equivalent lives saved at the 3-percent discount rate and 19.92 equivalent lives saved at the 7-percent discount rate (summing values from Table 1 and Table 3). Converting that to dollars, the benefits of this rule for the HV portion of the MY 2020 light vehicle and LSV fleet are $320.0 million at the 3-percent discount rate and $247.5 million at the 7-percent discount rate (Table 4).[6] NHTSA estimates that the cost per equivalent life saved for the light EV, HV, and LSV fleet would range from a cost of $1.67 million to a cost savings of $0.10 million across the 3-percent and 7-percent discount levels, respectively. When compared to our comprehensive cost estimate of the value of a statistical life of $9.2 million, this final rule is cost effective.

TABLE 4—TOTAL BENEFITS AND COSTS SUMMARY FOR LIGHT VEHICLES AND LOW SPEED VEHICLES, MY2020, 2013$

| | 3% Discount rate | 7% Discount rate |
|---|---|---|
| Total Monetized Benefits | $320.0M | $247.5M |
| Total Costs (Install + Fuel) | 42.M | 41.5M |
| Total Net Impact (Benefit − Costs) | 278.0M | 205.9 |

## II. Background and Summary of Notice of Proposed Rulemaking

### *A. Pedestrian Safety Enhancement Act and National Traffic and Motor Vehicle Safety Act*

On January 4, 2011, the Pedestrian Safety Enhancement Act of 2010 (Pub. L. 111–373) was signed into law. The Pedestrian Safety Enhancement Act (PSEA) requires NHTSA to conduct a rulemaking to establish a Federal Motor Vehicle Safety Standard (FMVSS)[7] requiring an ''alert sound''[8] for pedestrians to be emitted by all types of motor vehicles[9] that are electric vehicles[10] (EVs) or hybrid vehicles[11] (HVs). Trailers are specifically excluded from the requirements of the PSEA.

The PSEA requires NHTSA to establish performance requirements for an alert sound that allows blind and other pedestrians to reasonably detect a nearby EV or HV. The PSEA defines ''alert sound,'' as that term is used in the statute, as a vehicle-emitted sound that enables pedestrians to discern the presence, direction,[12] location, and operation of the vehicle.[13] Thus, in order for a vehicle to satisfy the requirement in the PSEA to provide an ''alert sound,'' the sound emitted by the vehicle must satisfy that definition. The alert sound must not require activation by the driver or the pedestrian, and must allow pedestrians to reasonably detect an EV or HV in critical operating scenarios such as constant speed, accelerating, or decelerating.

In addition to those operating scenarios, the definition of alert sound in the PSEA requires the agency to establish requirements for a sound while the vehicle is stationary but active and when the vehicle is operating in reverse. PSEA states that the alert sound must allow pedestrians to ''discern vehicle presence, direction, location, and operation.''[14] We read the requirement that pedestrians be able to ''discern vehicle presence'' along with the requirements that the sound allow pedestrians to discern direction, location, and operation. The term ''presence'' means something that is in the immediate vicinity. The term ''operation'' means a state of being functional or operative. Read together, the definition of alert sound requires that pedestrians be able to detect vehicle presence when the vehicle is in operation. A vehicle with its gear selector not in ''park'' is in an operational state even though it may not be moving. It is therefore the agency's position that the provision of the PSEA that requires pedestrians to be able to detect the presence of a vehicle in operation requires that the vehicle emit a minimum sound level when its gear selector is in any position other than ''park,'' whether that be when the vehicle is moving forward, stationary, or operating in reverse.

[6] NHTSA's benefits calculation does not include light EVs because manufacturers of light EVs were already adding sound to those vehicles prior to NHTSA issuing the NPRM. However, this analysis includes LSVs because those vehicles currently do not have added sound.

[7] NHTSA is delegated authority by the Secretary of Transportation to carry out Chapter 301 of Title 49 of the United States Code. *See* 49 CFR 501.2. This includes the authority to issue Federal motor vehicle safety standards. *See* 49 U.S.C. 30111.

[8] The definition of the term ''alert sound'' is discussed below.

[9] Section 2(4) of the PSEA defines the term ''motor vehicle'' as having the meaning given such term in section 30102(a)(6) of title 49, United States Code, except that such term shall not include a trailer (as such term is defined in section 571.3 of title 49, Code of Federal Regulations). Section 30102(a)(6) defines ''motor vehicle'' as meaning a vehicle driven or drawn by mechanical power and manufactured primarily for use on public streets, roads, and highways, but does not include a vehicle operated only on a rail line.

[10] Section 2(10) of the PSEA defines ''electric vehicle'' as a motor vehicle with an electric motor as its sole means of propulsion.

[11] Section 2(9) of the PSEA defines ''hybrid vehicle'' as a motor vehicle which has more than one means of propulsion. As a practical matter, this term is currently essentially synonymous with ''hybrid electric vehicle.''

[12] The PSEA does not specify whether vehicle ''direction'' is to be defined with reference to the vehicle itself (thus meaning forward or backward) or the pedestrian.

[13] PSEA Section 2(2).

[14] Public Law 111–373, 2(2), 124 Stat. 4086 (2011).

The agency believes that it is reasonable to conclude that Congress intended the term ''operation'' in the PSEA to be the condition in which a driver is operating the vehicle, as opposed to just the operation of the vehicle's propulsion system. It is the operation of the vehicle by a driver, not the operation of the vehicle's propulsion system, that creates the safety risk to pedestrians who fail to detect hybrid and electric vehicles. Consequently, when the vehicle's gear selector is in ''park,'' the propulsion system may or may not be activated but, in such a condition when the propulsion system is activated, the vehicle is not operable by the driver until the gear selector is moved from ''park'' to some other gear selector position. Therefore, we have determined that the PSEA does not require us to establish minimum sound requirements for when a vehicle has its gear selector control in the ''park'' position.

Because the PSEA directs NHTSA to issue these requirements as an FMVSS under the National Traffic and Motor Vehicle Safety Act (Vehicle Safety Act),[15] the requirements must comply with that Act as well as the PSEA. The Vehicle Safety Act requires each safety standard to be performance-oriented, practicable [16] and objective [17] and meet the need for safety. In addition, in developing and issuing a standard, NHTSA must consider whether the standard is reasonable, practicable, and appropriate for each type of motor vehicle covered by the standard.

As an FMVSS, the minimum sound standard in today's final rule will be enforced in the same fashion as other safety standards issued under the Vehicle Safety Act. Thus, violators of the standard will be subject to civil penalties.[18] Vehicle manufacturers will be required to conduct a recall and provide remedy without charge if their vehicles are determined to fail to comply with the standard or if the vehicle's alert sound were determined to contain a safety related defect.[19]

Under the PSEA, the standard must specify performance requirements for an alert sound that enables blind and other pedestrians to reasonably detect EVs and HVs operating below their crossover speed.[20] The PSEA specifies several requirements regarding the performance of the alert sound to enable pedestrians to discern the operation of vehicles subject to the Act. First, the alert sound must be sufficient to allow a pedestrian to reasonably detect a nearby EV or HV operating at constant speed, accelerating, decelerating or operating in any other scenarios that the Secretary deems appropriate.[21] Second, it must reflect the agency's determination of the minimum sound level emitted by a motor vehicle that is necessary to allow blind and other pedestrians to reasonably detect a nearby EV or HV operating at or below the crossover speed.[22] Today's final rule will ensure that EVs and HVs are detectable to pedestrians by specifying performance requirements for sound emitted by these vehicles so that they will be audible to pedestrians across a range of ambient noise environments, including those typical of urban areas.

Nothing in the PSEA specifically requires the alert sound to be electrically generated. Therefore, if manufacturers wish to meet the minimum sound level requirements specified by the agency through the use of sound generated by the vehicle's power train or any other vehicle component, there are no conflicts with the PSEA to limit their flexibility to do so.

The alert sound must also reflect the agency's determination of the performance requirements necessary to ensure that each vehicle's alert sound is recognizable to pedestrians as that of a motor vehicle in operation.[23] We note that the requirement that the alert sound be recognizable as a motor vehicle in operation does not mean that the alert sound be recognizable as a vehicle with an internal combustion engine (ICE). The PSEA defines ''conventional motor vehicle'' as ''a motor vehicle powered by a gasoline, diesel, or alternative fueled internal combustion engine as its sole means of propulsion.'' [24] We believe that if Congress had intended the alert sound required by the PSEA to be recognizable as an ICE vehicle, Congress would have specified that the sound must be recognizable as a ''conventional motor vehicle'' in operation rather than a motor vehicle because Congress acts purposefully in its choice of particular language in a statute.[25]

While the mandate that NHTSA develop performance requirements for an alert sound that is recognizable as a motor vehicle does not mean that the sound must be based solely on sounds produced by ICE vehicles, the mandate does impose substantive requirements that the agency must follow during the rulemaking. The Vehicle Safety Act defines a motor vehicle as a ''vehicle driven or drawn by mechanical power and manufactured primarily for use'' on public roads.[26] The requirement that the agency develop performance requirements for recognizability means that the pedestrian alert sound required by this standard must include acoustic characteristics common to all sounds produced by vehicles driven by mechanical power that make those sounds recognizable as a motor vehicle based on the public's experience and expectations of those sounds.

The PSEA mandates that the standard shall not require the alert sound to be dependent on either driver or pedestrian activation. It also requires that the safety standard allow manufacturers to provide each vehicle with one or more alert sounds that comply, at the time of manufacture, with the safety standard. Thus, a manufacturer may, if it so chooses, equip a vehicle with different sounds to denote different operating scenarios, such as stationary, forward or reverse. Each vehicle of the same make and model must emit the same alert sound or set of sounds. The standard is required to prohibit manufacturers from providing anyone, other than the manufacturer or dealers, with a device designed to disable, alter, replace or modify the alert sound or set of sounds emitted from the vehicle. This language prohibits NHTSA from allowing

[15] 49 U.S.C. Chapter 301.

[16] In a case involving passive occupant restraints, the U.S. Circuit Court of Appeals for the District of Columbia said that the agency must consider public reaction in assessing the practicability of required safety equipment like an ignition interlock for seat belts. Pacific Legal Foundation v. Department of Transportation, 593 F.2d 1338 (D.C. Cir. 1978). cert. denied, 444 U.S. 830 (1979).

[17] In a case involving passive occupant restraints, the U.S. Circuit Court of Appeals for the 6th Circuit said, quoting the House Report (H.R. 1776, 89th Cong. 2d Sess. 1966, p. 16) for the original Vehicle Safety Act, that ''objective criteria are absolutely necessary so that 'the question of whether there is compliance with the standard can be answered by objective measurement and without recourse to any subjective determination.' '' *Chrysler* v. *Department of Transportation,* 472 F.2d 659 (6th Cir. 1972).

[18] 49 U.S.C. 30112 and 30165.

[19] 49 U.S.C. 30118–30120.

[20] Section 2(3) of the PSEA defines ''crossover speed'' as the speed at which tire noise, wind resistance, or other factors make an EV or HV detectable by pedestrians without the aid of an alert sound. The definition requires NHTSA to determine the speed at which an alert sound is no longer necessary.

[21] PSEA Section 3(a). Under the PSEA, as with most legislation like it, the Secretary of Transportation delegates responsibility for achieving the legislation's objectives to the appropriate Department of Transportation Administration, in this case NHTSA.

[22] PSEA Section 3(b).

[23] PSEA Section 3(b)(2).

[24] PSEA Section 2(5).

[25] *See Keene Corp.* v. *United States,* 508 U.S. 200, 208 (1993) (stating the cannon of statutory construction that ''where Congress includes particular language in one section of a statute but omits it in another . . ., it is generally presumed that Congress acts intentionally and purposely in the disparate inclusion or exclusion.'').

[26] 49 U.S.C. 30102(a)(6).

manufacturers from installing an off switch or volume control switch that allows the driver to turn off or turn down the alert sound used to meet the requirements of this standard.

Additionally, vehicle manufacturers, distributors, dealers, and motor vehicle repair businesses would be prohibited from rendering the sound system inoperative under Section 30122 of the Vehicle Safety Act. A manufacturer or a dealer, however, is allowed to alter, replace, or modify the alert sound or set of sounds in order to remedy a defect or non-compliance with the safety standard.

It is the agency's intention that the requirements of this standard be technology neutral. For this reason, we have chosen to establish minimum sound requirements for a vehicle-level test, as opposed to a component-based bench test or some other type of test, to ensure any kind of technology used can be properly tested.

The agency interprets the requirement in the PSEA that each vehicle of the same make and model emit the same sound as applying only to sound added to a vehicle for the purposes of complying with this standard. We also interpret the PSEA requirement that NHTSA prohibit manufacturers from providing anyone with a means of modifying or disabling the alert sound and the prohibition on making required safety systems inoperative contained in Section 30122 of the Vehicle Safety Act as applying only to sound added to a vehicle for the purposes of complying with this proposed standard.

Many changes to a vehicle could affect the sound produced by that vehicle. In issuing this proposal the agency does not wish to prevent manufacturers, dealers, and repair businesses from making modifications to a vehicle such as adding a spoiler or changing the vehicle's tires that may have the effect of changing the sound produced by the vehicle.

The PSEA requires that the final rule provide a phase-in period, as determined by the agency. In response to that requirement, full compliance with the standard must be achieved for all vehicles manufactured on or after September 1st of the calendar year beginning three years after the date of publication of the final rule. This final rule is establishing the requirement for 100-percent compliance for all light vehicles subject to the requirements of this rule produced for sale in the U.S. by all manufacturers no later than September 1, 2019. This requirement includes a one-year, 50-percent phase-in period beginning September 1, 2018.

*B. Safety Problem*

Comparing the Vehicle-to-Pedestrian Crash Experience of ICE Vehicles to HVs and EVs

Crash Risk

Public safety advocacy groups have raised pedestrian safety concerns regarding HVs because a vehicle using an electric motor may be quieter than an ICE vehicle and may not emit the sounds that non-motorists rely on for warning as vehicles approach them.

In 2009, NHTSA released the report ''Incidence of Pedestrian and Bicyclist Crashes by Hybrid Electric Passenger Vehicles'' which found that, when comparing similar vehicles, 77 out of 8,387 total HVs reported to be in any crash incident were involved in pedestrian crashes, and 3,578 out of 559,703 total ICE vehicles were involved in similar pedestrian crashes.[27] The report used data collected from 12 individual states. The years for which data were available varied across different states. Generally, the data used ranged from the years 2000 to 2006. The ratio of pedestrian crashes to overall crashes was 40-percent higher for HVs than for other vehicles. In situations involving certain low-speed maneuvers, HVs were twice as likely to be involved in a pedestrian crash as ICE vehicles in similar situations.

In 2011 NHTSA released a second report ''Incidence Rates of Pedestrian And Bicyclist Crashes by Hybrid Electric Passenger Vehicles: An Update'' which verified these previous findings[28] by adding additional years of state crash files as well as by increasing the number of states included in the analysis from 12 to 16, which increased the number of crashes included in the analysis. Overall, a statistical approach referred to as odds ratios indicated that the odds of an HV being in either a pedestrian or bicycle crash is greater than the odds of an ICE vehicle being in a similar crash, 19-percent higher for pedestrian crash odds and 38-percent higher for bicycle crash odds.[29] The crash factors of speed limit, vehicle maneuver, and location were examined to determine the relative incidence rates of HVs versus ICE vehicles and whether the odds ratio was different under different circumstances. The analysis also indicated that the largest differences between the involvement of HVs and ICE vehicles in pedestrian crashes occur with speed limits of 35 mph and lower and during certain maneuvers typically executed at low speed such as making a turn, starting up, and pulling into or backing out of a parking space. HVs were about 1.38 times more likely to be involved in a pedestrian crash than a vehicle with an ICE during a low speed maneuver. The results of the updated analysis show trends similar to those first reported in our 2009 analysis. The sample sizes of pedestrian and bicycle crashes were re-examined to verify that there was sufficient statistical power in this updated analysis.

The state data set that NHTSA used to determine the pedestrian and pedalcyclist crash rates for HVs did not include any information about the vision status of the pedestrians involved in the crashes, so we were unable to determine whether any of the pedestrians involved in these crashes were blind or visually-impaired.

While this updated analysis provides insightful comparisons of the incidence rates of HVs versus ICE vehicles involved in pedestrian crashes, there are some limitations to consider: The use of data from 16 states cannot be used to directly estimate the national problem size; and there is still not enough data to draw conclusions in all scenarios of interest such as for individual low-speed maneuvers such as making a turn, starting up, or in parking lots.

It has been an ongoing concern that HVs have a very small share among all vehicles (approximately 0.5 percent). The conditional probability of HV pedestrian or pedalcyclist crashes is very small if whole populations of both HV and ICE are included. Therefore, the sample size of HV may have an impact on the comparison of crash rates between HVs and ICE vehicles. For this reason, NHTSA has further updated the comparison between HV and ICE crash data in order to include additional HV crashes.

[27] R. Hanna (2009) Incidence of Pedestrian and Bicyclists Crashes by Hybrid Electric Passenger Vehicles, Report No. DOT HS 811 204. U.S. Dept. of Transportation, Washington, DC.

Available at *http://www-nrd.nhtsa.dot.gov/Pubs/811204.PDf*.

[28] Wu, et al. (2011) Incidence Rates of Pedestrian And Bicyclist Crashes by Hybrid Electric Passenger Vehicles: An Update, Report No. DOT HS 811 526. Dept. of Transportation, Washington, DC. Available at *http://www-nrd.nhtsa.dot.gov/Pubs/811526.pdf*.

[29] The incidence rates for pedestrian and pedalcyclist crashes involving HVs and EVs were calculated from the State data by comparing the pedestrian and pedalcyclist crash rates for all HVs contained in the State data set with the crash rates for all ICE vehicles from that data set. Because this proposal does not apply to HVs that always have their ICE turned on while moving, the agency removed the Honda Civic and the Honda Accord from the HV category and included those vehicles in the calculations as ICE vehicles in estimating the incidence rate used in the benefit calculations.

In our recent calculations [30] we used the latest State data available up to 2011 from the same 16 states, in which the sample sizes of HV vehicles of all crashes are increased to 68,950 (with 420 pedestrian crashes for all hybrid vehicle models). The earlier research obtained the pedestrian crash odds ratios of HV versus ICE vehicle with much smaller sample sizes. The new analysis showed that after the Honda Civic and Accord models are moved from the hybrid category to the ICE category the odds ratio of HV vs. ICE pedestrian crashes for all speeds is 1.21 and the odds ratio for slower speed maneuvers is 1.52. This analysis also shows that the odds ratio of HV vs. ICE pedalcyclist crashes is 1.58 for all speeds including all speed maneuvers, and 1.50 for slower maneuvers.

In the NPRM, the agency asked for comments on whether the differences in pedestrian crash rates between HV and ICE vehicles are solely due to pedestrians' inability to detect these vehicles based on sound, or whether there may be other factors that we have not identified that affect the difference in crash rates.

Ideally, in order to determine whether this lack of sound is causing accidents, NHTSA would have compared accident rates for HVs and EVs with and without sound. However, there have not been enough HVs and EVs with sound for a long enough period of data to be able reasonably conduct this analysis. NHTSA has also been unable to directly measure the pedestrian and pedalcyclist crash rates per mile travelled for HVs and EVs to the rates for ICEs because the Agency does not have data on VMT for HVs and EVs. Therefore, we have instead used the number of other types of crashes vehicles are involved in and using that as a proxy for VMT. While this is a standard technique in analyzing crash risk, it does raise the possibility that there may be other explanations than the lack of sound for hybrids having higher-than-average rates of pedestrian and pedalcyclist crashes relative to other crashes.

Various comments noted that the agency should consider the possibility that factors other than sound will have an impact on the difference in crash rates between HVs and ICE vehicles. Commenters stated that driver characteristics and higher rates of exposure to pedestrians were factors that could contribute to the higher rate of pedestrian crashes among HVs when compared to ICE vehicles.

Nissan North America, Inc. (Nissan) stated that NHTSA should take into account the fact that the ''making a turn'' and ''backing'' maneuvers, which constitute a majority of the low speed maneuvers examined in the agency's crash analysis, are maneuvers during which it is difficult for drivers to detect pedestrians. American Honda Motor Co. (Honda) stated that NHTSA should examine whether there is a significant difference between HEV/EV pedestrian crashes and ICE pedestrian crashes for vehicles starting from stationary.

Advocates stated that elevated crash rates between EVs/HEVs and pedestrians and pedalcyclists, concerns of blind advocacy groups, and the international attention focused on the issue support the conclusion that minimum sound requirements for EVs and HEVs will reduce the rate of pedestrian crashes involving these vehicles. The Insurance Institute for Highway Safety stated that, according to research from the Highway Data Loss Institute (HDLI), hybrid vehicles where 17.2 percent more likely to cause injuries to pedestrians than their ICE vehicle counterparts.

Agency Response to Comments

After review of the comments received on the NPRM, we utilized a multivariate logistic regression model to examine whether other variables besides type of powertrain in the State Data System contributed to increased risk of pedestrian collisions. In addition, we utilized the calculated odds ratio to compare HVs and ICEs using a case-control analysis. The variables that NHTSA examined in the regression are: Whether the vehicle was an HV or ICE; whether the vehicle was involved in a low-speed maneuver at the time of the crash; city size; driver age; vehicle age; and calendar year. The results of the regression analysis show that an HV may have 1.18 times higher likelihood of hitting a pedestrian than an ICE after accounting for these other confounding risk factors included in the State Data System. NHTSA believes that our case-control analysis, the results of our multivariate logistic regression, and the results of HDLI's research show that there is a difference in crash rates between HVs and ICE vehicles that is attributable to sound. We note that we were unable to calculate a statistically significant difference in crash rates between HVs and ICE vehicles for pedestrian crashes when the vehicle was starting from a stopped position because of the small number of crashes involving HVs in the State Data System.

We have considered the fact that many of the crashes in the low-speed maneuver data in our crash analysis include crashes in which the driver was making a turn or backing and may have had an obstructed view of the pedestrian. Because backing crashes are addressed by our recent final rule to increase the field of view requirements of FMVSS No. 111, *Rear Visibility,* we have adjusted our benefits calculation for this rulemaking to remove those crashes addressed by FMVSS No. 111. Also, the fact that the driver's view may have been obstructed supports the need to establish minimum sound requirements for HVs and EVs so that pedestrians can detect when those vehicles are pulling out or approaching in situations in which the pedestrian is potentially obscured from the driver's view.

Fatalities

The Fatality Analysis Reporting System (FARS) contains a census of all traffic fatalities. HVs and EVs that struck and killed a pedestrian were identified using the Vehicle Identification Numbers (VINs) contained in the 2001 through 2009 FARS files. During this period, there were 53 pedestrian fatalities attributed to crashes involving 47 HVs and three EVs. Almost all of these fatalities (47 of the 53) involved vehicles that were identified as passenger vehicles. In 2008, there were 10 HVs or EVs that struck and killed 10 pedestrians, and in 2009, there were 11 HVs or EVs that struck and killed 11 pedestrians.

However, these fatalities are not included in the target population for analysis under this rulemaking for two reasons. The first is that pedestrian fatalities are not as likely to occur at low speeds for which the rate of HV pedestrian collisions is significantly higher than collisions between ICE vehicles and pedestrians. Today's final rule establishes minimum sound requirements for hybrid and electric vehicles operating at speeds up to 30 km/h (18.6 mph). A majority of pedestrian fatalities occur when the vehicle involved in the collision is not travelling at a low speed. Overall, 67 percent of the pedestrian fatalities involving HVs or EVs and with known speed limits occurred at a speed limit above 35 mph.[31] For all pedestrian fatalities with known speed limits, 62 percent occurred at a speed limit above 35 mph and 61 percent of those

[30] Wu, J., 2015, ''Updated Analysis of Pedestrian and Pedalcyclist Crashes of Hybrid Vehicles with Larger Samples and Multiple Risk Factors.''

[31] For those pedestrian fatalities that occurred on roads with a posted speed limit of 35 mph or less, we do not have any data on actual travel speed of the vehicles involved. Therefore, we are not able to tell if the vehicles involved were travelling at a speed at which they would be required to meet the requirements of the final rule.

involving passenger vehicles occurred at a speed limit above 35 mph.[32] The goal of this rule is to prevent injuries to pedestrians that result from pedestrians being unable to hear nearby hybrid and electric vehicles operating at low speeds. At speeds of 35 mph and above, at which a majority of fatal crashes involving pedestrians occur, it is very unlikely that lack of sound is the cause as the sound levels produced by hybrid and electric vehicles at those speeds are the same as the sound levels produced by ICE vehicles. Establishing minimum sound requirements for hybrid and electric vehicles operating at speeds up to 30 km/h is expected to prevent injury crashes but not necessarily have an impact on those crashes involving pedestrian fatalities, based on existing data.

The second reason is that the rate of pedestrian fatalities per registered vehicle for HVs and EVs is not larger (and is in fact smaller) than that for ICE vehicles. Using 2008 data, the fatality rate for pedestrians in crashes with HVs and EVs is 0.85 fatalities per 100,000 registered vehicles, and the corresponding rate for ICE vehicles is 1.57 per 100,000 vehicles.

There also could be fatalities involving HVs and EVs that occur in non-traffic crashes in places such as driveways and parking lots. However, a comprehensive search for HVs and EVs involved in pedestrian fatalities could not be undertaken because NHTSA's Not in Traffic Surveillance (NiTS) system does not provide VINs, and a search for model names that indicate hybrid or electric vehicles did not identify any crashes involving pedestrian fatalities.

Low-Speed Vehicles

NHTSA has no data on pedestrian or pedalcyclist crash rates for low-speed vehicles due to the low rate of sales of these vehicles as a percentage of the light vehicle fleet. NHTSA also has not found any examples of crashes involving LSVs and pedestrians or pedalcyclists that appear to be caused by the lack of sound in LSVs. However, we assume that the safety problem with these vehicles will be similar to that for HVs based on the acoustic profile of these vehicles.

Need for Independent Mobility of People Who Are Visually-Impaired

In addition to addressing the safety need in the traditional sense of injuries avoided as a result of preventing vehicle-pedestrian crashes, NHTSA believes it is important to note another dimension of safety that should be taken into account with respect to pedestrians who are blind or visually-impaired. Pedestrians who are blind or visually-impaired need to be able to travel independently and safely throughout their communities without fear and risk of injury, both as a result of collisions with motor vehicles and as a result of other adverse events in the environments they must negotiate. To a far greater extent than is the case for sighted people, vehicle sounds help to define a blind or visually-impaired person's environment and contribute to that person's ability to negotiate through his/her environment in a variety of situations.[33]

The modern white cane and the techniques for its use help the user to navigate and allow sighted people to recognize that a person is blind or visually-impaired. Today, the ''structured discovery'' method of teaching independent travel for visually-impaired people emphasizes learning to use information provided by the white cane, traffic sounds, and other cues in the environment to travel anywhere safely and independently, whether the individual has previously visited the place or not.

Whether a blind or visually-impaired person uses a white cane or guide dog, the primary purpose of both travel tools is to help the blind traveler identify and/or avoid obstacles in his or her path using the sense of touch. The remaining information needed by a blind or visually-impaired person to safely and independently travel is provided primarily through the sense of hearing.

When traveling with a white cane or guide dog, the primary sound cue used by blind pedestrians is the sound of vehicle traffic, which serves two purposes: navigation and collision avoidance. Navigation involves not only ascertaining the proper time to enter a crosswalk and maintain a straight course through an intersection while crossing, but also the recognition of roadways and their traffic patterns and their relationship to sidewalks and other travel ways a blind or visually-impaired person might use.

Sound emitted by individual vehicles, as opposed to the general sound of moving traffic, is critical. The sound of individual vehicles helps to alert blind travelers to the vehicle's location, speed, and direction of travel. For example, a blind or visually-impaired person moving through a parking lot can hear and avoid vehicles entering or exiting the lot or looking for parking spaces; a blind person walking through a neighborhood can hear when a neighbor is backing out of a driveway. The vehicle sound also indicates to a blind or visually-impaired pedestrian whether a vehicle is making a turn, and if so, in which direction. The sound of individual vehicles also allows the blind traveler to detect and react to unusual or unexpected vehicle movement. The sound of a vehicle that has an activated starting system but is stationary (usually referred to as ''idling'' for vehicles with internal combustion engines) alerts the blind or visually-impaired traveler to the fact that the vehicle is not simply parked and that it may move at any moment. If a blind person is approaching a driveway and notes a vehicle that is stationary but running he or she will wait for the vehicle to pull out, or for an indication that it will not, for example by noting that the vehicle remains stationary for some time, indicating that the driver has no immediate plans to move.

In the NPRM, the agency described how the acoustic cues provided by vehicles help blind pedestrians discern changes in the road-way, determine whether an intersection has a traffic control device, and navigate intersections with unusual characteristics such as three-way intersections or roundabouts. The sounds made by traffic including the sounds of idling vehicles allow blind pedestrians to determine when it is safe to cross the street and maintain a straight travel path while walking through the intersection.

Using the white cane or guide dog and the sound of traffic, people who are blind or visually-impaired have been able to navigate safely and independently for decades. Blind and visually-impaired people travel to school, the workplace, and throughout their communities to conduct the daily functions of life primarily by walking and using public transportation. Safe and independent pedestrian travel is essential for blind or visually-impaired individuals to obtain and maintain employment, acquire an education, and fully participate in community life. Short of constantly traveling with a human companion, a blind or visually-impaired pedestrian simply cannot ensure his or her own safety or navigate effectively without traffic sound. To the extent that there are more and more HVs and EVs on the road that are hard to

[32] Data particularly tied to other speeds, such as 20 mph, is not available because of the structure of the databases used, *i.e.,* the relevant data variable is whether the speed limit was above or below 35 mph at the crash location.

[33] National Federation of the Blind (2011) How People Who are Blind Use Sound for Independent Travel, memorandum to the docket, NHTSA–2011–0148–0028, Washington, DC. That memorandum is the source for this information.

detect, people who are blind or visually-impaired will lose a key means—the sound of traffic—by which they determine when it is safe to cross streets, but also by which they orient themselves and navigate safely throughout their daily lives, avoiding dangers other than automobiles.

*C. Research on Vehicle Emitted Sounds and Detectability*

Early Research on Quiet Vehicles and Public Meeting

NHTSA began collaborating with a working group within the Society of Automotive Engineers International (SAE) in August 2007 to identify effective ways to address the safety issue of quiet hybrid and electric vehicles. This working group included representatives from the Alliance of Automobile Manufacturers, Global Automakers, the visually impaired community and NHTSA.

On June 23, 2008, NHTSA held a public meeting to bring together government policymakers, stakeholders from the visually impaired community, industry representatives, and public interest groups to discuss the technical and safety policy issues associated with hybrid vehicles, electric vehicles, and quiet internal combustion engine (ICE) vehicles, and the risks they present to visually impaired pedestrians. After this public meeting, NHTSA issued a research plan to investigate hybrid and electric vehicles and pedestrian safety.[34] The objectives of the research plan were to identify critical safety scenarios for visually impaired pedestrians, identify requirements for blind pedestrians' safe mobility (emphasizing acoustic cues from vehicles and ambient conditions), identify potential countermeasures, and describe the countermeasures' advantages and disadvantages.

In 2009 NHTSA issued the report ''Incidence of Pedestrian and Bicyclist Crashes by Hybrid Electric Passenger Vehicles,'' discussed in Section II.B of this notice, and a report titled ''Research on Quieter Cars and the Safety of Blind Pedestrians, A Report to Congress.''[35] The report to Congress briefly discussed the quieter vehicle safety issue, how NHTSA's research plan would address the issue, and the status of the agency's implementation of that plan.

In 2010 through 2014 the agency continued relevant quiet car research as briefly discussed below.

Phase 1 Research

In April 2010, NHTSA issued a report that began addressing the tasks listed in the research plan. This report, titled ''Quieter Cars and the Safety of Blind Pedestrians: Phase I,'' documents the overall sound levels and general spectral content for a selection of ICE vehicles and HVs in different operating conditions, evaluates vehicle detectability for two background noise levels, and considers the viability of countermeasure concepts categorized as vehicle-based, infrastructure-based, and systems requiring vehicle-pedestrian communications.[36]

The results show that the overall sound levels for the HVs tested are noticeably lower at low speeds than for the ICE vehicles tested. Overall, study participants were able to detect any vehicle sooner in the low ambient noise condition. ICE vehicles tested were detected sooner than their HV counterpart vehicles except for the test scenario in which the target vehicle was slowing down. In this scenario, HVs were detected sooner because of the distinctive sound emitted by the regenerative braking system on the HVs. Response time to detect a target vehicle varies by vehicle operating condition, ambient sound level, and vehicle type (*i.e.,* ICE vehicle versus HV or EV mode).

As part of Phase 1 research, NHTSA sought to identify operating scenarios necessary for the safety of visually impaired pedestrians. The researchers identified these scenarios based on crash data, literature reviews, and unstructured conversations with blind pedestrians and orientation and mobility specialists. Scenarios were defined by combining pedestrian vehicle environments, vehicle type, vehicle maneuver/speed/operation, and considerations of ambient sound level. The operating scenarios identified in Phase 1 were: Vehicle approaching at low speed; vehicle backing out (as if coming out of a driveway); vehicle travelling in parallel and slowing (like a vehicle that is about to make a turn); vehicle accelerating from a stop; and a vehicle that is stationary.

In Phase 1, NHTSA also compared the auditory detectability of HVs and ICE vehicles by pedestrians who are legally blind. Forty-eight independent travelers, with self-reported normal hearing, listened to binaural[37] audio recordings of two HVs and two ICE vehicles in three operating conditions, and two different ambient sound levels. The operating conditions included a vehicle: Approaching at a constant speed (6 mph); backing out at 5 mph; and slowing from 20 to 10 mph (as if to turn right). The ambient sound levels were a quiet rural (31.2 dB(A)) and a moderately noisy suburban ambient (49.8 dB(A)). Overall, participants took longer to detect the two HVs tested (operated in electric mode), except for the slowing maneuver. Vehicle type, ambient level, and operating condition had a significant effect on response time.

Table 5 shows the time-to-vehicle arrival at the time of detection by vehicle type, and ambient condition. Considering all three independent variables, there was a main effect of vehicle, vehicle maneuver, and ambient sound level. Similarly, there were interaction effects between vehicle type and ambient, vehicle type and maneuver, ambient and vehicle maneuver, and a three way interaction between ambient, vehicle type and vehicle maneuver.

TABLE 5—AVERAGE TIME-TO-VEHICLE ARRIVAL BY SCENARIO, VEHICLE TYPE, AND AMBIENT SOUND

| Scenario | Low ambient | | High ambient | |
|---|---|---|---|---|
| | HVs | ICE vehicles | HVs | ICE vehicles |
| Approaching at 6 mph | 4.8 | 6.2 | 3.3 | 5.5 |
| Backing out at 5 mph | 3.7 | 5.2 | 2.0 | 3.5 |

[34] A copy of the research plan is available at *www.regulations.gov* (Docket No. NHTSA–2008–0108–0025).

[35] Research on Quieter Cars and the Safety of Blind Pedestrians, A Report to Congress. U.S. Dept. of Transportation, Washington, DC, October 2009, available at *http://www.nhtsa.gov/DOT/NHTSA/NVS/Crash%20Avoidance/Technical%20Publications/2010/RptToCongress091709.pdf.*

[36] Garay-Vega, et al. (2010) Quieter Cars and the Safety of Blind Pedestrians: Phase I, Report No. DOT HS 811 304, U.S. Dept. of Transportation, Washington, DC. Available at *http://www.nhtsa.gov/DOT/NHTSA/NVS/Crash%20Avoidance/Technical%20Publications/2010/811304rev.pdf.*

[37] Binaural recordings reproduce the acoustic characteristics of the sound similar to how a human perceives it. Binaural recordings reproduce a more realistic three dimensional sensation than conventional stereo and are intended for playback through headphones, rather than loudspeakers.

TABLE 5—AVERAGE TIME-TO-VEHICLE ARRIVAL BY SCENARIO, VEHICLE TYPE, AND AMBIENT SOUND—Continued

| Scenario | Low ambient | | High ambient | |
|---|---|---|---|---|
| | HVs | ICE vehicles | HVs | ICE vehicles |
| Slowing from 20 to 10 mph | 2.5 | 1.3 | 2.3 | 1.1 |

The Phase 1 research showed that HVs were more difficult for pedestrians to detect by hearing than ICE vehicles. The Phase 1 research report also discussed various countermeasures to mitigate pedestrian safety risks associated with quiet vehicles. The Phase 1 report also concluded that a vehicle-based audible alert signal was the countermeasure that both provided all the necessary information to blind pedestrians to make safe travel decisions and produced benefits for other pedestrians and for pedalcyclists.

Phase 2 Research

In October 2011 NHTSA released a second report examining issues involving hybrid and electric vehicles and blind pedestrian safety titled ''Quieter Cars and the Safety of Blind Pedestrians, Phase 2: Development of Potential Specifications for Vehicle Countermeasure Sounds.'' [38] The Phase 2 research developed various methods to specify a sound to be used as a vehicle-based audible alert signal that could be used to provide information at least equivalent to the cues provided by ICE vehicles, including speed change, and evaluated sounds using human factors testing to examine whether the sounds could be detected and recognized as vehicle sounds. This research used acoustic data acquired from a sample of ten ICE vehicles to examine the sound levels at which synthetic vehicle sounds used could be set, and used psychoacoustic models to examine issues of detectability and masking of ICE-like sounds and alternative sounds, and also included a human factors study to examine the detectability of synthetic sounds.

The methods for specifying sounds discussed in the Phase 2 final report assumed that the vehicle acoustic countermeasure should:

• Provide information at least equivalent to that provided by ICE vehicles, including speed change; and

• Provide for detection of a vehicle in residential, commercial, and other suburban and urban environments in which blind pedestrians would expect to be able to navigate using acoustic cues. **Note:** Human factors tests for Phase 2 were conducted in an ambient of approximately 58–61 dB(A).

As part of the Phase 2 research, Volpe conducted a human factors study to compare the auditory detectability of potential sounds for hybrid and electric vehicles operating at a low speed and how those sounds compared to an ICE control vehicle. The human factors testing in Phase 2 suggested that synthetic sounds resembling an ICE produce similar detection distances as actual ICE vehicles. In some instances, the results indicated that synthetic sounds designed according to psychoacoustic principles can produce double the detection distances relative to the reference vehicle. The results also suggested that synthetic sounds that contain only the fundamental combustion noise are relatively ineffective. None of the analyses found a significant effect of vision ability.[39] Participants who were legally blind, on average, were no better or worse than sighted participants in detecting the approach sounds.

Phase 3 Research

In order to develop possible test procedures and requirements for an FMVSS proposing to establish minimum acoustic requirements for hybrid and electric vehicles, NHTSA initiated a third phase of research to develop an objective, repeatable test procedure and objective specifications for minimum sound requirements. NHTSA's Vehicle Research and Test Center (VRTC), as part of its effort to develop a test procedure, conducted acoustic measurements and recordings of several HVs and EVs and those vehicle's ICE pair vehicles.[40] Volpe used these recordings as well as data from the Phase 1 and Phase 2 research to identify parameters and criteria for sounds to be detectable and recognizable as a motor vehicle.

VRTC Acoustic Measurements

The primary focus of Phase 3 research conducted by VRTC was to develop an objective and repeatable test procedure to measure vehicle-emitted sound. This work consisted mainly of evaluation of the new SAE J2889–1, *Measurement of Minimum Noise Emitted by Road Vehicles,* test method, and several variations used to test operating conditions that were not included in SAE J2889–1, and development of a practical test procedure for collecting test track acoustic data from HVs, EVs and ICE vehicles. The data collected was then evaluated to begin establishing potential performance criteria. The draft version of SAE J2889–1 used by VTRC included recommended procedures for measuring minimum sound pressure levels of vehicle-emitted sound but did not include any recommended performance requirements for minimum levels of vehicle-emitted sound. SAE J2889–1 was still in draft form at the start of the research, but the version published in September 2011 was not significantly different from the draft.

The research was conducted using three HVs, one EV, and four ICE vehicles. The vehicles were used to gather sample data on the difference in sound pressure levels between ICE sounds and EV or HV sounds. VRTC also gathered data to determine how synthetic vehicle sounds emitted from speakers projected around the vehicle, as referred to as the directivity of the sound, and sound quality levels. Some of the hybrid and electric vehicles were tested with multiple alert sounds. Some of the hybrid and electric vehicles were also tested with no alert sound at all, to examine the difference between the sound pressure level produced by hybrid and electric vehicles and ICE vehicles.

One of the purposes of the Phase 3 acoustic measurements was to gather additional data on the difference in sound levels between ICE vehicles and EVs and HVs operating in electric mode. For the pass-by tests at 10 km/h in Phase 3, the ICE vehicles were between 6.2 and 8.5 dB(A) louder than the EV/

[38] Garay-Vega, et al. (2011) Quieter Cars and the Safety of Blind Pedestrians, Phase 2: Development of Potential Specifications for Vehicle Countermeasure Sounds, Report No. DOT HS 811 496. Dept. of Transportation, Washington, DC. Available at *http://www.nhtsa.gov/DOT/NHTSA/NVS/Crash%20Avoidance/Technical%20Publications/2011/811496.pdf.*

[39] All participants were required to wear a blindfold during the study.

[40] Evans and Harris. (2012) Quieter Vehicle Performance Test Development Research Report, U.S. Dept. of Transportation, Washington, DC. Available at *www.regulations.gov*, Document ID: NHTSA–2011–0148–0047.

HVs without added sound. At 20 km/h the difference between the HV/EVs and ICE vehicles varied, but the average delta was 3.5 dB(A) louder for the ICE vehicles. At 30 km/h the sound levels of the HV/EVs approached the levels of the ICE vehicles and the individual measurements for the two types of vehicles have considerable overlap. Table 6 shows the results of HV/EV vehicles with no sound alert as compared to their ICE counterparts.

TABLE 6—PASS-BY SOUND LEVEL FOR HV/EV VEHICLES WITHOUT ALERT SOUND VERSUS COUNTERPART ICE VEHICLES

| Manufacturer | Speed, km/h | HV/EV Sound Level, dB | ICE Sound Level, dB | ICE minus HEV/EV, dB |
|---|---|---|---|---|
| Nissan | 10 | 50.5 | 56.6 | 6.1 |
| | 20 | 60.0 | 62.3 | 2.3 |
| | 30 | 66.5 | 68.1 | 1.6 |
| Prototype Vehicle G | 10 | 51.4 | 59.9 | 8.5 |
| | 20 | 60.5 | 63.1 | 2.6 |
| | 30 | 67.0 | 67.5 | 0.5 |
| Prototype Vehicle H | 10 | 51.2 | 59.7 | 8.5 |
| | 20 | 59.3 | 64.5 | 5.2 |
| | 30 | 65.3 | 69.2 | 3.9 |
| Average | 10 | 51.0 | 58.7 | 7.7 |
| | 20 | 59.9 | 63.3 | 3.4 |
| | 30 | 66.3 | 68.3 | 2.0 |

The measurements from the startup and stationary but active scenarios were used to measure the directivity of the vehicles' sound. The purpose of measuring the directivity pattern of the vehicles was to compare the directivity pattern of ICE vehicles to those hybrid and electric vehicles equipped with a speaker system. For the ICE vehicles, the sound pressure level behind the vehicle was 6 to 10 dB lower than that directly in front of the vehicle. For the hybrid and electric vehicles with a speaker system, the sound level behind the vehicle was 12 to 15 dB lower behind the vehicle. There was a systematic difference from left to right for some vehicles, particularly with an artificial sound.

Volpe Acoustic Analysis

As another part of the Phase 3 research, Volpe conducted an analysis of existing acoustic data and data collected during the previously mentioned VTRC testing to develop recommendations for performance requirements for minimum levels of vehicle emitted sound to be proposed in the NPRM. This work consisted of examining the frequency ranges, minimum sound levels for selected one-third octave bands, and requirements for broadband noise and tones as possible criteria for setting minimum requirements for vehicle-emitted sound. Evaluations were conducted using a loudness model [41] to determine when the sounds might be detectable in a given ambient. Of the several different loudness models examined by Volpe, Moore's Loudness provided the most pertinent information about the perceived loudness and detectability of a sound. Two approaches were used to identify potential detectability specifications for alert sounds to be included in the NPRM: (1) Sound parameters based on a loudness model and detection distances and (2) sound parameters based on the sound of ICE vehicles.

Volpe's work in developing the sound specifications based on a loudness model and detection distances was guided by several aspects of the agency's Phase 1 and Phase 2 research. Volpe analyzed the acoustic data of the sounds used in the human factors research in Phase 2 from a psychoacoustic perspective to determine the loudness of the sounds and whether the sounds would be detectable in several different ambient environments. Because the response of the study participants in the human factors experimentation in Phase 2 varied significantly due to variations in the ambient,[42] Volpe determined that any analysis of sounds using a loudness model should use a synthetic ambient that did not vary with respect to the frequency profile or overall sound pressure level. Volpe used a synthetic ambient sound with the loudness model during Phase 3 in developing the specifications contained in the NPRM.

This research showed that pedestrians' ability to detect synthetic sounds would be maximized if the alert signal contains detectable components over a wide frequency range. The research also explored how tones and broadband content could enhance the detectability of synthetic alert sounds. The report used acoustic data for directivity to estimate minimum sound levels for 'reverse' or 'backing' maneuvers. Volpe then used the results of this analysis of the detectability of sounds as estimated by psychoacoustic models to make recommendations for potential minimum sound levels for the NPRM.

In addition to using psychoacoustic models to develop recommendations for minimum sound specifications, Volpe created a set of minimum sound specifications based on the sound produced by ICE vehicles. Volpe considered multiple minimum sound specifications in an attempt to derive at the most optimal approach for defining sound specification requirements in order to provide recommendations for a variety of sound specifications for NHTSA to seek comment on in the NPRM. Volpe created the specification based on the sound produced by ICE vehicles (using data captured during Volpe's Phase 2 research) and recordings of vehicles provided by automobile manufacturers. Volpe aggregated this data to create minimum acoustic specifications based on the mean sound levels of ICE vehicles and the mean sound levels of ICE vehicles minus one standard deviation.

Agency Research and Analysis Conducted Since the NPRM

After the NPRM was issued, NHTSA conducted research to examine additional aspects of minimum sound requirements for hybrid and electric vehicles. The research involved human

[41] Loudness models are computer simulations used to estimate the minimum sound levels needed for alert sounds to be detectable in the presence of ambient noise.

[42] Garay-Vega, et al. (2011) Quieter Cars and the Safety of Blind Pedestrians, Phase 2: Development of Potential Specifications for Vehicle Countermeasure Sounds, Report No. DOT HS 811 496. Dept. of Transportation, Washington, DC. Available at *http://www.nhtsa.gov/DOT/NHTSA/NVS/Crash%20Avoidance/Technical%20Publications/2011/811496.pdf.*

factors testing and acoustic modeling to examine the detectability of sounds with different acoustic characteristics. The research also involved acoustic measurement of heavy-duty vehicles and motorcycles, analysis of indoor testing conducted by Transport Canada, and additional light vehicle testing to refine the test procedure proposed in the NPRM. The research is documented in multiple separate research reports and is summarized below. In some cases, as identified below, more details of the research are provided in the appropriate sub-sections of Section III of this preamble. In those cases, the agency discusses the important aspects of the research that were utilized to make decisions finalized in this rule.

Human Factors Research and Acoustic Modeling

In the NPRM, NHTSA proposed minimum sound pressure levels for a specific set of one-third octave bands that included low frequency bands (315, 400, and 500 Hz) and high-frequency bands (2000, 2500, 3150, 4000, and 5000 Hz) for various operating conditions. These proposed specifications for minimum sound pressure levels were identified based on a psychoacoustic loudness modeling approach and safe detection distances.[43] After the NPRM was published, the agency conducted a study to quantify the differences between predicted detection levels of vehicle sounds in the presence of an ambient (as indicated by the loudness model) and the actual responses by participants listening to these vehicle sounds through headphones. This was done in order to evaluate the accuracy of the psychoacoustic model in predicting when sounds would be detected. The study also explored the effect of different factors such as the number of bands at threshold, adjacent and non-adjacent bands, and signal type (*e.g.,* pure tones, bands of noise).[44] In addition to the human factors study, Volpe also conducted an analysis of acoustic data in order to predict the probability that a sound would be detected in different ambients as the number of one-third octave bands making up the sound changes.

The key performance metrics for the human factors study were the response time and associated time-to-vehicle arrival. Response time is the elapsed time, in seconds, from the start of the trial to the instant the participant presses the push-button as an indication he/she detected the target signal. The time-to-vehicle arrival is the elapsed time, in seconds, from first detection of a target signal to the instant the vehicle passes the pedestrian location. The detection distance is the separation between the vehicle and the pedestrian location at the moment of detection. The detection distance can be computed from the time-to-vehicle arrival and vehicle speed. Signals meeting the minimum sound levels, computed according to the approach described in the NPRM, are expected to be detectable at least 2.0 seconds or 5 meters away (for a vehicle approaching at 10 km/h). Table 7 shows the time-to-vehicle arrival and detection distances for the signals examined in this study. The signals used in the study included sounds developed by Volpe to test different hypotheses involving the detection model, recordings of prototype synthetic sounds provided by vehicle manufacturers, and a recording of an ICE vehicle. The ''Source'' column in Table 7 describes the origin of each sound.

TABLE 7—SOUND STIMULI TESTED

| Signal ID | Significant component frequencies, Hz | Levels, dB(A) | Source | Comment | Time-to-vehicle arrival, s | Vehicle distance at detection, m |
|---|---|---|---|---|---|---|
| 3 | 315, 400, 500, 630, 2000, 2500, 3150, 4000, 5000. | Threshold | Simulation | Tone @315 Hz, TNR 9 dB. | 4.9 | 13.6 |
| 6 | 315, 400, 500, 630, 2000, 2500, 3150, 4000, 5000. | Threshold | Simulation | Tone @630 Hz, TNR 9 dB. | 4.3 | 11.9 |
| 9 | 315, 400, 500, 630, 2000, 2500, 3150, 4000, 5000. | Threshold | Simulation | Tone @2500 Hz, TNR 9 dB. | 4.5 | 12.5 |
| 10 | 315, 400, 500, 630, 2000, 2500, 3150, 4000, 5000. | Threshold | Simulation | NNPRM + 630 Hz | 4.4 | 12.2 |
| 11 | 315 | Threshold | Simulation | Single Noise Band | 2.3 | 6.4 |
| 12 | 630 | Threshold | Simulation | Single Noise Band | 2.9 | 8.1 |
| 13 | 2500 | Threshold | Simulation | Single Noise Band | 2 | 5.6 |
| 14 | 315, 400, 500, 2000, 2500, 3150, 4000, 5000. | Threshold | Simulation | NPRM | 4.3 | 11.9 |
| 15 | 50 to 10,000 | Threshold | Simulation | Noise in all Bands | 4.6 | 12.8 |
| 17 | 315, 400, 500 | 46, 54, 48 | Prototype Recording. | ASG as Recorded (No calibration). | 5.8 | 16.1 |
| 18 | 315, 400, 500, 2000, 2500, 3150, 4000, 5000. | Threshold | Prototype Recording. | ASN (Calibrated to match NPRM). | 4.5 | 12.5 |
| 19 | 2500 | 56 | Prototype Recording. | ASN as Recorded (No calibration). | 5.8 | 16.1 |
| 20 | 315, 400, 500, 2000, 2500, 3150, 4000, 5000. | Threshold | Prototype Recording. | ASV Sound4 (Calibrated to match NPRM). | 6.7 | 18.6 |
| 23 | 4000, 5000, 6300, 8000, 10000 | 37, 36, 34, 32, 31. | ICE Recording | ASF ICE (No Calibration). | 3.1 | 8.6 |
| 25 | 315, 400, 500 | Threshold | Simulation | Low Frequency Noise | 4.2 | 11.7 |
| 26 | 315, 630, 2000, 5000 | Threshold | Simulation | Non-adjacent Noise | 4.5 | 12.5 |
| 27 | 630, 800, 1000, 1250, 1600 | Threshold | Simulation | Mid-frequency Noise | 3.7 | 10.3 |
| 28 | 800, 2500 | 39, 45 | Simulation | 1 below threshold, 1 at threshold. | 2.2 | 6.1 |
| 29 | 800, 2500 | 45, 39 | Simulation | both below threshold | 1.4 | 3.9 |

[43] Hastings, et al. (2012). Research on Minimum Sound Specification for Hybrid and Electric Vehicles. Docket NHTSA–2011–0148–0048.

[44] Hastings, et al. Detectability of Alert Signals for Hybrid and Electric Vehicles: Acoustic Modeling and Human Subjects Experiment. (2015) Washington, DC: DOT/NHTSA.

TABLE 7—SOUND STIMULI TESTED—Continued

| Signal ID | Significant component frequencies, Hz | Levels, dB(A) | Source | Comment | Time-to-vehicle arrival, s | Vehicle distance at detection, m |
|---|---|---|---|---|---|---|
| 30 | 800, 2500 | 50, 50 | Simulation | 1 ~ threshold, 1 above threshold. | 3.6 | 10.0 |
| 31 | 2000, 2500, 3150, 4000, 5000 | Threshold | Simulation | High Frequency Noise | 3.2 | 8.9 |
| 32 | 315 | Threshold | Simulation | Pure Tone | 3.1 | 8.6 |
| 33 | 630 | Threshold | Simulation | Pure Tone | 2.9 | 8.1 |
| 34 | 2500 | Threshold | Simulation | Pure Tone | 2.4 | 6.7 |

The data showed that all signals tested in the study exceeded the 2.0-second detection criterion except for signal 29, which was detected 1.4 seconds before pass-by.[45] Exceeding the 2.0-second detection criterion was expected for signals with content in more than one one-third octave band, since the modeled thresholds were based on a signal with content in a single band. Content in multiple one-third octave bands could increase the time-to-vehicle arrival if subjects aggregated the energy across bands or if they utilized a 'best' single band strategy. That is, with more one-third octave bands, the signal can be more easily detected either because it is stronger overall or because, given the many possible random factors that could affect detectability, more components creates a greater probability that at least one band will be easier to detect.

An ICE vehicle (signal 23), without calibration to minimum one-third octave band levels for detection used in the NPRM, was detected 3.1 seconds away on average. Two prototype alert signals (signals 17, 19), without calibration to minimum one-third octave band levels for detection used in the NPRM, were detected 5.8 seconds away. In general, signals with a pure tone (signals 32, 33, 34) were detected sooner than signals with a single band of noise at the same frequency (signals 11, 12, 13). For example, the average time-to-vehicle arrival was 3.1 seconds for a pure tone at 315 Hz and 2.3 seconds for a single band of noise at the same frequency. A statistical analysis also found that the interaction of sound type (tones or noise) and frequency was significant.

The study results indicated that, except for frequency sensitivity for high frequency components, the modeling approach for determining detection thresholds was conservative, meaning that the study participants were able to detect sounds sooner than predicted by the model. In order to correct for frequency sensitivity differences and to develop the best agreement between modeled detection thresholds and those of the participants so that the minimum one-third octave band levels for detection in the final rule more closely align with pedestrians' ability to detect sounds in the real world, Volpe performed a linear regression to reconcile the predicted detection values in the model and the performance of the participants in the experiment.

In order to ensure that the model was as predictive of real-world experience as possible, that is, in order to obtain the best agreement between modeled detection thresholds and those of the participants, and also to correct for frequency sensitivity differences, Volpe did a series of linear regressions using different loudness metrics. The best agreement between modeled and actual participant detection times occurred when a detection threshold of 0.079 sones[46] per ERB was used[47] (see Figure 1). The R-squared value achieved for this model was 0.72, indicating that the model performs well on average although, as anticipated, outcomes are not always exactly the same due to random variation and other differences between the model predictions and participant performance. Thus, the agency chose to use the detection threshold of 0.079 sones per ERB in the Moore's model as the basis for deriving the revised minimum levels for each of the one-third octave bands in the final rule.

[45] Signal 29 had two components, and the levels were set below the minimum detection thresholds.

[46] Sone is a unit of subjective loudness on a linear scale. The Moore's Loudness model used by the agency in the NPRM and this final rule utilizes loudness (in sones) and partial loudness (in sones per equivalent rectangular bandwidth or ''ERB'') parameters as a basis for determining thresholds, *i.e.,* minimum sound levels, required for vehicle detection.

[47] Hastings A.; and McInnis, C. ''Detectability of Alert Signals for Hybrid and Electric Vehicles: Acoustic Modeling and Human Subjects Experiment'' Docket NHTSA–2011–0148. Washington, DC: DOT/NHTSA.

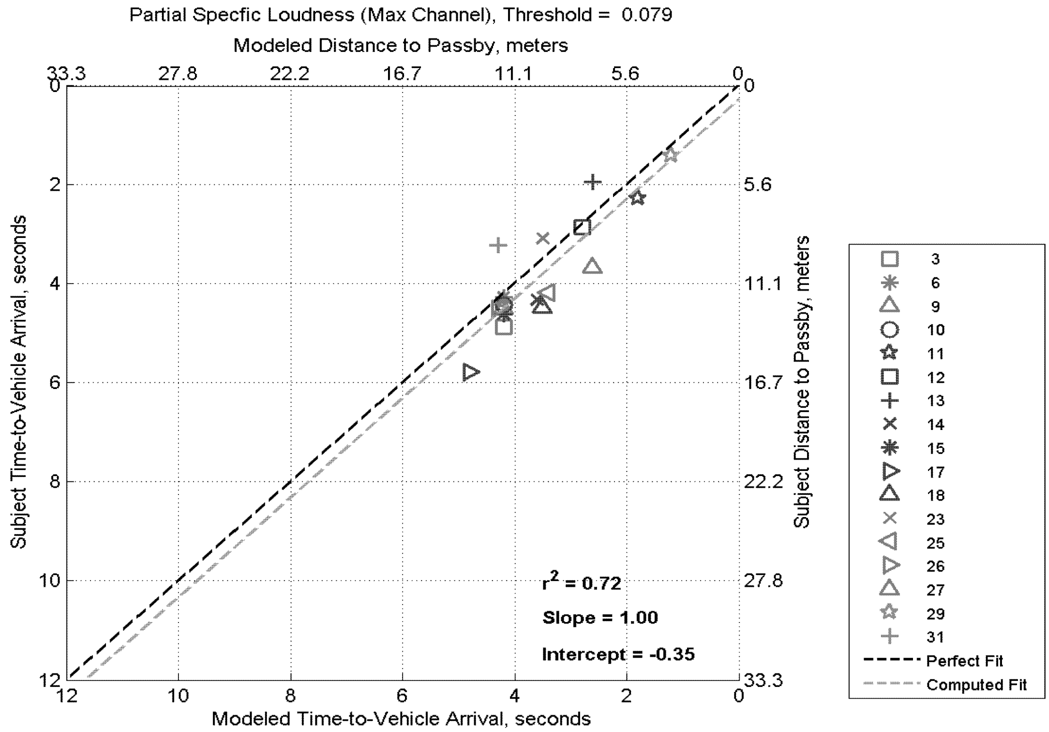


**Figure 1. Metric and Criterion with Best Agreement between Modeled and Subject Time-to-Vehicle Arrival. (Signal identification numbers are explained in Section II.C)**

The agency also conducted an analysis of acoustic recordings to evaluate the detectability of signals with varying numbers of non-adjacent components in the presence of additional ambient conditions different from the standardized ambient used to develop the one-third octave band minimum levels for detectability in the NPRM or this final rule. The analysis provides an estimate of how often pedestrians would be able to detect a sound signal in a 55 dB(A) ambient, with expected spectral variation, as a function of the number of one-third octave bands meeting the revised minimum thresholds.[48] Ambient data were collected at 17 locations along Centre Street in Newton, Massachusetts, signalized and stop-controlled intersections (some with relatively high traffic volume and some removed from the main road), one-way streets, and side streets or driveways. The spectral shape of the ambient varies from sample to sample, as would be expected given the different locations in which they were collected. Some samples are dominated by low frequency content while other samples are dominated by high frequency content or have a mix of high and low frequency content. Each ambient sample was normalized to an overall sound pressure level of 55 dB(A), so that the effect of the spectral content of each ambient on the detectability of a signal could be examined in isolation from other variables. This analysis differs from the modeling approach used to develop the minimum one-third octave band levels for detection in the NPRM and the final rule because that approach used a single ambient that was chosen for consistency in development of minimum standards. NHTSA refers to the resistance to masking of a signal evaluated using this analysis as the ''robustness'' of the signal. Signals evaluated for robustness contained from one to seven non-adjacent components within the 315 to 5000 Hz frequency range. In most cases, these signals were scaled so that the components just met the minimum one-third octave band levels for detectability derived from the human factors study.

This analysis predicted that, as ambient conditions vary, the probability that at least one component is detectable increases with increasing number of components when each component is set to the minimum detection levels calculated based on the human factors study. This is true for all operating conditions. For signals with content in 1, 2, 3, 4, 5, 6, and 7 one-third octave bands, the predicted probabilities were about 55, 81, 93, 97, 98, 100, and 100 percent, respectively. The analysis indicates that there is a rapid increase in detectability as the number of components increases from 1 band to 4 bands when each band is set at the specified minimum detectable level. Additional bands beyond 4 do not appear to increase the detectability level significantly. An eight-band sound was not included in the analysis because eight non-adjacent one-third octave bands do not fit in the frequency range over which we are establishing minimum requirements in the final rule. This analysis also showed that some signals with content in only 2 one-third octave bands are expected to be detected with the same frequency in multiple ambients as signals with content in 4 one-third octave bands. Because signals with content in 2 one-third octaves bands could be equally detectable as sounds with content in 4 one-third octave bands the agency decided to include minimum requirements for content in either 2 or 4 one-third octave bands in the final rule.

Heavy Vehicle and Motorcycle Testing

The research NHTSA conducted prior to the NPRM focused exclusively on

[48] For practical reasons, this analysis is limited in that it includes 17 measurement locations for the ambient that are in one State, Massachusetts. Also, ambient samples were not categorized or weighted according to 'preferred crossable' opportunities for pedestrians.

light vehicles. However, since issuing the NPRM, the agency has conducted some acoustic measurements on hybrid and electric heavy-duty vehicles (GVWR over 10,000 lb.) and electric motorcycles.[49] The test protocol used for those measurements followed procedures in SAE–2889–1 (May 2012).

Two electric motorcycles were tested at the Transportation Research Center in Columbus, Ohio, on a test surface conforming to ISO 10844–2011 specifications. NHTSA was able to apply the proposed test procedure to the motorcycles without major issues.[50] The overall sound pressure levels for a 2012 model Brammo Enertia were 57.0, 63.2 and 66.5 dB(A) for the 10, 20, and 30 km/h pass-by, respectively. The overall sound pressure levels for a 2012 model Zero S were between 6.2 to 7.9 dB lower with 49.1, 57.0 and 59.6 dB(A) for the 10, 20, and 30 km/h pass-by, respectively.

The one-third octave band levels for the two motorcycles were computed and compared to the minimum levels needed for detection (as determined in NHTSA's research described in Section II.C [51]) in the frequency range from 315 Hz to 5000 Hz. Results for the 2012 Brammo Enertia show that the measured levels were equal or greater than the minimum levels in two bands for the 10 km/h pass-by and in three bands for the 20 km/h pass-by. Sound levels for the Enertia for the 30 km/h pass-by did not meet the minimum levels for detection in any one-third octave bands from 315 Hz to 5000 Hz. Sound levels for the 2012 Zero S did not meet the minimum levels for detection in any of the bands for all pass-by tests (*i.e.,* 10, 20, and 30 km/h). While there is an appreciable difference between the two models tested, these results indicate that both models operate quietly over all or part of the range of speeds up to 30 km/h.

As discussed in Section III.B, the agency has determined that, as with other types of hybrid and electric vehicles, it is appropriate that the requirements of this final rule should apply to hybrid and electric motorcycles.

NHTSA also collected acoustic data for a pure electric heavy vehicle (Navistar eStar two-axle delivery van) on a surface compliant with ISO 10844 and suitable for heavy vehicles. No issues were encountered in applying the test protocol to the heavy vehicle tested. It is important to note that only this one delivery truck was tested. The agency was unable to obtain electric or hybrid heavy-duty vehicles with different sizes and configurations for testing. The overall sound pressure levels for the Navistar eStar were 55.4, 64.5, 73.4, and 75.2 dB(A) for the stationary, 10, 20, and 30 km/h pass-by scenarios, respectively. The acoustic measurements for this vehicle were computed and compared to the minimum levels needed for detection in the frequency range from 315 Hz to 5000 Hz.[52] The data showed that the measured one-third octave band levels for the e-Star heavy vehicle are equal to or greater than the minimum levels for detection in seven bands for stationary, nine bands for the 10 km/h pass-by, eight bands for the 20 km/h pass-by, and seven bands for the 30 km/h pass-by. Thus, this vehicle generated appreciable sound at low speeds without the addition of a pedestrian alert system, and we would expect this vehicle to be detectable. However, because this testing was limited to only one electric truck, the agency is not able to reach any general conclusions that hybrid and electric heavy vehicles should be exempt from the final rule.

The agency also collected ''screening'' data for four hybrid and electric heavy-duty vehicles. Screening tests were conducted in the field (not on ISO 10844 sound pads) at convenient locations using portable sound level meters. We note that the test protocol used for the screening tests did not fulfill all the parameters stated in SAE–J2889–1, and the measurements may not have been within the constraints of the SAE standard for acoustic environment, operating conditions, test surface, number of microphones, and microphone position. The results obtained from screening data therefore may deviate appreciably from results obtained using protocols and test conditions that strictly adhere to the SAE standard. Data were collected at three locations, Dayton, Ohio; Washington, DC; and Cambridge, Massachusetts. The four vehicles in the screening tests were all transit buses and included a New Flyer diesel-electric hybrid bus in Washington, DC; a trackless electric trolley bus and a diesel-electric hybrid trolley bus in Dayton, and a Neoplan trackless electric trolley bus in Cambridge. Each vehicle was tested in as many of the applicable operating scenarios (stationary, 10, 20, and 30 km/h pass-by) as possible. However, due to vehicle or site limitations, not all vehicles were tested in all of those operating scenarios.

The screening data showed that the overall levels for these vehicles range from 55.9 to 59.0 dB(A) for a stationary test; 61.7 to 69.3 dB(A) for a 10 km/h pass-by test; and 66 to 70.3 dB(A) for a 20 km/h pass-by test. The acoustic measurements for these vehicles were computed and compared to the NPRM minimum levels for detection in the frequency range from 315 Hz to 5000 Hz, for the eight bands included in the NPRM.[53] The data showed that the measured levels for the heavy vehicles tested are equal to or greater than the minimum levels in five to seven bands for stationary; five to eight bands for the 10 km/h pass-by; two to five bands for the 20 km/h pass-by; and seven bands for the 30 km/h pass-by. The screening data were informative about hybrid and electric medium-duty and heavy-duty vehicle noise levels, but they were not intended to be conclusive, and thus the agency did not determine from this testing that it would be appropriate to exclude medium and heavy vehicles from the final rule.

Analysis of Indoor Test Data

NHTSA also analyzed acoustic data measured in hemi-anechoic chambers equipped with a chassis dynamometer.[54] The data acquired at indoor test facilities included measurements of electric, hybrid, and internal combustion engine vehicles. NHTSA's analyses examined ambient noise, repeatability, and reproducibility of the indoor acoustic measurements. Acoustic data were collected at two indoor facilities: The General Motors Milford Proving Grounds (MPG), in Milford, MI and the International Automotive Components (IAC) facility,

[49] Hastings, et al. Acoustic Data for Electric Heavy Vehicles and Electric Motorcycles. (2014) DOT/NHTSA.

[50] One notable change is that the motorcycles were run just to the right of the center of the lane with respect to the direction of travel. This was done so the motorcycles' tires were not rolling on the painted center line, since it was important to keep the tires on the portion of the test track which had pavement meeting the ISO specification (the painted center line is not intended to meet the ISO specification.) Additionally, motorcycles were not tested in reverse since they did not have reverse capabilities.

[51] Hastings, et al. Detectability of Alert Signals for Hybrid and Electric Vehicles: Acoustic Modeling and Human Subjects Experiment. (2015) Washington, DC: DOT/NHTSA. As described in this report, the minimum levels needed for detection were determined using an acoustic loudness model that was adjusted for actual human hearing responses to vehicle sounds and other sounds by using the results of a series of human factors experiments conducted by Volpe for NHTSA.

[52] Hastings, et al. Detectability of Alert Signals for Hybrid and Electric Vehicles: Acoustic Modeling and Human Subjects Experiment. (2015) Washington, DC: DOT/NHTSA.

[53] Hastings, et al. Detectability of Alert Signals for Hybrid and Electric Vehicles: Acoustic Modeling and Human Subjects Experiment. (2015) Washington, DC: DOT/NHTSA.

[54] Hastings, et al. Analysis of Acoustic Data for Hybrid and Electric Vehicles measured on Hemi-Anechoic Chambers. Washington, DC: DOT/NHTSA. A hemi-anechoic chamber is a specially-designed room with walls that absorb sound waves for better acoustic analysis.

in Plymouth, MI. Indoor test data was provided to NHTSA by Transport Canada.[55] Outdoor test data were collected by NHTSA's Vehicle Research and Test Center (VRTC) at the Transportation Research Center (TRC), East Liberty, OH, and NHTSA did a comparison of indoor and outdoor measurements. The dataset available to support these analyses included eight vehicles. Test vehicles were transported between the Milford and Plymouth facilities so that the exact same vehicles were used at both indoor test sites. Vehicle make and model were consistent between indoor and outdoor testing,[56] but the outdoor test results have been aggregated over several testing efforts and do not in all cases represent the exact same test vehicles.

Repeatability at each indoor test site was evaluated by computing the standard error of the mean for each one-third octave band from the sound pressure measurements, considering each measurement as an estimate of the mean for each vehicle. The standard errors for these two indoor test sites were typically around 0.5 to 0.75 dB for the 315 Hz one-third octave band and above. This indicates that about 95 percent of measured one-third octave band levels for a given vehicle and operating speed will be within a range of ±1 to ±1.5 dB and, when estimating a mean value using four samples, the mean value should be within about 0.5 to 0.75 dB of the true mean with 95-percent confidence.

Measurement reproducibility between the two indoor test sites was evaluated by comparing the average values of each vehicle at each one-third octave band for each speed. The differences between sites were about 2 dB on average at 10 km/h and only about 1 dB on average at 20 and 30 km/h. Although the average difference is generally less than 2 dB between the two sites, differences for specific vehicle/speed/frequency pairs are still significant. When considering site-to-site differences, the 95-percent confidence intervals for estimated means range from ±2.5 dB to ±6.7 dB depending on the one-third octave band. Bands at and below 400 Hz consistently have standard deviations greater than 2 dB and bands 500 Hz and above typically have standard deviations less than 2 dB (exceptions being 630 Hz and 800 Hz). The reproducibility between sites appears good. We believe the measurement differences are due to inherent test variability, as discussed in section III.K of this document, and also to differences in each site's dynamometer/tire interaction.

In addition to comparing the two indoor test sites to one another, both facilities were also compared with outdoor measurements made at TRC. Measurement reproducibility between each indoor test facility and the outdoor test facility was evaluated by comparing the average sound pressure levels of each vehicle at each one-third octave band for each speed at the respective sites. Results showed that the indoor facilities tend to have higher sound pressure levels, especially at 20 and 30 km/h. Because the differences are smaller at 10 km/h, it is not likely that the differences in acoustic reflections from the indoor floor and the outdoor pavement are causing the difference. Rather, it is likely that the tire/dynamometer interaction is producing the higher sound pressure levels. Considering confidence intervals of estimated mean values for individual vehicle/speed/frequency pairs, the standard deviation between TRC and MPG was as high as 5 dB and the standard deviation between TRC and IAC was as high as 4.7 dB. Therefore, tolerance values associated with 95-percent confidence intervals would be as large as ±9.8 and ±9.2 dB respectively.

These confidence intervals include site-to-site differences and differences as a result of using different vehicles and in some cases different model years. It is anticipated that this confidence interval would be reduced if identical vehicles were tested. This indoor/outdoor analysis involved only a very limited amount of data and the data in some cases was not from the exact same vehicle. The agency would prefer to conduct additional testing in a more highly controlled fashion to allow for more conclusive results. In the absence of that, we have not changed our position on using outdoor testing as proposed in the NPRM.

Acoustic Measurements of Hybrid and Electric Vehicles

NHTSA's VRTC conducted additional acoustic measures for hybrid vehicles, electric vehicles, low speed electric vehicles, and internal combustion engine (ICE) vehicles to collect additional sound measurements and to evaluate the repeatability of the test procedure proposed in the NPRM.[57] Sound levels were measured while vehicles were stationary and while they were driving or coasting past microphones at constant speeds of 10, 20, and 30 km/h.

The repeatability of the measurement of the sound pressure level was assessed by performing multiple tests with one vehicle (a 2010 Ford Fusion) on one surface. The TRC ISO-compliant surface was used for this work and tests were performed twice a month from April to October 2012. Each test consisted of eight individual measurements for each scenario. Results showed that the 95-percent confidence interval of the overall sound pressure level ranged from ±0.7 dB to ±1.9 dB for the various scenarios. There was no significant systematic change in overall sound pressure levels over the six month period.

Data were also collected at different ISO 10844-compliant surfaces to examine test reproducibility. The reproducibility of sound pressure levels was estimated by testing the 2010 Ford Fusion twice on two other ISO-compliant surfaces (at Ford Motor Company Proving Ground in Romeo, Michigan, and at the Navistar Test Track in Fort Wayne, Indiana). The average sound pressure levels for all scenarios on the other ISO surfaces fell within the experimental errors of the average sound pressure levels measured on the TRC ISO surface. The 95-percent confidence interval of site-to-site variation for overall sound pressure level ranged from ±0.6 dB to ±2.1 dB and the 95-percent confidence estimates for reproducibility, including the repeatability of the measurements, ranged from ±1.3 dB to ±2.4 dB.

To determine if acoustic testing locations could include test areas with surfaces that are not ISO-compliant, the agency investigated using correction factors to adjust data from non-ISO-compliant surfaces, the agency compared overall sound pressure levels measured on ISO 10844-compliant surfaces to overall sound pressure levels measured on three other asphalt surfaces of varying characteristics. The alternative surfaces were located at TRC in East Liberty, OH, and included: A new asphalt surface in the vehicle dynamics area; a sealed asphalt surface; and a skid calibration lane. These pavements were appropriate examples of potential test surfaces that are not ISO-compliant to examine the impact that testing using different surfaces may have on measuring vehicle sound.

Overall sound pressure levels on the three asphalt surfaces were compared to the results on the TRC ISO surface using the 2010 Ford Fusion, and an EV with

[55] Whittal, I.; Jonasch, R.; and Meyer, N. Quiet Vehicle Sounds Test Data (2013) Transport Canada. Docket NHTSA–2011–0148–0321.

[56] Indoor results from a 2012 Nissan Leaf were compared to outdoor results from a 2010 Nissan Leaf.

[57] Garrott, W. R., Hoover, R. L., Evans, L. R., Gerdus, E., and Harris, J. R., ''2012 Quieter Vehicle Testing Report: Measured Sound Levels for Electric, Hybrid Electric, and Low Speed Vehicles'' Washington, DC, DOT/NHTSA, November 2016.

an active external sound generator, as well as an EV without an active external sound generator. Results showed that one surface tended to produce overall sound pressure levels significantly lower than the ISO-compliant surface at 0 and 10 km/h. Researchers concluded that this was due to greater absorptivity of this asphalt composition. The other two surfaces tended to generate results not significantly different than the ISO-compliant surface when the vehicles were stationary or traveling at 10 km/h. On these surfaces, sound levels increased more rapidly than for the ISO surface as the vehicle speed increased. The overall sound pressure levels at 20 and 30 km/h tended to be significantly higher for these two surfaces compared to the ISO surface. Researchers concluded that these surfaces tended to generate more tire noise than the ISO-compliant surface. An attempt to use the data from the Ford Fusion to normalize the sounds from the different surfaces was unsuccessful. Consequently, we did not conclude that it is feasible to test on surfaces other than an ISO-compliant one.

To examine the sound levels emitted by low speed electric vehicles (LSVs), VRTC tested five of examples of these vehicles. LSVs typically are lighter than EVs and often use different tires, so it was prudent to conduct separate measurements of LSVs rather than assume they are as quiet as EVs. The sound levels produced by the LSVs were very similar to those of the EVs, with the main difference being that four of the LSVs were equipped with back-up beepers of varying sound pressure levels. Other than during reverse acceleration, the LSVs showed overall sound levels with standard deviations ranging from about 1 to 2.5 dB.

To provide data for the agency's analysis of the crossover speed of HVs and EVs, the agency tested additional HVs and one EV as well as a number of ICE peer vehicles (in cases where a peer vehicle was available for the HVs and the EV selected for testing) and compared the ICE peer vehicle test results to the HV and EV results. At 10 km/h, the three HVs tested (none with external sound generators) had an average SPL 2.4 dB lower than their ICE peer vehicles. An EV without an active external sound generator had an average SPL 7.3 dB lower than its ICE peer vehicle. At 20 km/h, the three HVs (none with external sound generators) had an average sound pressure level 1.1 dB lower than their ICE peer vehicle and the EV without external sound had an average sound pressure level of 3.5 dB below its ICE peer vehicle. At 30 km/h the HVs and EV had sound pressure levels that were not significantly different from their ICE peer vehicles. One-third octave band data and comparisons were also reported.

In addition, the agency compared the sound pressure levels of ICE vehicles in motion with their engines running to the same ICE vehicles coasting past the microphones with their engines turned off. These comparisons were made at 10, 20, and 30 km/h. The sound pressure levels for the vehicles with their engines running were an average of 7.9 dB higher than in the coasting (engine-off) condition at 10 km/h (min. 4.3 dB, max. 11.6 dB); 2.2 dB higher than in the coasting (engine off) condition at 20 km/h (min. 0.6 dB, max. 5.7 dB); and 0.9 dB higher than in the coasting (engine off) condition at 30 km/h (min. 0.5 dB; max. 1.7 dB).

*D. Notice of Proposed Rulemaking*

In the NPRM we proposed to apply the minimum sound requirements to all hybrid and electric passenger cars, light trucks and vans (LTVs), medium and heavy-duty trucks and buses, low speed vehicles (LSVs), and motorcycles, that are capable of propulsion in any forward or reverse gear without the vehicle's ICE operating.

The proposed minimum sound requirements would apply to these HVs and EVs in three circumstances: (1) When operating up to 30 km/h (18 mph), (2) when the vehicle's starting system is activated but the vehicle is stationary,[58] and (3) when the vehicle is operating in reverse. The NPRM also contained requirements for the sound produced by hybrid and electric vehicles to increase and decrease in pitch as the vehicle increases and decreases speed so that pedestrians would be able to detect those changes. We proposed a crossover speed of 30 km/h because this was the speed at which tire noise, wind resistance noise, and other noises from the vehicle become the dominant noise and eliminate the need for added alert sounds.[59]

The agency proposed to require HVs and EVs to make a minimum amount of sound in each of eight different one-third octave bands, under each of several test conditions. The agency developed the minimum sound levels for each one-third octave band using a detection model that estimated the distance at which a pedestrian would be able hear a given sound in the presence of a given ambient sound profile. In the NPRM, NHTSA proposed to require eight one-third octave bands with the perspective that required sounds should be detectable in a wide variety of ambients, including ambients that had different acoustic characteristics from the ambient that we used with our detection model. The NPRM also required that sound produced by EVs and HVs be recognizable to pedestrians as motor vehicle sounds by containing low frequency tones and broadband content because these are characteristics commonly associated with sounds produced by internal combustion engines.

The compliance test procedure specified in the NPRM was to be performed outdoors and was based in part on SAE J2889–1 SEPT 2011. The compliance test procedure contained tests for stationary, reverse, and pass-by tests conducted at 10 km/h, 20 km/h, and 30 km/h. We explained in the NPRM that NHTSA believed that outdoor pass-by testing would be preferable to indoor testing in hemi-anechoic chambers using dynamometers because outdoor testing is more representative of the real-world interactions between pedestrians and vehicles. We also expressed concern that specifications for indoor testing were not as developed and did not have the same level of objectivity, repeatability, and reproducibility as test specifications for outdoor testing.

The NPRM proposed a phase-in schedule consistent with the PSEA which would require ''full compliance with the required motor vehicle safety standard for motor vehicles manufactured on or after September 1st of the calendar year that begins 3 years after the date on which the final rule is issued.'' In the NPRM we stated that if the final rule was issued January 4, 2014, compliance would commence on September 1, 2015, which would mark the start of a three-year phase-in period. The NPRM proposed the following phase-in schedule:

- 30 percent of the subject vehicles produced on or after September 1 of the first year of the phase-in;
- 60 percent of the subject vehicles produced on or after September 1 of the second year of the phase-in;
- 90 percent of the subject vehicles produced on or after September 1 of the third year of the phase-in; and
- 100 percent of all vehicles produced on or after, by September 1 of

[58] The NPRM contained minimum sound requirements for the stationary but active condition because the definition of alert sound in the PSEA requires the agency to issue minimum sound requirements to allow pedestrians to detect the operation of nearby hybrid and electric vehicles, including those vehicles that are operating but stationary.

[59] For additional details about how and why the agency selected the crossover speed of 30 km/h refer to section III.D. in this document.

the year that begins three years after the date that the final rule is issued.

In the NPRM, we tentatively concluded that this phase-in schedule was reasonable for manufacturers and allowed the fastest implementation of the standard for pedestrian safety.

*E. Summary of Comments to the NPRM*

The agency received comments to the NPRM from a wide variety of commenters, including trade associations,[60] vehicle manufacturers,[61] advocacy groups,[62] suppliers,[63] academia,[64] standards-development organizations,[65] governments,[66] and approximately 225 individuals.

The primary issues raised by the advocacy groups and manufacturers concerned our proposal to require sound while hybrid and electric vehicles are stationary but active and our proposal to establish minimum sound requirements up to a speed of 30 km/h. Manufacturers and trade association groups argued that a sound at stationary is not required for safety. These commenters stated NHTSA should instead mandate a commencing motion sound that activated when the driver of an HV/EV removed her foot from the brake pedal. Manufacturers and trade associations also commented that the agency should only establish minimum sound requirements up to 20 km/h, arguing that above 20 km/h tire and wind noises are the dominant contributors to the sound produced by moving vehicles, and provide enough sound for pedestrians to safely detect hybrid and electric vehicles.

NFB and ACB supported the agency's proposal to require that hybrid and electric vehicles produce sound in the stationary but active operating condition, because it would help blind and visually-impaired pedestrians be aware of nearby vehicles and avoid collisions. NFB, ACB, and Advocates also supported the agency's proposal to establish minimum sound requirements for speeds up to 30 km/h, stating that they believe that the agency's research supports establishing minimum sound requirements to those limits.

Manufacturers and groups that represent manufacturers were supportive of the concept of adding sound to EVs and HVs to enhance pedestrian detection but expressed concern that the minimum sound requirements proposed in the NPRM were more restrictive than necessary to accomplish this goal. They argued that sounds meeting the requirements proposed in the NPRM would be annoying to consumers and might negatively affect sales of hybrid and electric vehicles. Regarding the agency's proposed compliance test procedure, manufacturers and groups that represent manufacturers requested the option to conduct compliance testing in indoor hemi-anechoic chambers using dynamometers, arguing that that is a more accurate and consistent method of testing because it is a more controlled environment that minimizes the kind of ambient variations that are expected in outdoor environments. They also raised issues regarding the agency's proposed method of measuring a vehicle's change in pitch as it increases or decreases speed, commenting that pitch shifting should be measured using a component-level test, *i.e.,* a bench test procedure, rather than testing the entire vehicle.

Manufacturers also disagreed with the agency's estimate of the cost of speaker systems needed to produce sounds capable of complying with the requirements in the NPRM, stating that speakers capable of producing the low frequency content specified in the proposed minimum sound requirements were more expensive than the agency estimated.

Organizations that represent manufacturers of motorcycles and heavy-duty and medium-duty vehicles took issue with the agency's basis for applying the rule to the vehicles they manufacture, stating that the agency had not shown a safety need based on crash data. They stated that the final rule should not apply to those vehicles because hybrid and electric motorcycles and heavy- and medium-duty trucks and buses do not pose an increased risk to pedestrians over ICE vehicles.

A number of individual commenters either expressed general support for the rule or general opposition to increasing the amount of sound produced by hybrid and electric vehicles. Several individuals also questioned why the agency was limiting the scope of the proposed rule to hybrid and electric vehicles. These commenters stated that the minimum sound requirements in the NPRM should apply to all vehicles including ICE vehicles that do not produce enough sound to be safely detected by pedestrians.

## III. Final Rule and Response to Comments

*A. Summary of the Final Rule*

Today's final rule generally adopts the proposed standard but modifies the requirements in several ways. As proposed, we will require hybrid and electric vehicles to emit sound at minimum levels while the vehicle is stationary (although not necessarily at all times when the vehicle propulsion system is active); while the vehicle is in reverse; and while the vehicle is in forward motion up to 30 km/h. Today's final rule also adopts the agency's proposal to conduct compliance testing outdoors.

The agency is adopting numerous changes to the proposal in response to additional analysis conducted by the agency and in response to the comments on the proposal. The most significant change relates to the scope of the final rule. This final rule only applies to hybrid and electric passenger cars and LTVs with a GVWR of 4,536 kg (10,000) pounds or less and LSVs. This final rule does not apply to medium and heavy duty trucks and buses with a GVWR over 4,536 kg (10,000) pounds or to motorcycles. Based on a review of the available acoustic data regarding these vehicles and the comments, we have determined that we do not have enough information at this time to apply this final rule to medium and heavy duty vehicles and motorcycles.

We have determined the final rule should apply to LSVs, because unlike electric motorcycles and medium and heavy duty trucks and buses with a GVWR over 4,536 kg (10,000) pounds, we have acoustic data showing that LSVs are quiet. Therefore, we do not have any justification to exclude them

[60] The trade associations representing manufacturers that submitted comments included the International Motorcycle Manufacturers Association (IMMA), the Truck and Engine Manufacturers Association (EMA), the Electric Drive Transportation Association (EDTA), the Motorcycle Industry Council (MIC) and the Organization Internationale DES Constructeurs d' Automobiles (OICA). The Alliance of Automobile Manufacturers and Global Automakers submitted a joint comment that is referenced here as the ''Alliance/Global'' comment.

[61] Such as Toyota Motor North America (Toyota), Volkswagen Group of America (Volkswagen), Porsche Cars North America (Porsche), Ford Motor Company (Ford), American Honda Motor Co. (Honda), Mercedes-Benz USA (Mercedes), General Motors Company (General Motors), Mitsubishi Motors R&D of America (Mitsubishi), Chrysler Group LLC (Chrysler), Navistar, Inc. (Navistar), Nissan North America, Inc. (Nissan) and BMW of North America, LLC (BMW).

[62] The public safety advocacy groups submitting comments to the proposal included National Federal of the Blind (NFB), National Council of State Agencies of the Blind, the Advocates for Highway Safety (the Advocates), Noise Pollution Clearinghouse, the Insurance Institute for Highway Safety (IIHS), Safe Kids Worldwide, the World Blind Union, and American Council of the Blind (ACB).

[63] Such as Denso International America, Inc. (Denso) and Hear for Yourself, LLC.

[64] Such as the Mercatus Center at George Mason University, Western Michigan University (Western Michigan), and Accessible Designs for the Blind (ADB).

[65] SAE International.

[66] The European Commission Enterprise and Industry Directorate-General (DG Enterprise), and the Disability and Communication Access Board of Hawaii.

from the coverage of the final rule given the requirements of PSEA.

We have also made significant changes to the detectability specifications in the NPRM, *i.e.,* what sounds HV/EVs are permitted to make that the agency would consider compliant with the standard. After further consideration of the NPRM specifications, we are establishing new specifications in this final rule that provide greater flexibility for manufacturers in this respect, but that will still allow pedestrians to safely detect EVs and HVs. Specifically, whereas in the NPRM we proposed that HV/EVs would have to meet minimum acoustic requirements in eight separate one-third octave bands, in this final rule, the agency is providing two alternative acoustic specifications, either of which the agency would consider to be compliant, and both of which reduce the number of one-third octave bands for which there are minimum levels. Under the first compliance option, hybrid and electric vehicles would have to meet minimum acoustic requirements in four one-third octave bands instead of eight. Under the second compliance option, hybrid and electric vehicles would have to meet minimum acoustic requirements in two one-third octave bands, plus meet an overall sound pressure minimum.

Under the four one-third octave band compliance option, the minimum sound requirements for each band would be slightly lower than the values proposed in the NPRM and the overall sound pressure of sounds meeting the four one-third octave band compliance option will be similar to those meeting the proposed requirements for eight bands in the NPRM. Under the two one-third octave band compliance option, the minimum sound requirements for each band are lower than those of the eight one-third octave band proposal in the NPRM for the low and mid frequency bands and higher than the minimum values in the NPRM for the high frequency one-third octave bands centered at 4000 Hz and 5000 Hz. Neither the four-band compliance option nor the two-band compliance option include requirements for tones or broadband content contained in the NPRM.

For both the two-band and four-band compliance options, the final rule expands the range of acceptable one-third octave bands to include those between 630 Hz and 1600 Hz (these bands were excluded in the NPRM). Reducing the number of required one-third octave bands while expanding the number of possible bands that manufacturers can use to meet the minimum requirements provides additional flexibility to manufacturers for designing pedestrian alert systems. Sounds meeting these new requirements will have a similar overall sound pressure level to those meeting the requirements in the NPRM. These changes preserve the agency's goal of establishing requirements that will lead to pedestrian alert sounds that are detectable in ambient sound environments with different spectral shapes. The detectability specifications are discussed further in Section III.E of this final rule.

The agency originally proposed to require ''pitch shifting,'' meaning that as HV/EVs increased or decreased in speed (from stationary up to the cutoff of 30 km/h), the frequency of the sound produced by the HV/EV had to vary up or down with speed by one percent per km/h. After further consideration, we have concluded that the proposed pitch shifting compliance test is likely to have repeatability issues and may involve subjective assessments in compliance evaluations. For those reasons, and also in response to information raised in manufacturers' comments, the agency has decided instead to require simply that the vehicle-emitted sound increase and decrease in volume by a specified amount as the vehicle's speed increases and decreases. The agency believes this revised requirement, like the proposed pitch shifting requirement, will appropriately convey to pedestrians when a vehicle is accelerating or decelerating. This approach also has a testing advantage in that changes in vehicle speed and corresponding changes in vehicle-produced sound can be determined using the same data collected during the stationary and constant-speed pass-by tests. This issue is discussed further in Section III.G of this final rule.

The agency also proposed to require the pedestrian alert sound to contain a low frequency tone under 400 Hz to aid recognizability by pedestrians, stating that this would make the required alert sounds more similar to ICE vehicle sounds which typically include low frequencies. Based on additional analysis indicating that low-frequency tones are not essential for vehicle-emitted sounds to be recognized as motor vehicles in operation, and manufacturer comments arguing that low-frequency tones would be intrusive to vehicle occupants and expensive to reproduce, we have decided against including the proposed requirement in the final rule. Section III.F discusses this issue in more detail.

Also to aid recognizability, we originally proposed to require that the vehicle-emitted sounds contain broadband sound between 160 Hz and 5000 Hz. This means sound across a wide range of frequencies, and reflects the fact that ICE vehicles produce broadband sound when operating at low speed. We agree with commenters that this requirement is not critical for sound recognition because we believe that pedestrians will use other sound cues that provide more information in order to recognize sounds meeting the requirements of the final rule as vehicle-emitted sounds. In addition to the revised requirement that the alert sound level must increase as a vehicle increases speed, we believe that pedestrians would use other cues to recognize EVs and HVs such as the location of the sound source and the frequency and level changes caused by the motion of the sound, so tones and broadband content are not essential for these vehicles to be recognizable. This issue is discussed more in Section III.F of this final rule.

With regard to test procedures, the final rule also makes a number of changes from the proposal. We have modified the procedure for determining whether the sound produced by two hybrid or electric vehicles of the same make, model, and model year is the same. After further analysis, we have determined that requiring the sound produced by two hybrid or electric vehicles of the same make, model, and model year to be within three dB(A) for every one-third octave band between 315 Hz and 5000 Hz would not guarantee that the sound produced by the two vehicles would be the same. We have instead decided to ensure that EVs and HVs of the same make, model, and model year produce the same sound by requiring that all vehicles of the same make, model, and model year use the same alert system hardware and software, including specific items such as the same digital sound file where applicable, to produce sound used to meet the minimum sound requirements in today's final rule. We have also made numerous other changes to the proposed test procedures in response to comments.

While we have retained the requirement that EVs and HVs must generate an alert when stationary, the final rule requires an alert only when a vehicle's transmission gear selector is not in the ''Park'' position. We have changed the test procedure accordingly, and we will test this condition with the vehicle's gear selector in ''Drive'' or any forward gear. We believe that this modification to the stationary requirement will provide pedestrians with a way to detect those vehicles that pose the greatest risk to them (*i.e.,* those vehicles that could begin moving at any moment) while ensuring that EVs and HVs do not produce unwanted sound in situations in which they do not pose a threat to pedestrians, such as when they are parked. The final rule requirements and procedures also address vehicles with manual transmission. Test procedures are discussed in more detail in Sections III.J and III.K of this preamble.

With regard to the phase-in schedule for the standard, we have simplified the proposed phase-in schedule by shortening it to include a single year of phase-in, rather than the three-year phase-in that the agency proposed in the NPRM. This simplification provides somewhat greater lead-time and responds to vehicle manufacturers' comments that the proposed phase-in was unnecessarily complex. Half of each manufacturer's HV and EV production must comply with this final rule by September 1, 2018, and 100 percent of each manufacturer's HV and EV production must comply with this final rule by September 1, 2019. The phase-in does not apply to multi-stage and small volume manufacturers: 100 percent of their HV and EV production must comply with this final rule by September 1, 2019.

### *B. Applicability of the Standard*

#### Definition of a Hybrid Vehicle

The PSEA defines ''hybrid vehicle'' as ''a motor vehicle which has more than one means of propulsion.'' As discussed in the NPRM, we concluded that the definition in the PSEA requires the agency to apply the standard only to hybrid vehicles that are capable of propulsion without the vehicle's ICE operating, because if the ICE is always running when these vehicles are operating, then the fact that these vehicles may not provide sufficient sound for pedestrians to detect them cannot be attributed to the type of propulsion. Under the agency's interpretation of the definition of ''hybrid vehicle'' in the PSEA, more than one means of propulsion therefore means more than one *independent* means of propulsion. This definition of ''hybrid vehicle'' would exclude from the applicability of the proposed standard those vehicles that are equipped with an electric motor that runs only in tandem with the vehicle's ICE to provide additional motive power, for example a vehicle that cannot operate in a purely electric drive mode.

The NPRM also stated that the PSEA did not limit the definition of ''hybrid vehicle'' to hybrid-electric vehicles, so the proposed rule would apply to any vehicle with multiple independent means of propulsion. However, the definitions section of the NPRM regulatory text did not include a specific definition of ''hybrid vehicle.''

Alliance/Global and OICA disagreed with the agency's proposal that the standard should apply to any vehicle with multiple independent means of propulsion, and argued that it should apply only to those vehicles that have an electric motor as the additional means of independent propulsion. Alliance/Global and OICA stated they do not believe that vehicles with non-electric hybrid powertrains should be subject to the requirements of the final rule, because the agency has not demonstrated that those vehicles are quiet. Alliance/Global and OICA also stated that the final rule should include a definition of ''hybrid vehicle'' in paragraph S4 of the regulatory text.

#### Agency Response to Comments

We agree that a definition of ''hybrid vehicle'' should be included in the rule and have added one. The definition appears in Section S4 of the regulatory text, and is based on the definition for a hybrid vehicle that was presented in the ''Application'' section of the NPRM preamble, where we stated that a hybrid vehicle is ''a motor vehicle that has more than one means of propulsion for which the vehicle's propulsion system can propel the vehicle in the normal travel mode in at least one forward drive gear or reverse without the internal combustion engine operating.''

In response to the industry request to limit the scope of the rule to only HVs with an electric motor as the additional means of propulsion, we are aware that some alternative hybrid vehicles may use something other than an electric drive system in conjunction with an ICE, for example, a hybrid that uses hydraulic or flywheel energy storage in place of electric motor and batteries, although we currently are not aware of hybrid vehicles other than hybrid-electrics that are for sale in the U.S.

Regardless of whether such vehicles are currently available for sale, however, we continue to believe that any hybrid operating under an independent, non-ICE means of propulsion should be required to meet the minimum sound requirements of this standard because we have no evidence that they may *not* be capable of operating as quietly as electric hybrids. From a safety perspective, the agency is concerned with all hybrids that might operate quietly, regardless of the power source for their non-ICE propulsion, and commenters provided no information about whether hybrid vehicles other than hybrid-electrics would be any less quiet than hybrid-electric vehicles when not equipped with pedestrian alert systems. As for hybrids other than electric ones, if the vehicle produces sound levels in excess of those required by this final rule then no additional alert would be required; if not, an additional alert would be required.

#### Vehicles With a GVWR Over 10,000 lbs.

In the NPRM, we stated that the PSEA requires the agency to apply the requirements of the standard to all hybrid and electric motor vehicles which includes cars, multipurpose passenger vehicles, trucks, buses, low-speed vehicles and motorcycles.[67] However, we acknowledged that ICE vehicles with a gross vehicle weight rating (GVWR) over 10,000 pounds (lbs.) have a lower rate of collisions involving pedestrians than light ICE vehicles,[68] and we stated that we were not able to calculate a separate incidence rate for collisions between pedestrians and hybrid and electric vehicles with a GWVR over 10,000 lbs. because the number of those vehicles in the on-road vehicle fleet was extremely limited. Because we were not able to calculate a separate incidence rate for collisions involving pedestrians and hybrid and electric heavy vehicles, we did not calculate the benefits of applying the rule to them in the NPRM. We stated in the NPRM that we believe that as the number of these vehicles in the fleet increases, the difference in pedestrian collision rate between heavy HV/EVs and heavy ICE vehicles would be similar to the difference in pedestrian collision rate between light HV/EVs and light ICE vehicles.

The agency also recognized at the time of the NPRM that we had very limited data about the sound levels produced by hybrid and electric heavy vehicles. We also acknowledged that there are a limited number of test pads having pavements that meet ISO 10844, *Acoustics—Specification of test tracks for measuring noise emitted by road vehicles and their tires,* that can accommodate the extra weight of heavy vehicles.

Manufacturers and organizations that represent manufacturers of heavy-duty vehicles stated that NHTSA should not apply the final rule to heavy-duty vehicles because the agency had not established that these vehicles are quiet, could not demonstrate a safety need to

[67] The PSEA specifically excludes trailers from the scope of the required rulemaking.

[68] For the purposes of this document we refer to all motor vehicles with a GVWR over 10,000 lbs. as ''heavy-duty vehicles.''

merit applying the requirements of the proposal to these vehicles, and had not developed appropriate requirements and compliance tests for these vehicles. Safety advocacy organizations and organizations that represent individuals who are blind and visually-impaired, in contrast, stated that NHTSA should apply the requirements of the final rule to heavy-duty vehicles because these vehicles would pose an increased risk of collision with pedestrians if they were quiet.

EDTA stated in its comments that NHTSA should defer application of minimum sound requirements in the final rule to heavy-duty vehicles, motorcycles and low-speed vehicles until the agency establishes a more complete record showing the need for these vehicles to meet those requirements. EDTA further stated that if the agency found that the requirements in the final rule should apply to heavy-duty vehicles, motorcycles and low-speed vehicles, the agency should develop audibility specifications that reflect the technologies, duty cycles and uses, and sound profiles specific to these types of vehicles.

EMA and Navistar stated that NHTSA should exclude hybrid and electric vehicles with a GVWR over 10,000 lb. from the scope of this rulemaking until the agency identifies a potential unreasonable risk to safety caused by the quiet nature of these vehicles, develops acoustic requirements specifically for these vehicles, and develops appropriate compliance test procedures.

EMA stated that, in addition to the incidence rate of collisions between pedestrians and heavy vehicles, NHTSA also should consider the exposure level of pedestrians to being struck by heavy-duty vehicles. EMA stated that certain heavy vehicles such as truck tractors do not typically operate in environments where pedestrians are present, so their risk of collision with pedestrians is much lower than the risk for passenger cars. In addition to having lower rates of exposure to pedestrians, heavy-duty vehicles make up a small fraction of the on-road vehicle fleet when compared to light vehicles. EMA suggested that the risk of a pedestrian being struck by a heavy-duty vehicle is much lower than the risk of a pedestrian being struck by a light vehicle when the percentage of heavy vehicles in the on-road fleet and their exposure to pedestrians are considered. EMA further suggested that lower rate of collisions with pedestrians and the low exposure show that NHTSA should not apply a single countermeasure with the same test procedures to all hybrid and electric vehicles.

EMA stated that NHTSA does not have any acoustic data that shows that heavy-duty hybrid and electric vehicles are quieter than heavy ICE vehicles and pose a safety risk to blind and other pedestrians. EMA stated that the NPRM did not contain any data comparing the sound produced by heavy-duty ICE vehicles to heavy-duty hybrid and electric vehicles. EMA stated that without acoustic data on heavy vehicles, NHTSA is unable to know what the crossover speeds are for heavy-duty vehicles or whether heavy-duty vehicles produce sufficient sound that they do not need to be equipped with a sound generation device. In addition, EMA stated that the crossover speed developed for light vehicles might be inappropriate for heavy-duty vehicles. Because these vehicles have larger tires than light vehicles and often have more tires and have a less aerodynamic body design they produce more sound than light vehicles under the same operating conditions.

EMA stated in its comments that applying the requirements in the NPRM to heavy-duty vehicles would violate the PSEA because NHTSA has not determined a separate crossover speed for heavy vehicles. EMA stated that to comply with the PSEA NHTSA must determine the crossover speed for each type of heavy-vehicle to which the final rule would apply. EMA stated further that applying the NPRM to heavy-duty vehicles violates the Vehicle Safety Act because the NPRM did not assess whether a different standard was needed for heavy vehicles.

Advocates commented that NHTSA should apply the final rule to hybrid and electric heavy vehicles. Advocates suggested that as advances in alternative energy increase, there will be a greater number of these types of vehicles. Advocates stated ''the agency should consider its findings that pedestrians and pedalcyclists, especially the visually-impaired, utilize the different sound of heavy vehicles when compared with light vehicles to modify their estimation of when it is safe to undertake a movement, like crossing a road, which may vary with vehicular traffic.'' [69] For that reason, Advocates suggested NHTSA should consider establishing different acoustic requirements to ensure that pedestrians and others can accurately identify and distinguish between heavy and light EVs and HVs. Advocates further stated that NHTSA should standardize the backing sound across all heavy vehicles so that pedestrians and bicyclists can differentiate backing heavy vehicles from other vehicles.

ACB and NFB stated that the final rule should apply to heavy-duty hybrid and electric vehicles because these vehicles pose the same safety risks to pedestrians as light vehicles, and the number of these vehicles in the fleet will likely increase in the future.

Western Michigan University stated that if the intent of the rule is to address potential hazards to the travel of blind pedestrians, then potentially quiet hybrid and electric heavy-duty vehicles should be required to meet the minimum sound requirements in the final rule. WMU stated that it was not aware of research on the audibility of hybrid and electric buses or light rail vehicles but that it seemed better to err on the side of caution and include heavy-duty hybrid and electric vehicles in the coverage of the final rule.

Agency Response to Comments

Despite what was proposed in the NPRM, we have decided not to apply the requirements of this final rule to heavy-duty hybrid and electric vehicles. We reached this decision because we do not believe that we currently have enough information to determine whether the acoustic requirements or the crossover speed in this final rule are appropriate for heavy-duty hybrid and electric vehicles. Therefore, we plan to conduct further research on sound emitted by heavy-duty hybrid and electric vehicles before issuing a new NPRM proposing acoustic requirements for these vehicles.

As described in Section II.C, after NHTSA issued the NPRM, we conducted testing to examine the sound levels produced by heavy-duty electric and hybrid vehicles. The agency tested the Navistar eStar Electric Heavy Vehicle following the procedures in SAE J2889–1, MAY 2012, using an ISO asphalt pad meeting the specifications of International Standards Organization (ISO) 10844 ''Acoustics—Specification of test tracks for measuring noise emitted by road vehicles and their tyres.'' [70] The agency compared the acoustic recordings of the Navistar eStar to the four-band acoustic specifications in today's final rule. The eStar met or exceeded a number of minimum one-third octave levels at the 10, 20, and 30 km/h pass-by test conditions. According to the agency's detection model, given a background noise level at the standard ambient, a vehicle is detectable if it

[69] Document No. NHTSA–2011–0148–0270.

[70] Hastings, et al., (2014) Acoustic Data for Hybrid and Electric Heavy-duty Vehicles and Electric Motorcycles.

meets or exceeds the minimum levels for detection in at least one of thirteen one-third octave bands. So the eStar without any noise enhancements would be expected to be detectable at least in the standard ambient at the tested pass-by speeds. For the stationary test, the eStar had acoustic content that met or exceeded the minimum values in three non-adjacent one-third octave bands. So in many ambient environments, in addition to the standard ambient, the eStar without any enhancements would be expected to be detectable at stationary.

The agency also conducted screening tests in the field of the sound levels of a selection of other heavy-duty EVs and HVs using a simplified procedure. For these screening tests, NHTSA measured four different electric or hybrid-electric transit buses, as described in the agency's report ''Acoustic Data for Hybrid and Electric Heavy-duty Vehicles and Electric Motorcycles'' [71] which provides details of those measurements.[72] These screening tests were basic evaluations of the sound characteristics of these vehicles, and they were conducted at facilities belonging to transit agencies or at other suitable locations. Therefore they did not utilize an asphalt pad meeting the specifications in ISO 10844. Additionally, for these screening tests the agency used hand-held (or tripod-mounted) sound level meters rather than the requisite microphone array specified in SAE J2889–1.

In conducting these screening measurements, the agency only recorded results for the eight one-third octave bands for which we proposed requirements in the NPRM. The agency compared the measurements to the revised minimum detectability thresholds based on our human factors research.

Of the three vehicles the agency evaluated in the stationary condition, all had sound content in several bands, and all would have been detectable in some ambient conditions according to the agency's detection model. At the 10 km/h pass-by, all of the vehicles tested would be expected to be detectable according to the detection model. At the 20 km/h pass-by, three of the vehicles would be expected to be detectable according to the detection model, and two would have met the requirements of the final rule.[73]

This heavy vehicle screening data showed that some hybrid and electric heavy-duty vehicles may already make sufficient sound in some operating conditions to be detected by pedestrians according to the agency's model. Because the data the agency collected during screening testing is limited in scope and was not obtained on an ISO 10844 compliant surface, the agency needs to conduct further evaluation in this area before we can draw conclusions regarding the sound levels produced by these vehicles.

Furthermore, the agency does not have any data on the crossover speed of heavy vehicles. Given that heavy vehicles have very different tires and wind noise characteristics than light vehicles, and these factors heavily influence crossover speed, it is possible that the light vehicle crossover speed is inappropriate for heavy vehicles. The agency anticipates conducting further research and evaluation to make these determinations and, if it proves necessary, to develop separate acoustic requirements for these vehicles.

Regarding EMA and Advocates comments that the agency should develop a separate acoustic specification for heavy-duty vehicles, for the reasons discussed above NHTSA agrees and plans to conduct further evaluations on this issue.

Given that NHTSA has not yet established that heavy hybrid and electric vehicles are too quiet to be detected without a pedestrian alert system, and the agency has not determined that the same acoustic requirements and crossover speed for light vehicles in today's final rule are appropriate for heavy vehicles, we are excluding both those categories from the applicability section of today's final rule, and we anticipate conducting a separate rulemaking effort to address the potential need for pedestrian alert systems on those vehicles.

Electric Motorcycles

In the NPRM, we stated that we had tentatively concluded that the proposed rule should apply to electric motorcycles, because Congress defined ''electric vehicle'' broadly in the PSEA and did not exclude motorcycles from the definition. We acknowledged that the agency was not able to determine whether the incidence rate of collisions between pedestrians and electric motorcycles is different than the incidence rate of collisions between pedestrians and motorcycles with ICEs, but stated that we expected that the difference in pedestrian collision rates between electric motorcycles and their traditional ICE counterparts would be similar to the difference in pedestrian collision rates between light HVs and light ICE vehicles should the number of electric motorcycles in the fleet match the current market penetration of light HVs and EVs. Additionally, while we did not have data on the extent to which electric motorcycles are quieter than ICE motorcycles of the same type, we also noted that neither did we have information indicating whether electric motorcycles produced sound levels sufficient to allow pedestrians to detect these vehicles in time to avoid collisions. The NPRM did, however, cite crash statistics contained in BMW's comments on the NOI regarding incidents of motorcycle collisions with pedestrians. BMW cited data from NHTSA's General Estimates System (GES) for the period between 2005 and 2009 shows that 1.07 percent of the pedestrians injured in motor vehicle crashes were injured in crashes involving motorcycles to illustrate the low rates of crashes between motorcycles and pedestrians.[74]

We also stated in the NPRM that the proposal was technology-neutral and that it would be possible for electric motorcycles to meet the requirements in the NPRM without the use of a speaker system if they already produced sufficient sound to meet the performance requirements. We sought comment on whether the minimum sound requirements should be applied to electric motorcycles.

The comments that the agency received in response to the NPRM from organizations that represent motorcycle manufacturers for the most part reiterated the concerns expressed by MIC and BMW in response to the NOI. BMW and MIC stated in their comments to the NOI that, because of the unique attributes of motorcycles, there is no safety need for NHTSA to establish minimum sound levels for electric motorcycles. MIC reiterated this point in their NPRM comments. According to

[71] Hastings, et al., (2014) Acoustic Data for Hybrid and Electric Heavy-duty Vehicles and Electric Motorcycles.

[72] Using the informal measurement procedures to capture these recordings allowed the agency to gather data on heavy-duty hybrid and electric vehicles without the difficulty and expense of transporting these vehicles to a location where they could tested on a sound pad meeting the specifications of International Standards Organization (ISO) 10844 ''*Acoustics—Specification of test tracks for measuring noise emitted by road vehicles and their tyres*'' as required by SAE J2889–1.

[73] The agency only tested one of the four vehicles at 30 km/h.

[74] BMW's comments on the NOI. *Available at http://www.regulations.gov*, Docket No. NHTSA–2011–0100–0020. Referring to the data cited, BMW argued in its NOI comments that based on the number of crashes between motorcycles and pedestrians and the percentage of all pedestrian crashes involving motorcycles, there is no safety need for minimum sound requirements for electric motorcycles.

MIC and BMW, motorcycle riders are able to better see and avoid pedestrians than automobile drivers because their view is unobstructed by pillars and sun visors and they are more alert because they themselves are vulnerable road users. BMW and MIC maintained that because motorcycles are unstable at low speeds, riders are required to maintain a high level of alertness, which minimizes the likelihood of collisions with pedestrians during low speed maneuvers.

Also in their NOI comments, both BMW and MIC stated that adding a speaker system to a motorcycle could involve technical challenges not present for other vehicles because there is less space on the motorcycle to install the speaker and the weight of the speaker would have a greater impact on the vehicle's range. MIC and BMW also suggested that electric motorcycles should not be subject to the minimum sound level requirements in this proposal because electric motorcycles are not quiet.[75]

MIC commented in response to the NPRM that motorcycles should be exempt from meeting the minimum sound requirements in the final rule because motorcycles, both electric and ICE, pose less of a risk to pedestrians than other vehicles, citing statistics that the collision rate between motorcycles and pedestrians is 0.27 percent compared with 0.76 percent for other vehicles under conditions most likely to pose a threat to pedestrians (backing up, turning, entering or leaving parking spaces, starting, or slowing).[76]

MIC argued that NHTSA's assumption that electric motorcycles will show a similar increase in rate of pedestrian collisions as four-wheeled ''HEVs'' (MIC's term for hybrid and electric vehicles, collectively) is invalid because four-wheeled HEVs in fact do not pose a greater threat to pedestrians than ICE vehicles. MIC stated that the higher incidence of collisions between pedestrians and HEVs does not mean that HEVs collide with pedestrians at a higher frequency, arguing that NHTSA's comparison of incidence rates of pedestrian collisions between ICEs and HEVs to determine the overall frequency of pedestrian crashes between each group of vehicles is only valid if both classes of vehicles have similar overall crash rates. However, according to MIC, that is not the case, and the difference in overall crash rates is supported by FARS data which indicate that the overall crash rate for HEVs is only half of the overall crash rate for ICEs. MIC stated that the higher incidence rate of HEV-pedestrian collisions is likely to be artificial and driven by demographic factors other than sound, mainly that HEV drivers actually tend to be safer drivers on average, which makes their overall crash rate lower and which inflates their rate of pedestrian crashes as a percentage of all crashes. MIC pointed out that motorcycle pedestrian crash frequency is actually no higher than for ICEs. MIC stated that crash rate differences due to demographic factors are not uncommon and are, for example, what explain large differences in fatality rates between different types of motorcycles (*e.g.,* touring bikes compared to sport bikes). Overall, MIC concluded that, because motorcycles have a lower overall crash rate than four-wheeled vehicles, the risk they pose to pedestrians is actually lower than the incidence rate of motorcycle-pedestrian crashes might indicate.

MIC also argued that it is logical that motorcycles should have a lower rate of collisions with pedestrians because motorcycles require two hands to operate so there is a lower chance of the operator being distracted, which should decrease the risk to pedestrians.

MIC stated that, in addition to having a low rate of crashes involving pedestrians, electric motorcycles are not quiet. MIC referenced a report submitted in response to the NPRM by Brammo, Inc., a manufacturer of electric motorcycles, that MIC believes shows that by design, electric motorcycles are not silent vehicles when moving.[77] MIC stated that unlike EV automobiles, the engine and drivetrain are open and exposed to the surrounding environment, and will produce sound levels that exceed the sound level minimums proposed by NHTSA. MIC stated that two motorcycles tested by Brammo, the Empulse and the Enertia Plus, produced sound levels that were 8 to 18 dB(A) higher than the minimum requirements in the NPRM.

MIC also stated that the NPRM did not take into account that motorcycles do not have a reverse gear and therefore do not collide with pedestrians while backing.

MIC stated that NHTSA should not establish minimum sound requirements for electric motorcycles until there is evidence that these vehicles pose a safety risk to pedestrians. MIC stated that if NHTSA does decide to establish minimum sound requirements for motorcycles, it should extend the exemption for small-volume manufacturers indefinitely.

IMMA suggested that electric motorcycles do not introduce a new threat to blind and visually impaired pedestrians because blind and visually impaired pedestrians already are exposed to pedalcyclists on both the road and on sidewalks (and bicycles would not be any louder than electric motorcycles). Operators of electric motorcycles, like pedalcyclists, have the advantage of greater awareness of nearby pedestrians and greater ability to avoid them.

IMMA stated that limited data exists on crashes between motorcycles and pedestrians and pedalcyclists but that there are a significant number of incidences of crashes involving motorcycles and four-wheeled vehicles, which it argued showed the high vulnerability of motorcycle riders and their inherent alertness to other road users including pedestrians. They also commented that motorcycles by design provide the operator with better vision of the surrounding environment which increases awareness of nearby pedestrians and pedalcyclists.

IMMA commented that studies have shown that pedestrians are at greater risk of being struck by HVs while the vehicle is operating in reverse, but this is not a concern for motorcycles because the vast majority of motorcycles do not have a reverse gear and those that do cannot move quickly in reverse.

IMMA stated that preliminary data shows that electric motorcycles are not quiet and suggested that this data, coupled with the fact the electric motorcycles do not pose an increased risk to pedestrians, shows that electric motorcycles should not be subject to the minimum sound requirements in the final rule.

DG Enterprise stated that the detectability parameters determined for EVs and HEVs in the NPRM may require the installation of an alert sound system on other quiet vehicles such as electric motorcycles and mopeds as well as electrically assisted bicycles. DG Enterprise inquired whether NHTSA plans to mandate the installation of and ''AVAS'' (Acoustic Vehicle Alerting Systems) in all these vehicle categories.

Western Michigan stated that all quiet vehicles traveling at the slow speeds covered by the NPRM, whether they are light-duty EVs and HVs or electric motorcycles, have the potential of

[75] MIC submitted measurements of overall sound pressure level of two electric vehicle models recorded at 8 km/h (5 mph) and 16 km/h (10 mph) in its comments to the NOI. MIC did not provide any measurements of overall sound pressure level for ICE motorcycles as a comparison. *Available at, www.regulations.gov*, Docket No. NHTSA–2011–0100–0028.

[76] Docket No. NHTSA–2011–0148–0268.

[77] The report submitted by Brammo, Inc. is available through *www.regulations.gov,* Docket No. NHTSA–2011–0148–0268.

causing harm to pedestrian who are blind.

Agency Response to Comments

Although the agency proposed in the NPRM to include motorcycles in the final rule, we have decided not to apply the requirements of this final rule to electric motorcycles. As is the case with heavy hybrid and electric vehicles, we currently do not have enough information to determine whether the light vehicle acoustic requirements or the crossover speed in this final rule are appropriate for electric motorcycles. Instead, the agency is planning to conduct further research on sound emitted by electric motorcycles before issuing a new NPRM, if needed, to propose acoustic requirements for these vehicles.

As described in Section II.C of this notice, after issuing the NPRM the agency conducted acoustic testing on two electric motorcycles following the procedures in SAE J2889–1, MAY 2012.[78] The agency compared the one-third octave band measurements of these electric motorcycles to the minimum levels needed for detection based on the agency's detection model. The first motorcycle, the 2012 Brammo Enertia, had two one-third octave band measurements at the 10 km/h pass-by that met or exceeded the minimum levels for detection out of the thirteen one-third octave bands in the range of interest (315Hz to 5kHz); for the 20 km/h pass-by, the Enertia met or exceeded the minimum in three of the thirteen bands. The second motorcycle that the agency evaluated, the 2012 Zero S, did not have any one-third octave bands that were equal to or greater than the minimum levels for detection at the speeds tested. The overall sound pressure levels for the Brammo Enertia in the 10 km/h, 20 km/h, and 30 km/h pass-bys were 57 dB(A), 63.2 dB(A), and 66.5 dB(A). The overall sound pressure levels for the Zero S in the 10 km/h, 20 km/h, and 30 km/h pass-bys were 49.1 dB(A), 57 dB(A), and 59.6 dB(A).

According to the agency's detection model, a vehicle is detectable in the 55 dB(A) standard ambient utilized in the agency's acoustic evaluations if it meets or exceeds the minimum levels for detection in at least one of the thirteen one-third octave bands.[79] When compared to the agency's detection model, the Brammo Enertia would be expected to be detectable in the 55 dB(A) standard ambient at 10 and 20 km/h. According to the agency's model, the Zero S would not be expected to be detectable in the 55 dB(A) ambient at any of the three speeds tested.

When compared to the average overall sound pressure level of four-wheeled ICE vehicles, the sound level produced by the Brammo Enertia was similar, based on a broad selection of ICE measurement data which the agency acquired from its own testing and from other sources (shown in Table 13 of the NPRM). The Zero S produced a lower overall sound level than the ICE mean and also was lower than the mean-minus-one-standard-deviation of the same ICE data (shown in Table 14 of the NPRM.)

Based on comparing the one-third octave band data to the agency's detection model and comparing the overall sound pressure levels to the sound produced by four-wheeled ICE vehicles, the agency believes the acoustic data from these two electric motorcycles are inconclusive as to whether electric motorcycles might be too quiet for pedestrians to detect by hearing. Furthermore the agency has not collected any data or conducted any analysis regarding the crossover speed for electric motorcycles, which might be different from that of four-wheeled vehicles. Because our acoustic data show that one of the two electric motorcycles would be detectable by pedestrians within a safe detection distance, but the other one would not be, we believe that further evaluation of electric motorcycles is needed before we can determine if it is appropriate that they be subject to the same acoustic requirements and crossover speed as four-wheeled vehicles.

Commenters stated that adding an alert system to a motorcycle would be a technical challenge because motorcycles are very different from cars in terms of layout and architecture, and a pedestrian alert system which includes a speaker is a significant amount of hardware to integrate into a motorcycle. NHTSA has not determined if this design burden would make it impracticable for electric motorcycles to be required to meet today's final rule.

The agency also needs to further evaluate whether electric motorcycles require distinct specifications separate from four-wheeled vehicles. For example, there is nothing in the minimum sound requirements that would allow pedestrians to specifically recognize a vehicle as a motorcycle. Furthermore, motorcycles do not need a backing sound since they generally are not driven in reverse.[80] For these reasons, this final rule does not apply to motorcycles, and we anticipate conducting a separate rulemaking effort to address the potential need for pedestrian alert systems on electric motorcycles.

Low Speed Vehicles

In the NPRM, we stated that we had tentatively concluded that Low Speed Vehicles (LSV) should be required to meet the minimum sound requirements in the proposed standard. We stated that while we had not conducted any acoustic testing of these vehicles and had limited real-world data on crashes involving LSVs and pedestrians, we expected LSVs equipped with electric motors would be extremely quiet.

EDTA stated that NHTSA should defer application of minimum sound standards to LSVs until a more complete record establishing the need for standards for these vehicles exists. EDTA suggested that if the agency documents a need for LSVs to meet the minimum sound requirements in the final rule, the agency should then develop audibility specifications that reflect the technologies, duty cycles and uses, and sound profiles specific to these types of vehicles.

Western Michigan stated that LSVs should be required to meet the requirements in the final rule because they could pose a potential hazard to blind pedestrians. NFB stated that the rule should apply to LSVs.

Agency Response to Comments

We have decided to apply the minimum sound requirements in today's final rule to LSVs. The PSEA requires NHTSA to establish minimum sound requirements for all motor vehicles that are hybrid or electric motor vehicles. Because trailers are the only vehicles excluded from the scope of the required rulemaking, NHTSA's interpretation is that Congress intended for the agency to apply minimum sound requirements to all other vehicles that are HVs or EVs including LSVs.

The agency tested five LSVs to determine the sound levels produced by these vehicles. The sound levels

[78] Hastings, et al., (2014) Acoustic Data for Hybrid and Electric Heavy-duty Vehicles and Electric Motorcycles.

[79] While a sound with one one-third octave band at the detectable threshold would be expected to be detectable in the 55 dB(A) ambient utilized in the agency's research, such a sound may not be detectable in other ambient conditions with the same overall sound pressure level depending on the spectral shape of the ambient.

[80] One or more models of touring motorcycle are fitted with a reverse feature that uses the engine starter motor to assist in backing, for example when the rider is unable to walk the motorcycle out of an inclined parking space. This feature is intended for limited use. Currently this feature is not present on any electric motorcycles. As a result, reverse operation is not considered to be a safety issue for motorcycles as it is with passenger cars.

produced by the LSVs for the 10 km/h, 20 km/h, and 30 km/h pass-bys were similar to the sound levels produced by the electric passenger cars that the agency evaluated during VTRC's testing in 2012.[81] The sound levels produced by the LSVs when operating in reverse varied significantly because four of the five LSVs were equipped with back-up beepers.

Results of the acoustic testing of these LSVs confirmed the agency's understanding that these vehicles produce similar sound levels as EVs and HVs. Also, they operate in locations where pedestrian exposure is similar to that of EVs and HVs. Therefore, the agency believes that electric LSVs pose an increased risk to pedestrians when they are operating at low speed when compared to conventional vehicles. Vehicles in the LSV category have a maximum speed limitation of 25mph, so by definition LSVs operate at low speeds. These speeds are reflective of those for which HVs and EVs have the highest risk of involvement in pedestrian crashes when compared to ICE vehicles, as noted in Section II.B of today's final rule. The agency is not aware of any factors related to the use of LSVs that would mitigate the risk to pedestrians created by the low sound levels produced by these vehicles. Because of the low sound level produced by LSVs and the fact they operate primarily at low speeds, the agency believes that it is necessary for hybrid and electric LSVs to meet the minimum sound requirements in today's final rule. This is in contrast to electric motorcycles and EVs/HVs with a GVWR over 10,000 for which our test data were inconclusive regarding the sound levels those vehicles achieve before having any sound added.

In response to the comment submitted by EDTA, NHTSA believes that acoustic requirements for light duty EVs and HVs are appropriate for LSVs. LSVs are not sufficiently different from vehicles that are not speed limited when those vehicles are traveling at low speeds, so LSVs do not require a separate acoustic specifications in order for pedestrians to detect them.

Quiet ICE Vehicles

In the NPRM, we chose not to apply the proposed requirements to conventional ICE vehicles for the time being. We acknowledged that it is possible that some ICE vehicles may pose a risk to pedestrians because of the low level of sound that they produce when operating at low speeds. We stated in the NPRM that the agency would decide whether to apply the minimum sound requirements established for HVs and EVs to ICE vehicles after completing the Report to Congress on ICE vehicles, as required by the PSEA.

We also stated in the NPRM that while some of the ICE vehicles the agency tested during our research did not meet the proposed requirements, these vehicles emit sound in areas of the audible spectrum not covered in the proposed requirements. We stated that this characteristic of ICE vehicles made it difficult to compare the detectability of ICE vehicles to hybrid and electric vehicles solely based on acoustic measurements.

In response to the NPRM, we received several comments from members of the general public stating that if the agency chose to establish minimum sound requirements for hybrid and electric vehicles it should also establish requirements for quiet ICE vehicles. These commenters stated that NHTSA should make the determination regarding which vehicles will be subject to the final rule based on whether the vehicle poses an increased risk to pedestrians when operating at low speed not based on the vehicle's propulsion type. These commenters suggested that requiring only hybrid and electric vehicles to meet the requirements of the final rule discriminates against those types of vehicles.

DG Enterprise inquired whether NHTSA had plans to require quiet ICE vehicles to meet the requirements of the final rule. DG Enterprise further inquired whether the agency considered that the minimum sound requirements in the final rule might influence the installation of alert sound systems on quiet ICE vehicles.

WMU stated that, although increases in the number of hybrid and electric vehicles in the on-road fleet have brought about an increased awareness of the safety risks to pedestrians posed by quiet vehicles, there are many modern ICE vehicles that are too quiet to be safely detected by pedestrians who are blind. ADB stated that pedestrians who are blind are at just as much risk from a quiet ICE as they are from an EV or HV. ADB believes that quiet ICE vehicles should be subject to the final rule because the agency has not conducted enough research about the detectability of these vehicles.

Agency Response to Comments

We have chosen to limit the application of the final rule to hybrid and electric vehicles. The PSEA required NHTSA to establish minimum sound requirements for hybrid and electric vehicles. After completing the rulemaking to establish minimum sound requirements for hybrid and electric vehicles, NHTSA is required to complete a study and submit a report to congress on whether there is a safety need to apply the final rule to ICE vehicles. If NHTSA subsequently determines that there is a safety need to apply the rule to ICE vehicles, the agency is required to initiate a rulemaking to do so. Because we have not yet completed the required report to Congress, we have not yet determined whether a safety need exists to apply the requirements of today's final rule to ICE vehicles. Because they agency has not yet determined whether a safety need exists for quiet ICE vehicles to produce additional sound, we have no basis at this time to subject these vehicles to the requirements of today's final rule.

We are aware that some ICE vehicles do not meet the requirements of the final rule, and that this could lead to the inference that some ICE vehicles do not produce sufficient sound to allow pedestrians to detect these vehicles. We do not think that it is appropriate, however, to make the assumption—based solely on the data mentioned above—that some ICE vehicles must produce additional sound to be safely detected by pedestrians. As we stated in the NPRM, ICE vehicles produce sounds in areas of the audible spectrum that make it difficult to draw conclusions about how detectable they are by comparing them to the requirements in today's final rule. In addition, the sound produced by an ICE includes acoustic characteristics such as modulation that enhance detectability that are not included in the final rule. Therefore, it is likely that ICE vehicles that are readily detectable by pedestrians might not meet the requirements of the final rule.

The agency will examine whether there is any crash data that shows that ICE vehicles that produce a lower sound level have an increased risk of crashes with pedestrians as part of the agency's investigation of whether there is a safety need to apply the requirements of today's final rule to ICE vehicles as part of the agency's report to Congress.

*C. Critical Operating Scenarios*

Stationary but Active

The agency proposed to require hybrid and electric vehicles to meet

[81] Garrott, W.R., Hoover, R.L., Evans, L.R., Gerdus, E., and Harris, J.R., ''2012 Quieter Vehicle Testing Report: Measured Sound Levels for Electric, Hybrid Electric, and Low Speed Vehicles.'' Washington, DC, DOT/NHTSA, November 2016.

minimum sound requirements in the ''stationary but active'' condition. The agency used the term ''stationary but active'' to describe the state of a stationary hybrid or electric vehicle that has its propulsion system active. This is an important scenario to include because these vehicles typically do not idle in the way that an ICE vehicle does. The NPRM explained that the ''stationary but active'' condition included any time following activation of the vehicle's starting system without regard to the transmission gear position or any other factor affecting the vehicle's ability to begin moving (*i.e.,* parking brake application). The NPRM proposed requiring EVs and HVs to meet the minimum sound requirements for the stationary but active condition beginning 500 milliseconds after the vehicle's starting system is activated.[82]

In the NPRM, we explained that the PSEA required the agency to establish minimum sound requirements for this operating condition. The PSEA states that the required safety standard must allow pedestrians ''to reasonably detect a nearby electric or hybrid vehicle in critical operating scenarios including, but not limited to constant speed, accelerating, or decelerating.'' [83] This encompasses the possibility that ''stationary but active'' could be a ''critical operating scenario.'' Also, the PSEA defines ''alert sound'' as ''a vehicle-emitted sound to enable pedestrians to discern vehicle presence, direction, location and operation.'' [84] Thus, in order for a vehicle to satisfy the requirement in the PSEA to provide an ''alert sound,'' the sound emitted by the vehicle must satisfy that definition.[85] We explained in the NPRM that in order to satisfy the definition of alert sound in the PSEA the agency was required to establish minimum sound requirements for EVs and HVs in the stationary but active operating condition.

We also stated that, in addition to being a required operating condition under the PSEA, the agency believed that there was a safety need for hybrid and electric vehicles to emit a sound in the stationary but active condition. A sound emitted by an HV or EV when stationary but active is analogous to the sound produced by an ICE vehicle idling while at a standstill. We stated that this requirement ensures that the responsibility to avoid a collision between a vehicle and a pedestrian is shared between the driver of the vehicle and the pedestrian by providing pedestrians with an acoustic cue that a vehicle may begin moving at any moment. While there are some scenarios in which a driver starting from a stopped position should be able to see a pedestrian in front of the vehicle and thus avoid a crash, the driver may not always be relied upon, especially in situations where the driver may have an obstructed view. A driver pulling out of a parking space in a crowded parking lot is an example of a situation in which a driver might not be able to see a pedestrian and the pedestrian may step into the path of a vehicle just as the vehicle is beginning to move. If the pedestrian is able to hear the vehicle before it begins to move, the pedestrian would be able to exercise caution and avoid a collision by not stepping in the path of the vehicle.

The agency also discussed incidents of HVs colliding with pedestrians when starting from a stopped position that appear in the data that the agency used for the statistical analysis of crashes between hybrid vehicles and pedestrians. The NPRM noted that instances of HVs starting from a stopped position and colliding with pedestrians are present in our data although the sample size is not large enough to prove a statistically significant incidence rate. We stated that this limited data showed there could be a safety risk which, if correct, would grow commensurate with the population of HV/EVs, such that it would be appropriate to require that vehicles provide adequate sound cues while stationary.

In the NPRM, we also noted that sound cues produced by idling ICE vehicles are critical for safe navigation by blind pedestrians. The sound produced by vehicles idling while waiting to pass through an intersection provides a reference to visually-impaired pedestrians so they are able to cross a street in a straight line and arrive safely at the other side. The sound of vehicles idling on the far side of the street while waiting to pass through an intersection also provides visually-impaired pedestrians with a reference for how wide a street is so they can accurately gauge the amount of time needed to safely cross.[86]

The NPRM further stated that the agency did not believe that there would be any incremental increase in cost that would result from requiring a sound at the stationary but active operating condition for vehicles already equipped with an alert sound system and that the draft EA showed that requiring sound at stationary would not have any appreciable impact on ambient noise levels.

In their comments to the NOI and in meetings with agency staff prior to the NPRM, representatives from several auto manufacturers said that the agency should not establish minimum sound requirements for the stationary but active condition. These manufacturers did not believe there was a safety need for an alert sound when vehicles are stationary. They were concerned that the sound of EVs and HVs standing in highway traffic and other scenarios in which pedestrians would not be expected to be present would unnecessarily contribute to increases in environmental noise. Advocacy organizations for individuals who are blind or visually impaired, in contrast, argued prior to the NPRM that NHTSA should establish minimum sound requirements for the stationary but active condition. These organizations stated that sound made by stationary vehicles is necessary for the safety of blind or visually impaired pedestrians to avoid collisions with EVs and HVs operating at low speeds because it allows individuals who are blind to proceed with caution when they hear a nearby ''idling'' vehicle.

The NPRM also discussed and sought comment on a suggestion from Mercedes for alerting nearby pedestrians that a hybrid or electric vehicle was about to begin moving without requiring a sound in the stationary but active condition. Mercedes had suggested that instead of emitting sound when the vehicle was stationary with the propulsion system active, hybrid and electric vehicles should be required to emit a ''commencing motion sound'' that would activate when the vehicle was in ''drive'' and the driver released his or her foot from the brake pedal.

[82] The NPRM proposed that vehicles with manual transmissions meet the stationary but active requirement when the vehicle's gear selection control is in ''neutral.''

[83] Public Law 111–373, 124 Stat. 4086 (January 4, 2011).

[84] *Id.*

[85] Given that the language of the PSEA definition of 'alert sound' uses the conjunction 'and' when listing the circumstances of vehicle operation that a pedestrian must be able to discern, *i.e.,* ''presence, direction, location, and operation,'' it is apparent that a pedestrian must be able to discern any vehicle operation, which would include the condition in which the vehicle could imminently be in motion and present a risk to a pedestrian.

[86] The NPRM also discussed how NHTSA staff traveled to the headquarters of the National Federation of the Blind in Baltimore, Maryland to receive training on white cane travel techniques used by individuals who are blind. This allowed NHTSA staff to experience firsthand the necessity of sound at stationary to the mobility of individuals who are blind. When approaching intersections, NHTSA staff found the sound of idling vehicles necessary for determining whether there was a vehicle present at the intersection and whether it was safe to cross.

When the driver released the brake pedal, the vehicle would emit a sound for a brief period that would be noticeably higher than the sound required at low speed. According to Mercedes, this brief, elevated sound would uniquely signal the onset of vehicle motion. Once the vehicle began to move, the alert sound would revert to a low-speed sound which would have to comply with the acoustic requirements proposed for speeds up to 10 km/h. The agency sought comment on using a ''commencing motion sound'' approach.

The NPRM also solicited comment on whether the final rule should allow the sound at stationary to be reduced or deactivated if the vehicle had been stationary for a prolonged period of time.

Many industry commenters responding to the NPRM raised many of the same points raised in their comments to the NOI and in meetings with agency staff prior to the agency issuing the NPRM. Auto manufacturers and groups that represent them commented that sound at stationary is not necessary for safety, and that Europe and Japan do not require sound at stationary. Industry commenters expressed concern that requiring sound in the stationary but active condition could annoy drivers, which would harm EV and HV sales, and that it also would lead to increases in environmental noise pollution. These commenters also argued that a sound at stationary would mask the sound of other approaching vehicles.

Industry commenters including Alliance/Global, Denso, EDTA, Mercedes, Mitsubishi, OICA, and Volkswagen requested that NHTSA require a ''commencing motion sound'' rather than establishing minimum sound requirements for either when a vehicle is in ''park'' or when the vehicle is in ''drive'' but is stationary. Some of these commenters pointed out that the NPRM did not define ''active'' and argued that NHTSA should define ''stationary but active'' specifically as the condition in which the vehicle's gear selector is in the ''drive'' position and the driver has released the service brake. Alliance/Global commented that requiring a commencing motion sound that activates when a vehicle begins moving would satisfy the requirement in the PSEA that the alert sound allow pedestrians to discern the presence, direction, location, and operation of the vehicle. Honda and Nissan, in addition to opposing a requirement for stationary sound without further research on the need for it, commented that NHTSA should not require a commencing motion sound and should instead leave that as an option for manufacturers. Some manufacturers, including Mercedes and Nissan, said that sound at stationary can mask the sound of other vehicles that are in motion. Mercedes stated that it had enlisted researchers to conduct some experimentation on this topic. They found in preliminary trials that it was easier for pedestrians to detect when a vehicle begins to move if the vehicle did not produce sound when stationary, and that this might be because the sound activates just as the vehicle initiates movement. Nissan also conducted trials that they said indicated that blind pedestrians were less aware of traffic moving adjacent to an alert-emitting stationary vehicle, *i.e.,* when the stopped vehicle emitted no sound, the pedestrians were more aware of the nearby moving traffic.

Volkswagen stated that vehicles that are not moving do not pose a threat to pedestrians or pedalcyclists. Volkswagen argued that it is unlikely that drivers will fail to make sure that the vehicle's path is clear of pedestrians when starting up from a full stop, and that in the rare case in which an inattentive driver begins to accelerate from a stop toward a pedestrian who is in or about to enter the vehicle's path in that case, a ''commencing motion'' sound would provide the pedestrian with a warning that the EV or HV is beginning to move, so that the pedestrian could take appropriate action.

EMA commented that it is unreasonable to require heavy vehicles to emit sound continuously while idling because many types of heavy-duty vehicles must idle for extended periods in order to power a variety of utility functions such as operating on-board equipment like hydraulic lifts or pumps.

Industry commenters also commented that the level of sound for the stationary condition proposed in the NPRM is too high, and sound level is higher than that of ICE vehicles at idle. They stated that, if NHTSA did decide to establish minimum sound levels for when a vehicle is stationary with an active propulsion system, those levels should be lower than the levels in the NPRM. In addition, the sound should be required only when the vehicle's gear selector is in the ''drive'' or ''reverse'' position and not when the gear selector is in the ''park'' position.

Volkswagen noted, ''for the foreseeable future, it is exceedingly unlikely that a blind pedestrian will encounter a line of vehicles stopped at a traffic light that is comprised entirely of EVs and HVs.'' [87] Volkswagen stated that because ICE vehicles will be present a majority of the times that blind pedestrians are attempting to cross at signal-controlled intersections, the sound produced by the idling ICE vehicles will provide the acoustic cues needed to ''shoreline.'' [88] Volkswagen stated that, by the time the market penetration of EVs and HVs increases to the level at which they would make up the majority of vehicles idling at an intersection, technology will eliminate the need for pedestrians who are blind to rely on vehicle-emitted sound to safely navigate intersections.

Alliance/Global stated that NHTSA should follow the European and Japanese guidelines for pedestrian alert sound systems which concluded that there is no safety need for hybrid and electric vehicles to emit sound while stationary. Alliance/Global also suggested that requiring a commencing motion sound as an alternative to requiring sound in the stationary but active condition ''would lower the ambient noise level at intersections, thus making it easier for pedestrians to detect the presence and operating patterns of other moving vehicles.'' [89]

In general, commenters pointed out a number of reasons why sound in the stationary operating condition should not be required. They stated that EVs and HVs should only be required to emit sound when they are capable of moving, because vehicles with their gear selector in the ''park'' position and vehicles with the parking brake engaged are not capable of motion so NHTSA should not establish minimum sound requirements for these conditions. For instance, Toyota stated that, according to NHTSA's interpretation of the PSEA, a vehicle is capable of being ''operated'' even without an operator being present in the vehicle, and that a vehicle that is stationary is inherently incapable of striking a pedestrian, and therefore should not be required to emit sound.[90]

A number of commenters expressed concern about the environmental noise that would be created by alert sounds emitted by stationary vehicles. Alliance/Global stated that if EVs and HVs are required to produce an alert sound as soon as the starting system is activated,

[87] *See* document no. NHTSA–2011–0148–0250, *available at www.regulations.gov.*

[88] ''Shoreline'' refers to the practice by which pedestrians who are blind use walls, handrails, curbs or other features parallel to their direction of travel to help guide them. They may also use traffic sound for shorelining.

[89] *See* document no. NHTSA–2011–0148–0251, *available at www.regulations.gov.*

[90] *See* document no. NHTSA–2011–0148–0272, *available at www.regulations.gov.*

they will be required to make noise under conditions for which there is no threat to pedestrians, which in turn will needlessly increase environmental noise levels. Volkswagen stated that requiring EVs and HVs to emit a sound at stationary would cause many hours of unnecessary sound emissions, which will annoy vehicle owners and add to overall noise pollution. Volkswagen also claimed that requiring sound at stationary would lead to unnecessary wear and tear on the sound generation system components.

Representatives from Nissan, Toyota, Honda, GM, and Mitsubishi conducted a demonstration attended by NHTSA staff [91] to show that a vehicle that emits sound when stationary could mask the presence of other vehicles. They conducted the demonstration to highlight situations in which they believed pedestrians would be able to better detect other approaching vehicles if nearby hybrid and electric vehicles did not emit sound while they are stationary. Their contention was that requiring a stationary hybrid or electric vehicle to emit sound could mask the sound of a moving vehicle that was approaching in an adjacent lane.

Representatives from Nissan met with NHTSA staff and presented their analysis of when a sound at stationary would be beneficial to pedestrians and when it would mask the sound of an approaching vehicle that actually posed a threat to pedestrians.[92] In this analysis, Nissan examined thirty different traffic scenarios. Nissan stated that it had found that requiring EVs and HVs to emit a sound at stationary would make it more difficult to detect an approaching vehicle that posed a threat to pedestrians in twenty of the thirty scenarios, would have no impact in eight of the scenarios, and would aid the pedestrian in detecting the threat vehicle in only two of the scenarios. Nissan indicated that it would be more difficult for pedestrians to detect an approaching vehicle that posed a threat in these twenty scenarios because a stationary EV or HV producing an ''idle'' sound would mask the approaching vehicle that posed the threat.

Organizations that represent individuals who are blind or visually impaired and safety advocates including NFB, ACB, ADB, NCSAB, WBU, WMU, and Advocates stated that the agency should require hybrid and electric vehicles to produce sound when those vehicles are stationary with their propulsion systems active. Among the comments from these organizations was the contention that the sound of ''idling'' vehicles is useful for navigation by pedestrians who are blind in a number of scenarios and makes them aware of the presence of a nearby vehicle that is likely to start moving at any moment so the pedestrian has the opportunity to react safely once that vehicle begins to move. These organizations stated they do not believe that a ''commencing motion sound'' is sufficient to replace the acoustic cues provided by ''idling'' vehicles. However, some of these commenters suggested that they would not be opposed to a commencing motion sound if it is provided in addition to, not in place of, a stationary sound. Advocates commented that the sound required for a stationary vehicle in 'park' could be at a lower acoustic level until such time as the brake pedal is applied.

WMU stated ''pedestrians who are blind gain important information regarding vehicle presence from the sounds of idling vehicles'' [93] and ''blind pedestrians often rely heavily on the sound of vehicles starting up from a stop at an intersection (signalized or not) to decide when to cross and to understand the geometry and operation of the intersection.'' [94] These assertions were reflected to a great extent in comments from other organizations among this group.

WMU also stated that its research has shown that blind pedestrians have great difficulty detecting hybrid and electric vehicles (without an alert system) starting from a stopped position and, consequently, sound in the stationary but active condition should be required when the hybrid or electric vehicle's gear selection control is in ''park'' to alert blind pedestrians of potential conflict. WMU expressed concern that a hybrid or electric vehicle could be put into ''drive'' and begin moving quickly enough that a pedestrian walking near the vehicle would not have time to react.

WMU also stated that, while a commencing motion sound does not replace sound at stationary, it does allow pedestrians to more easily identify vehicles starting from a stopped position. WMU suggested that, if a vehicle has been stationary for a long time, that vehicle is less likely to begin moving and should not be required to produce a sound for a prolonged period.

Agency Response to Comments

As described in Section II.A of this final rule, NHTSA has concluded that the PSEA requires NHTSA's safety standard to specify that vehicles must have sound when stationary. However, based on careful review of the comments received, we have decided to modify the proposed sound at stationary requirement to apply only when a vehicle's gear selection control is not in the ''Park'' position.

The definition of ''alert sound'' in the PSEA requires the agency to establish minimum sound requirements to allow pedestrians to detect the presence of nearby vehicles that are in operation. Of the comments that suggested that the agency define ''stationary but active'' as the condition in which the vehicle's gear selection control is in ''drive'' and the driver is not applying the brake pedal, none of those comments explained how that approach would fulfill the mandate in the PSEA that the minimum sound requirements allow pedestrians to detect the ''presence'' and ''operation'' of a nearby vehicle, including one that is stationary.

The agency believes that adopting the sound at stationary requirements will mitigate the potential risk to pedestrians from HVs and EVs starting from a stopped position. As we stated in the NPRM, there is evidence in the crash data that these types of crashes do occur. A sound at stationary would help both blind and sighted pedestrians because it would alert them to the presence of a vehicle that might start moving so they could avoid walking into the vehicle's travel path. We are concerned that a ''commencing motion'' sound would not always give a pedestrian who was entering the path of a vehicle sufficient time to react to avoid a collision, as argued by ACB and NFB. While we agree that the onset of an alert sound coincident with the commencement of motion on a vehicle that was not emitting sound when it was stationary might be of some benefit, because the contrast provided by the activation of the sound might better help pedestrians who are blind detect when the vehicle begins to move, we do not believe that this outweighs the fact that requiring sound at stationary will help all pedestrians avoid collisions with vehicles starting from a stopped position by providing an audible indication of a nearby vehicle that could begin moving at any time.

While it may be some time in the future before it becomes likely that a pedestrian who is blind will encounter traffic that is comprised exclusively of EVs and HVs (as VW's comment

[91] See document no. NHTSA–2011–0148–0240, *available at www.regulations.gov*.

[92] *See* document no. NHTSA–2011–0148–0051, *available at www.regulations.gov*.

[93] *See* document no. NHTSA–2011–0148–0180, *available at www.regulations.gov*.

[94] *See id.*

suggested), a sound at stationary can assist pedestrians who are blind with navigation and orientation tasks before that scenario becomes a reality. A sound at stationary can assist pedestrians who are blind in performing orientation and mobility tasks in commonplace situations such as when a pedestrian encounters a single EV or HV at an intersection where the traffic flow is light. As stated above, a sound at stationary also would provide immediate benefits to pedestrians who are blind by allowing them to avoid collisions with EVs and HVs starting from a stopped position.

NHTSA does not believe that the possibility that a sound at stationary might mask the sound of other vehicles operating in the vicinity outweighs the benefits of requiring a sound in the stationary but active condition. After reviewing Nissan's analysis of scenarios, NHTSA is unable to determine whether a pedestrian who is blind would attempt to cross in the situations in which Nissan claimed that a sound at stationary would mask the sound of an approaching vehicle. For example, some of those scenarios involve a pedestrian who encounters a stationary vehicle that is being passed by another vehicle travelling in the same direction in an adjacent lane. The agency is unsure whether upon encountering a stationary vehicle, a pedestrian who is blind would proceed to cross in front of the vehicle without waiting for the vehicle to move away so the pedestrian can be sure no other traffic is present and that it is safe to cross.

Nissan presented data showing that some of the company's customers would find the sound at stationary to be unacceptable. In one Nissan study, over 60 percent of the subjects found an alert sound at stationary to be acceptable when the overall sound pressure level was similar to that of sounds meeting the requirements of today's final rule.[95] In a second Nissan study, which was conducted indoors, the number of participants who found an alert sound at stationary unacceptable was 50 percent with the windows of the vehicle rolled up when the overall sound pressure level was similar to that of sounds meeting the requirements of today's final rule.[96] No other commenter provided data or survey results showing that a sound at stationary would affect customer acceptance. Nissan did not submit any data that would indicate that customers would decline to purchase a vehicle equipped with sound at stationary.

NHTSA believes manufacturers will install alert sounds on vehicles that are acceptable to drivers because they do not want to annoy current or potential customers. We do not know whether the second study conducted by Nissan could have been influenced by the fact that the testing in question occurred indoors, and we would expect the circumstances under which a vehicle would be making a sound at stationary indoors to be limited. We do not believe that this second study is representative of the real-world situations in which a driver would be exposed to a sound at stationary. Given our questions about the findings of Nissan's second study, the fact that we do not have any other data on this issue from other manufacturers, and the fact that Nissan's original study showed that over 60 percent of customers would accept a sound at stationary, we do not have enough information to indicate that concerns regarding public acceptance of a sound at stationary are sufficient to outweigh the safety justifications for a sound at stationary or the requirements of the PSEA. Furthermore, a vast majority of ICE vehicles make a sound at stationary, and that sound does not deter customers from buying those vehicles.

In reference to comments about stationary alert sounds having environmental impact, the agency conducted an environmental assessment and concluded that the requirements overall will have a minor impact on environmental noise.[97]

After reviewing the comments and all information provided in response to the NPRM on this issue, the agency has decided to limit the requirements for the stationary but active condition to when an HV or EV's gear selector is not in ''Park.'' As stated in Section II.A, the term ''operation'' means a state of being functional or operative. The agency believes that it is reasonable to conclude that Congress intended the term ''operation'' in the PSEA to be the condition in which a driver is operating the vehicle as opposed to the operation of the vehicle's propulsion system. It is the operation of the vehicle by the driver, not the operation of the vehicle's propulsion system, that creates the safety risk to pedestrians who are unable to detect hybrid and electric vehicles.

We note that, as a result of this decision, the terminology ''Stationary but Active'' as used in the NPRM is no longer accurate because this final rule allows EVs and HVs to be ''active'' without emitting an alert sound. That is, the ignition of an HV or EV can be in the 'on' position while the vehicle is not emitting an alert, assuming the vehicle's gear selector is in Park. This scenario would not have been allowed under the proposed requirement. Therefore, we have chosen to simply use the term ''stationary'' rather than ''stationary but active'' for this operating condition. Furthermore, the regulatory text adequately specifies the conditions for stationary tests, and the words ''but active'' do not clarify any aspects of testing. For these reasons, the phrase ''stationary but active'' is not used in the final rule.

We believe that requiring sound at stationary only if a vehicle's gear selector is not in the ''Park'' position will still allow pedestrians to avoid crashes with HVs and EVs starting from the stopped position, while also minimizing sound in situations in which vehicles may pose no immediate risk to pedestrians, such as when they are parked with their ignition turned on. HVs and EVs that are stationary pose a risk to pedestrians only if they could begin moving at any moment. When a vehicle is in Park, the driver must step on the brake and move the gear selector to Drive or Reverse and then release the brake in order to begin moving, which takes some time. Although there are situations in which a driver could quickly shift a vehicle into Drive and begin moving, there also are situations in which a vehicle in Park with its ignition turned on will remain stationary for a prolonged period of time. Without data to indicate which of these scenarios is predominant, we believe that requiring an alert sound while HVs and EVs are stationary but are not in ''Park'' appropriately balances pedestrian safety, as provided for in the PSEA, with concerns about producing sound when it is not necessary to alert pedestrians. Such concerns were expressed by a number of commenters including vehicle manufacturers but also by a large number of individuals who commented on the NPRM and who stated that adding alert sounds to vehicles will create noise in environments and circumstances that otherwise would be quiet.

As with automatic-transmission HVs and EVs, our intent is that the stationary requirement will ensure that manual-transmission HVs and EVs also emit an alert sound in all routine in-traffic situations but not when they are parked. However, for manual-transmission vehicles, there is no gear selector

[95] *See* document no. NHTSA–2011–0148–0051, *available at www.regulations.gov*.

[96] *See* document no. NHTSA–2011–0148–0320, *available at www.regulations.gov*.

[97] ''Environmental Assessment—Minimum Sound Requirements for Hybrid and Electric Vehicles,'' docket no. NHTSA–2011–0100.

position exactly analogous to the Park position; the Neutral position is similar, but not the same. Automatic-transmission vehicles typically remain in Drive, *i.e.,* not in Park, as long as they are in traffic, but they typically are in Park when stationary for more than a short time. In contrast, manual-transmission vehicles may routinely be in Neutral both in traffic (*e.g.,* vehicles waiting at traffic lights) as well as when parked. If we were to specify that an alert sound is required on manual-transmission HVs and EVs only when the gear selector is in a position other than Neutral, that would fail to achieve the desired safety outcome because some routine in-traffic situations would not be covered (*e.g.,* vehicles waiting at traffic lights). Consequently, we have decided to focus on parking brake usage as an alternative factor to determine when an alert is needed on a stationary HV or EV with a manual transmission. We are specifying in the stationary requirement that the alert sound on manual transmission-equipped HVs and EVs must activate any time the ignition is turned on and the parking brake is not in the applied position. Thus, a vehicle with a manual transmission that is parked and idling will not be required to emit an alert sound as long as the parking brake is applied. We believe that this approach responds to comments, that it is within the scope of the proposal, and that it meets the goal of improving safety for blind and other pedestrians while minimizing non-essential vehicle noise.

As discussed elsewhere in today's final rule, the minimum sound level requirements for the stationary condition are based on the agency's detection model. These minimum requirements represent the sound levels that a pedestrian would need in order to hear a vehicle at a distance of two meters. For more discussion of the minimum sound requirements, see Section II.C in this notice.

Operation in Reverse

In the NPRM, we stated that reverse is a critical operating scenario for which the agency should issue minimum sound requirements for HVs and EVs to provide acoustic cues to pedestrians when the vehicles are backing out of parking spaces or driveways, to prevent collisions between EVs and HVs and pedestrians, and to satisfy the requirements of the PSEA.[98]

We also stated that HVs and EVs should be required to produce a sound while operating in reverse despite the agency's rear visibility requirements in FMVSS No. 111.

The NPRM stated that NHTSA's report on the incidence rates of crashes between HVs and pedestrians found 13 collisions with pedestrians when an HV is backing up.[99] We explained in the NPRM that while we could not establish a statistically significant incidence rate for backing crashes for HVs to compare to backing crashes involving ICEs due to the limited sample size, these accident reports do show that these crashes occur. We also stated that backing incidents occur in parking lots, garages, and driveways, as well as other ''off roadway'' locations that would not be captured in the State Data System, and thus they might be underreported.

Because of difficulties in conducting tests with the test vehicle is in motion in reverse, the NPRM stated that the agency would test the minimum sound requirements for reverse while the vehicle is stationary but with the reverse gear engaged.

Alliance/Global stated that HVs and EVs should not be required to make sound while stationary in reverse. Alliance/Global also stated that HVs and EVs should emit the same overall sound pressure level as in the stationary but active condition when in reverse and only when the vehicle is in motion.

Honda stated that the agency should not require pitch shifting when HVs and EVs are operating in reverse. Honda also stated that NHTSA should consider the role of pending changes to the requirements of FMVSS No. 111 that should serve to increase the driver's level of awareness of pedestrians who may be present while operating a vehicle in reverse.

*Agency Response to Comments*

We have decided to establish minimum sound requirements applicable to HVs and EVs with their gear selection control in reverse, both when stationary and when moving. We are requiring HVs and EVs to produce a sound in reverse for the reasons stated in the NPRM and in our discussion regarding sound at stationary. An HV or EV with its gear selection control in reverse could start moving at any time and pedestrians should be aware of the presence of such a vehicle so they can avoid walking into the vehicle's path.

As discussed in Section III.C, we are requiring the sound levels when the vehicle is in reverse to be slightly higher than when the vehicle is stationary and lower than the levels required for vehicles moving forward at more than 10 km/h because the vast majority of vehicle operation in reverse is likely to be limited to speeds around 10 km/h. In addition, drivers may be less aware of pedestrians passing behind their vehicle because of obstructed visibility to the rear.

For the reasons discussed in Section III.G, the final rule no longer contains requirements for pitch shifting, so there will be no such requirements when the vehicle is operating in reverse. We note that the requirement in the final rule that the volume of the sound produced by the vehicle increase as the vehicle increases speed does not apply when the vehicle is operating in reverse.

The agency has considered the potential impact on today's final rule of the NHTSA rulemaking on FMVSS No. 111 to expand the required rear field of view.[100] The expanded field-of-view requirements will reduce pedestrian crashes involving backing vehicles of all propulsion types. On the other hand, it will not eliminate those crashes. As we stated in the NPRM, establishing minimum sound level requirements for reverse operation will ensure that both the pedestrian and the driver continue to have the ability to avoid pedestrian-vehicle collisions. Nevertheless, we have adjusted the target population in our assessment of benefits to reflect the recent amendments to FMVSS No. 111 under which many vehicles will be equipped with rear vision cameras.

The proposed requirements in the NPRM for operation in reverse allowed the use of back-up beepers that most heavy vehicles are equipped with as a means of compliance with the pedestrian alert safety standard. As noted elsewhere in this preamble, this final rule does not apply to medium and heavy vehicles, so the proposed requirement to allow the use of back-up beepers is not included in this final rule.

Acceleration and Deceleration

In the NPRM, we did not include separate test procedures to measure vehicles when they are accelerating or decelerating. We stated that we chose not to propose separate requirements when EVs and HVs are accelerating and decelerating because of concerns that it was not feasible to test accelerating or decelerating vehicles accurately and repeatably. We stated that the proposed

[98] Because the PSEA requires NHTSA to issue minimum sound levels to allow pedestrians to discern vehicle presence and operation, and a vehicle moving in reverse is unquestionably operating, a minimum sound level is required for this condition.

[99] Wu et al. (2011) Incidence Rates of Pedestrian And Bicyclist Crashes by Hybrid Electric Passenger Vehicles: An Update, Report No. DOT HS 811 526. Dept. of Transportation, Washington, DC. Available at *http://www-nrd.nhtsa.dot.gov/Pubs/811526.pdf.*

[100] *See* 79 FR 19178, April 7, 2014.

pitch shifting requirements would allow pedestrians to detect the acceleration and deceleration of HVs and EVs, so separate acoustic requirements are not necessary. In the responses to the NPRM, the topic of acceleration and deceleration was not commented on separately from the topic of pitch shifting which is covered in Section III.G of this final rule.

For the reasons stated in Section III.G, we have not included a requirement for pitch shifting in today's final rule. Today's final rule instead contains a requirement that the sound produced by a vehicle must increase and decrease in loudness as the vehicle changes speed. The agency believes that a change in sound level produced by EVs and HVs as their speed changes will provide an acoustic cue for pedestrians to detect acceleration and deceleration.

In the NPRM, the required minimum level in each one-third octave band was greater at higher speeds to allow pedestrians to detect faster moving vehicles from farther away and to account for increased stopping distance at higher speeds. The NPRM, however, did not contain any maximum sound requirements, only minimums, at each operating condition so it would have been possible for an EV or HV to meet the acoustic requirements in the NPRM by producing the same, unvarying sound level from stationary up to 30 km/h. If a manufacturer chose this type of design, pedestrians would not have any acoustic cues to determine if the vehicle was changing speed if the sound produced by the vehicle also did not change in pitch. We believe this would make it more difficult for a blind pedestrian to distinguish a stopped or very slow-moving vehicle from one that is moving faster, and to determine if an approaching vehicle is slowing to a stop. To avoid this situation, the agency is requiring that the sound level produced by EV and HV pedestrian alert systems must increase as vehicle speed increases and must decrease as speed decreases. This requirement is implemented in Section S5.2 of the regulatory text of this final rule.

Vehicles in Forward Motion at Constant Speed

In the NPRM, the agency proposed that EVs and HVs produce sound sufficient to allow pedestrians to detect these vehicles at all speeds between 0 and 30 km/h (18.6 mph). The agency proposed to ensure that EVs and HVs produce a minimum sound level necessary for safe pedestrian detection at constant speeds by measuring vehicle sound output at 10 km/h (6.2 mph), 20 km/h (12.4 mph), and 30 km/h (18.6 mph). The proposal contained minimum acoustic requirements up to the speed of 30 km/h because, for the reasons discussed in the NPRM, the agency believed that 30 km/h was the appropriate crossover speed. The agency believed that it was necessary to include pass-by tests at speeds up to and including the crossover speed to ensure that EVs and HVs meet the minimum sound level requirements for all speeds within the range of speeds covered by the requirements.

The agency received no comments related specifically to the proposed constant speed pass-by performance requirements or associated tests. However, many commenters including manufacturers, manufacturer organizations, and advocacy groups argued either for or against the proposed crossover speed of 30 km/h. The details of the comments on crossover speed are discussed in the next section (Section III.D).

Agency Response to Comments

If a lower crossover speed had been selected for the final rule, the agency would have modified the pass-by test sequence to replace the 30 km/h test speed with the lower crossover speed. However, the agency has decided to maintain the 30 km/h crossover speed. Because of this decision, the constant speed pass-by scenarios in the final rule will remain as proposed in the NPRM.

*D. Crossover Speed*

In the NPRM, we stated that the agency had tentatively concluded that EVs and HVs should be subject to minimum sound requirements until they reach a speed of 30 km/h. The NPRM explained that the PSEA defined crossover speed as ''the speed at which tire noise, wind resistance, or other factors eliminate the need for a separate alert sound.'' We decided to propose a crossover speed of 30 km/h (18.6 mph) by examining the speed at which EVs and HVs produce a similar overall sound pressure level as their peer ICE vehicles, to determine the speed at which the powertrain noise of the ICE vehicle was no longer the dominant source of the vehicle sound. This peer vehicle method was one that NHTSA had used in research prior to the enactment of the PSEA. As far as the agency was aware, this method was a reasonable way to identify an appropriate crossover speed. We also examined the crash statistics from the State Data System to determine if there was a speed above which the rate of pedestrian crashes for HVs and ICE vehicles were the same.

In the NPRM, we explained that the peer vehicle method measures the speed at which the sound level produced by an HV or EV and the sound level produced by the vehicle's ICE ''peer'' become indistinguishable from one another in terms of overall sound pressure. We stated that this should establish the crossover speed, although that speed may differ depending on the make and model of the test vehicles. This method estimates the speed at which an HV or EV generates a sound level equivalent to the sound level that would be generated if the HV or EV was powered by an ICE rather than by electric power. We stated that our measurements of vehicles showed that a gap in sound level between HVs or EVs and their ICE peer vehicles still existed at 20 km/h (12.4 mph) and became much smaller or negligible in most tests at 30 km/h. For that reason, NHTSA tentatively concluded in the NPRM that ensuring EVs and HVs produce a minimum sound level until they reach a speed of 30 km/h will ensure that those vehicles produce sufficient sound to allow pedestrians to detect them. We requested comment specifically on whether the crossover speed should be 20 km/h instead of 30 km/h.

We also stated in the NPRM that the difference in rates of involvement in pedestrian crashes between HVs and ICEs is highest, according to our crash analysis, when the vehicle involved was executing a low speed maneuver prior to the crash.[101] Low-speed maneuvers do not have a defined speed range, but they include making a turn, slowing or stopping, backing, entering or leaving a parking space or driveway, and starting in traffic. Because vehicle noise increases as a vehicle goes faster, the agency tentatively concluded in the NPRM that a crossover speed of 30 km/h would ensure that EVs and HVs will produce sufficient sound up to the speed at which pedestrians can safely detect EVs and HVs without the aid of an alert system.

We noted in the NPRM that the agency was conducting an Environmental Assessment (EA) in connection with the rulemaking and the draft EA showed that the difference in ambient sound levels if the agency were to establish a crossover speed of 30 km/h compared to a crossover speed of 20 km/h was expected to be negligible.

Several commenters to the NOI and participants in United Nations Economic Commission for Europe

[101] Wu, et al. (2011) Incidence Rates of Pedestrian And Bicyclist Crashes by Hybrid Electric Passenger Vehicles: An Update, Report No. DOT HS 811 526. Dept. of Transportation, Washington, DC. Available at *http://www-nrd.nhtsa.dot.gov/Pubs/811526.pdf*.

(UNECE) informal working group meetings [102] stated that the agency should adopt a crossover speed of 20 km/h.

In the NPRM we discussed research presented by JASIC. JASIC determined the crossover speed for several vehicles by measuring when the tire noise was dominant over engine noise. In this research JASIC compared the sound produced by a vehicle when tested a constant speed with the vehicle's ICE on to the sound produced by the same vehicle when tested with its ICE off. The purpose of this test was to determine the point at which the vehicle produce a similar sound level with its ICE off as it did with its ICE on. JASIC concluded from its research that tire noise was dominant for every ICE and hybrid vehicle tested at speeds that exceeded 20 km/h. Honda and Nissan mentioned the JASIC data as adequate justification for a 20 km/h crossover speed. The data indicated that JASIC evaluated six different vehicles, each found to have a crossover speed very close to 20 km/h. At the time the NPRM was issued, the agency did not believe the JASIC data was sufficient for a 20 km/h crossover speed determination.

In the NPRM, the agency solicited comments on whether 20 km/h should be the crossover speed instead of the proposed speed of 30 km/h. The agency also requested additional research data that could be used to support a 20 km/h crossover speed decision.

All of the vehicle manufacturers and the organizations that represent manufacturers stated in their comments that NHTSA should adopt a crossover speed of 20 km/h in the final rule. These commenters stated that a crossover speed of 30 km/h is overly burdensome and would lead to increases in traffic noise. They also stated that the difference in sound of HVs and EVs compared to ICE vehicles is marginal at 20 km/h, and that a crossover speed of 30 km/h is not necessary to achieve safety goals. Manufacturers stated that at speeds higher than 20 km/h, tire and wind noise interfere with measurement of the alert sound. These commenters also stated that the agency should adopt 20 km/h as a crossover speed to align with UNECE and Japanese government recommended practices for pedestrian alert systems.

Alliance/Global stated that by the time an EV or HV reaches a cruising speed of 20 km/h, the sound it makes is practically indistinguishable from an equivalent ICE vehicle. Alliance/Global claims that at 20 km/h the EV or HV in electric power mode is only slightly quieter than an ICE vehicle. Alliance/Global also stated tire noise above 20 km/h interferes with the alert sound, making the detection and measurement of specific sound content in one-third octave frequencies much more difficult. Alliance/Global stated that a crossover speed above 20 km/h is not needed to fulfil the safety goals of the final rule.

The European Union commented that the limits on crossover or ''threshold'' speed indicated in the NPRM—30 km/h for forward motion and 18 km/h for reverse motion [the agency notes, however, that the latter figure does not reflect any proposed requirement, and may have been an oversight in the EU comment letter]—are considered excessive as many if not most EVs and HEVs produce sufficient noise emissions in the 20–25 km/h and 10–12 km/h speed ranges for forward and reverse motions, respectively. This can be attributed to the fact that EVs and HEVs use low-rolling resistance tires which produce more noise emissions than conventional ones as well as to the increased drivetrain/powertrain noise emissions when the vehicle is in reverse.

Honda said that acoustic data shows a convergence of the vehicle's sound profiles between the engine-on and engine-off condition at 20 km/h, and that acoustic sound requirements at 20 km/h or more might not be necessary.

Toyota explained that data presented by the Quiet Road Transport Vehicles (QRTV) group have indicated that the appropriate crossover speed is 20 km/h, because tire and wind noise exceed the noise of traditional ICE vehicle engines above this speed. Toyota mentioned that existing Japanese and European guidelines have adopted 20 km/h as the appropriate crossover speed and recommended that NHTSA do the same.

Volkswagen stated that the crossover speed in the final rule should be 20 km/h. Volkswagen stated that for customer satisfaction reasons it will design the alert sound to fade out gradually above the crossover speed, rather than abruptly shutting off immediately upon reaching the crossover speed. (Otherwise a driver travelling at the specified crossover speed would be highly aware of, and almost certainly annoyed by, a sound that toggled on and off abruptly as the vehicle crossed and re-crossed this speed.) Volkswagen suggested that other vehicle manufacturers will also implement alert sounds that fade out gradually, further weakening the rationale for setting a higher, 30 km/h, crossover speed in the final rule.

DG Enterprise stated that a 30 km/h crossover speed would be excessive because most EVs and HVs already produce sufficient sound in the 20–25 km/h speed range to be detected by pedestrians. DG Enterprise believes these vehicles make enough sound to be detectable because they use low-rolling resistance tires that produce more noise than conventional tires.

Advocacy groups for individuals who are blind stated in their comments that the crossover speed should be 30 km/h and that NHTSA had provided sufficient data to justify that decision.

NFB stated that the agency should establish a crossover speed of 30 km/h which would ensure that EVs and HVs are detectable when operating on quieter paved surfaces and/or when using quieter tires.

Agency Response to Comments

In this final rule, the agency has decided to maintain the crossover speed of 30 km/h as proposed in the NPRM.

In development of the NPRM and final rule the agency carefully considered the term ''crossover speed,'' what it means, and how it should be determined. The PSEA requires an alert be added to electric and hybrid vehicles up to the ''crossover speed.'' The PSEA defines crossover speed as ''the speed at which tire noise, wind resistance, or other factors eliminate the need for a separate alert sound as determined by the Secretary.'' ''Alert sound'' was itself defined as ''a vehicle-emitted sound to enable pedestrians to discern vehicle presence, direction, location, and operation.''

To date, it has been a common understanding that when ICE vehicles are operated at low speeds, they are detectable primarily due to the sounds generated by their internal combustion engine and drivetrain, and secondarily due to tire noise and wind resistance noise, which are speed dependent, and to other factors. At higher speeds, the sound generated by an ICE vehicle's tires, wind resistance, and other factors become the primary sound source, and the engine sound becomes secondary (there are exceptions, such as vehicles designed to have prominent noise from a tuned exhaust system.) Therefore, ICE vehicles generally are detectable at lower speeds because of the sound produced by the ICE and are detectable at higher speeds because of sound produced by the vehicle's tires, wind resistance, and other factors. A vehicle reaches its crossover speed when it can be detected based on these other, non-ICE sound sources. The effort to

[102] For more information about the agency's participation in the UNECE Quiet Road Transport Vehicles informal working group *see* NPRM, 78 FR 2848.

determine the speed at which this occurs is complicated by the fact that conventional vehicles emit a complex composition of sounds and tones at various overall sound pressure levels, such that crossover speed might not be that same from one vehicle model to another. Furthermore, it would be impractical for the agency to set different crossover speeds for different vehicles. Thus, in order to ensure that all vehicles to which this rule applies can be safely detected by pedestrians, the agency believes it must set crossover speed at a value that captures the higher end of the range of crossover speeds that exists among light vehicles.

The agency explained in the NPRM that, in the absence of a detailed analysis supporting another crossover speed, the agency tentatively concluded that a crossover speed of 30km/h would ensure that pedestrians will be able to safely detect EVs and HVs in situations in which these vehicles pose an increased risk to pedestrians because of their quiet nature.

After considering the comments received and evaluating vehicle measurements utilizing the method proposed by JASIC, as well as an analysis utilizing the agency's vehicle detection criteria, we have decided to require a crossover speed of 30 km/h in this final rule as proposed in the NPRM. No new compelling data was submitted to the agency that can be used to conclude that reducing the crossover speed from the proposed 30 km/h to 20 km/h is justified.

Because other methods (*i.e.,* the peer vehicle method and JASIC method) used to determine the crossover speed were inconclusive, as discussed later in this section, and did not directly answer the question of when the vehicles in the analysis produced enough sound to be detected by pedestrians, NHTSA did some additional evaluation of sounds produced by ICE vehicles with their IC engines turned off using the one-third octave band detectability thresholds from our acoustic model. The model used was the same one that was the source of the agency's minimum detection requirements in this final rule. We conducted this analysis after the NPRM comment period had closed to assist in considering the comments we had received. A technical paper on this crossover speed analysis has been included in the docket.[103]

By applying the detectability model to the measurements of sounds produced by the eleven ICE vehicles listed below with their IC engines turned off, we were able to assess if any of the A-weighted one-third octave band levels from any of the test vehicles met or exceeded the 20 km/h band threshold levels needed for a vehicle to be detectable in a standardized 55 dBA ambient, and to compare that outcome to the number of bands that met or exceeded the thresholds at 30 km/h. (We note that this was a re-analysis of vehicle data already collected, *i.e.,* this evaluation did not involve additional vehicle testing.) Whereas the peer vehicle and JASIC methods are relative measures because they compare one vehicle's overall sound to another vehicle's overall sound, this most recent NHTSA evaluation compared vehicle sounds directly to detection criteria.

The results of this analysis are summarized below according to test speed and vehicle model. The one-third octave bands listed are those for which the given test vehicle met or exceeded the threshold in NHTSA's final rule:

10 km/h with the IC engine off—
- 2012 Mini Cooper at 2000, 2500, 4000,and 5000 Hz
- 2012 Ford Focus at 5000 Hz

20 km/h with the IC engine off—
- 2012 Ford Focus at 800, 1000, and 1600 Hz

30 km/h with the IC engine off—
- 2010 Buick LaCrosse at 1000, and 1600 Hz
- 2012 Mini Cooper at 630, 800, 1000, 1600, 2000 Hz
- 2012 Ford Focus at 800, 1000, 1600 and 2000 Hz
- 2012 Lexus RX 350, 2011 Cadillac CTS, 2011 Honda Odyssey, 2012 Honda Fit, 2012 Toyota Camry, 2012 Toyota Corolla, and 2012 VW Golf ICE at 1600 Hz

These results show that at 20 km/h only one of the eleven tested vehicles had any one-third octave bands that met or exceeded the corresponding threshold for detection.[104] Therefore, ten of the eleven vehicles would not be detectable to pedestrians at 20 km/h only based on the tire and wind noise produced by the vehicle. This indicates that at 20 km/h it is unlikely that pedestrians would be able to detect a majority of EVs and HVs without an alert sound. Therefore, according to this data, a crossover speed of 20 km/h does not meet the requirements of the PSEA. At 30 km/h, four models had multiple bands that met or exceeded thresholds, and another seven models met or exceeded the threshold in the 1600 Hz band.

Our conclusion from this analysis is that at 20 km/h few HVs and EVs make sufficient sound to be detectable to pedestrians without the aid of a pedestrian alert system.

In light of this, and given other uncertainties discussed below, the agency has decided in this final rule to maintain the 30 km/h crossover speed proposed in the NPRM.

Regarding the different analysis relied upon by JASIC and other commenters to support a 20 km/h crossover speed, we sought additional data because the JASIC data was limited to a small number of test vehicles. So, in addition to the agency's detection-based analysis discussed above, in order to address crossover speed comments, NHTSA conducted tests using the same method that JASIC had used to derive its recommended 20 km/h crossover speed. As described previously in this section, the method involves comparing sound pressure levels from the same vehicle measured on the track during coast-down (engine off), which approximates an EV or HV in electric mode, and pass-by (engine on) performance tests. Under this analysis, the speed at which coast-down sound level is similar to the pass-by sound level is considered the crossover speed for that particular vehicle. This method identifies the speed at which the sound level due to all factors including tire and wind resistance noise, which are factors cited in the PSEA, is very close to the sound level of the same vehicle with its ICE operating. This method is similar to the peer vehicle method that the agency used in the NPRM, but it uses a single test vehicle in two operating conditions (engine-on and engine-off).

In other words, at any speed higher than the crossover determined according to this method there is no perceived difference between the sound produced by an HV or EV without an alert and the same vehicle with an ICE because the predominant sound in both test conditions comes from the tires and aerodynamic noise, and these factors are consistent for both test conditions.

NHTSA measured coast-down and pass-by sound pressure levels for eleven different ICE vehicles at 10, 20 and 30 km/h test speeds. The results are shown in Table 8.

[103] Quiet Car Coast Down Analysis (Final Rule) (June 2015).

[104] There are several important caveats in the use of this crossover speed analysis. The most important one is that the vehicle data is for coasting ICE vehicles (because the goal is to measure tire and wind noise), and thus it does not include the engine noise that the test vehicles would have in normal operation. Consequently, this evaluation should not be used to judge the sound level in actual operation of any of the test vehicles. Other caveats are enumerated in the docketed analysis paper.

TABLE 8—PASS-BY VS. COAST-DOWN MEASUREMENTS FOR ELEVEN VEHICLES AT 10, 20, AND 30 KM/H [105]

| | | Overall SPL (dBA) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10 km/h | | 20 km/h | | 30 km/h | |
| | | Pass-by (engine on) | Coast-down (engine off) | Pass-by (engine on) | Coast-down (engine off) | Pass-by (engine on) | Coast-down (engine off) |
| 1 | 2012 Toyota Camry | 57.8 | 48.4 | 62.1 | 60.3 | 67.2 | 66.6 |
| 2 | 2012 Toyota Corolla | 56.5 | 48.5 | 61.4 | 59.8 | 67.2 | 66.6 |
| 3 | 2012 VW Golf | 57.0 | 49.4 | 62.3 | 60.9 | 68.3 | 67.4 |
| 4 | 2012 Mini Cooper | 58.7 | 50.8 | 65.6 | 59.9 | 68.3 | 67.2 |
| 5 | 2011 Cadillac CTS | 56.7 | 50.4 | 62.0 | 60.2 | 68.1 | 66.7 |
| 6 | 2012 Toyota Yaris | 56.1 | 46.2 | 59.9 | 57.8 | 65.1 | 64.4 |
| 7 | 2012 Honda Fit | 56.6 | 48.3 | 62.2 | 59.3 | 66.6 | 66.1 |
| 8 | 2010 Buick Lacrosse | 55.8 | 49.9 | 63.8 | 60.4 | 68.4 | 66.7 |
| 9 | 2011 Honda Odyssey | 56.5 | 52.2 | 63 | 62.4 | 69.4 | 68.8 |
| 10 | 2012 Lexus RX 350 | 59.7 | 48.1 | 61.7 | 60.1 | 67.3 | 66.5 |
| 11 | 2012 Ford Focus | 57.5 | 49.3 | 62.6 | 60.8 | 68.0 | 67.1 |
| Average | | 57.2 | 49.2 | 62.4 | 60.2 | 67.7 | 66.7 |

From these data, coast-down measurements were subtracted from pass-by measurements to determine if, and at what speed, crossover occurred for each vehicle. The data are shown in Table 9. As explained in the NPRM,[106] differences in sound pressure level of less than 3dB generally are not distinguishable to humans (differences of 3dB might be noticeable only if two sounds were heard one after the other such that they could be directly compared). Based on this understanding, differences identified in Table 9 of less than 3 dB would indicate that the vehicle crossover speed has been achieved.

**Table 9. Pass-by Versus Coast-down Differences**

| Test Vehicle | 10 km/h Pass-by minus Coast-down (dB) | 20 km/h Pass-by minus Coast-down (dB) | 30 km/h Pass-by minus Coast-down (dB) |
|---|---|---|---|
| 2012 Toyota Camry | 9.4 | 1.8 | 0.6 |
| 2012 Toyota Corolla | 8.0 | 1.6 | 0.6 |
| 2012 VW Golf | 7.6 | 1.4 | 0.9 |
| 2012 Mini Cooper | 7.9 | 5.7 | 1.1 |
| 2011 Cadillac CTS | 6.3 | 1.8 | 1.4 |
| 2012 Toyota Yaris | 9.9 | 2.1 | 0.7 |
| 2012 Honda Fit | 8.3 | 2.9 | 0.5 |
| 2010 Buick Lacrosse | 5.9 | 3.4 | 1.7 |
| 2011 Honda Odyssey | 4.3 | 0.6 | 0.6 |
| 2012 Lexus RX 350 | 11.6 | 1.6 | 0.8 |
| 2012 Ford Focus | 8.2 | 1.8 | 0.9 |

These results indicate that at the vehicle speed of 10 km/h all eleven vehicles had coast-down sound pressure levels significantly less than their associated pass-by levels, meaning that none of the vehicles had attained its respective crossover speed. At 30 km/h, all eleven vehicles had coast-down sound pressure levels close to or within 3 dB of their associated pass-by levels, meaning that every vehicle had reached its respective crossover speed. Thus, the additional testing clarified that 10 km/h would not be sufficient and that all vehicles would reach their crossover speed by 30 km/h (when using the criterion that the results from the two test conditions are within 3 dB.)

The results at 20 km/h were less conclusive. Of the eleven vehicles tested, all had coast-down sound pressure levels below their respective pass-by test levels. However, all but two of the vehicles got to within a 3-dB differential, and the average differential of all vehicles was 2.2 dB. The two vehicles that did not were the Mini and Buick Lacrosse, which had sound differentials greater than 3 dB (5.7 dB and 3.4 dB, respectively) and thus did not reach the crossover speed as defined by the agency. These two vehicle models had the highest pass-by sound pressure levels of the eleven vehicles, and their coast-down sound pressure was close to the average level for all eleven vehicles. While we note that it is possible to interpret this narrow data sample as demonstrating that a lower crossover speed may be sufficient for a portion of the HV/EV fleet, we also conducted additional analysis and considered additional factors in arriving at our decision to maintain the approach to require the pedestrian alert sound up

[105] Garrott, W.R., Hoover, R.L., Evans, L.R., Gerdus, E., and Harris, J.R., ''2012 Quieter Vehicle Testing Report: Measured Sound Levels for Electric, Hybrid Electric, and Low Speed Vehicles'' Washington DC, DOT/NHTSA, November 2016.

[106] *see* NPRM, 78 FR 2838.

to 30 km/h, provided that vehicles are not able to satisfy the performance requirements without an alert sound.

This comparison of the engine-on and engine-off measurements for these vehicles does not directly answer the question of when a vehicle makes enough sound to be detected by pedestrians. We believe that it also demonstrates that at 20 km/h there is a question of whether some vehicles produce enough sound based on tire and wind noise alone to be detected by pedestrians.

Other factors we considered include the difference in pavements encountered in traffic compared to the ISO sound pad that is needed for testing, and the use of tires with low rolling resistance. The test data used to evaluate crossover speed were obtained on an ISO sound pad with a specified asphalt pavement. On public roadways, varying pavement conditions will be encountered that can increase or decrease a vehicle's acoustic sound profile. Also, low rolling resistance tires may tend to increase vehicle sound profiles, but not all vehicles will be operated with low rolling resistance tires. While these factors could increase vehicle noise, they also might decrease it. Selecting the higher crossover speed would ensure safety is not compromised when real-world roadway conditions result in the latter case.

Another consideration is that limitations in available crash data do not permit the agency to make determinations regarding safety benefits at specific speeds. Because the vehicle speed at the time of a crash into a pedestrian is not available in the data set, the agency is not able to quantify what portion of the safety benefits associated with today's final rule would be lost if we were to adopt a value for crossover speed below the real-world values for some specific vehicle models.

However, we continue to believe that this rule will prevent some unqualifiable number of additional injuries by adopting a 30 km/h crossover speed as opposed to a 20 km/h crossover speed. As discussed previously, our crash analysis indicated that the odds ratio of an HV being involved in a crash with a pedestrian was 1.52 when the vehicle in question was executing a low speed maneuver immediately prior to the crash. This means that HVs and EVs are 52 percent more likely to be involved in an incident with a pedestrian than an ICE vehicle under these circumstances. Low-speed maneuvers include making a turn, slowing or stopping, backing, entering or leaving a parking space or driveway, and starting in traffic. The agency also concludes that a crossover speed of 30 km/h (18 mph) will ensure that EVs and HVs will produce sufficient sound to allow pedestrians to safely detect them during low-speed maneuvers in which these vehicles would otherwise pose a risk to pedestrians because of the low sound level they produce. Because we believe that drivers may execute these low speed maneuvers at speeds up to at least 30 km/h, and these maneuvers represent the highest risk of crash between an EV or HV and a pedestrian, more injuries will be avoided due to this rule with a crossover speed of 30 km/h than with a crossover speed of 20 km/h.

As a further consideration, we note that a vehicle is not required to have added alert sound at any speed at which it meets the minimum detection requirements in this final rule. It would be acceptable for an alert system to be designed to turn off at some speed below the 30 km/h crossover speed if it could be demonstrated that, between that lower cut-off speed and 30 km/h, it meets the detectability specifications without the assistance of an alert system.

*E. Acoustic Parameters for Detection of Motor Vehicles*

In the NPRM, the agency proposed minimum sound levels for a specific set of one-third-octave bands [107] that included low-to-mid-frequency bands (315, 400, and 500 Hz) as well as high-frequency bands (2000, 2500, 3150, 4000, and 5000 Hz) for various vehicle operating conditions including stationary, reverse and forward motion up to 30 km/h. These one-third octave bands were selected in an effort to maximize the detectability of the proposed alert sounds while taking into consideration the masking effects of common ambient noise and the degraded hearing of some pedestrians. Specifying minimum sound pressure levels for a wide range of one-third octave bands means that sounds meeting the specifications will be detected in a wider range of ambient conditions with various acoustic profiles.

Low frequency bands (below 315 Hz) were not included in the proposed specifications due to the expected strong masking effects of the ambient noise at low frequencies and the premise that they do not contribute as much to detection. In addition, alert system devices, particularly speakers, that are able to produce high level, low-frequency sounds would most likely have to be larger, heavier, and more costly. Specifications for the low-to-mid-range frequency bands between 315 and 500 Hz were included to assist pedestrians in detecting HVs and EVs in ambient noise environments such as areas near construction activity with significant high frequency noise. In the NPRM, the agency omitted mid-frequency bands from 630 to 1600 Hz because many common ambient conditions include frequencies within this range. One-third octave band standards in this range would have to be set at a relatively high level to effectively compensate for the masking effects caused by ambient noise conditions. But these bands contribute more than other bands to a vehicle's overall alert sound level for the same increase in detectability. By omitting minimum requirements for the one-third octave bands in the 630 to 1600 Hz frequency range in the proposal, the agency was attempting to ensure that alert sounds allow pedestrians to safely detect nearby EVs and HVs without unnecessarily increasing overall ambient noise levels.[108] The high-frequency bands up to 5000 Hz provide good detectability for pedestrians with normal hearing.

The proposed sound specifications were based on a psychoacoustic modeling approach in combination with safe detection distances. The inherent assumptions for this analytical approach were that: [109]

- A vehicle should be detectable in the presence of a moderate suburban ambient, *i.e.,* ambient at 55 dB(A); [110]
- a psychoacoustic model can be used to determine minimum levels for detection of one-third octave bands in the presence of an ambient;
- sounds should be detectable in multiple one-third octave bands to increase the likelihood that a pedestrian will be able to detect the sound in multiple ambients with differing acoustic profiles; and

[107] Octave band and one-third octave band scales facilitate identifying the specific frequencies of sounds. Octave bands separate the range of frequencies audible to humans into ten bands, and the one-third octave bands split each of the ten octave bands into three smaller frequency bands. Each scale in the breakdown provides more information about the sound being analyzed.

[108] NPRM, ''Federal Motor Vehicle Safety Standards; Minimum Sound Requirements for Hybrid and Electric Vehicles, 78 FR 2829, (Jan. 14, 2013).

[109] Hastings, et al. (2012). Research on Minimum Sound Specification for Hybrid and Electric Vehicles. Docket NHTSA–2011–0148–0048.

[110] In the NPRM we stated that we chose an ambient with a 55 dB(A) overall sound pressure level because this represented a reasonable level below the 60 dB(A) ambient in which pedestrians would no longer be able to reasonably rely on hearing to detect approaching vehicles.

• minimum detection distances can be based on vehicle stopping distances and driver reaction times.

The agency used Moore's Partial Loudness model [111] to estimate the minimum sound levels needed for a sound to be detectable in the presence of an ambient. The first step in our approach was to determine the minimum levels for detection, using Moore's model and a simplified ambient, for a pedestrian at the vehicle location. We stated that the distance at which a pedestrian would need to hear a vehicle is at least as long as the distance travelled during the driver's reaction time, plus the vehicle's stopping distance. We calculated these distances from the guide on highway design [112] of the American Association of State Highway Transportation Officials (AASHTO) according to the following formula:

$$d = 0.278Vt + 0.039\,\frac{V^2}{a}\ \ (meters)$$

Where:

t = brake reaction time, sec.
V = design speed, km/h
a = deceleration rate, m/s²

We explained that we chose a reaction time of 1.5 seconds because that is the mean reaction time for surprise events [113] such as an object suddenly moving into a driver's path. We chose the 5.4 $m/s^2$ deceleration rate corresponding to dry pavement braking because most of the pedestrian crashes that the agency identified occurred in clear conditions. If we had decided to use instead a slower deceleration rate for wet pavement conditions, we believe the necessary sound profile for detection would have to be louder and for a longer period because it would take a greater distance to stop, and thus would be unnecessarily loud for most conditions.

Based on calculations using these values, the agency determined that the desired detection distances were 5 meters in front of the vehicle for the 10 km/h (6.2 mph) pass-by, 11 meters for the 20 km/h (12.4 mph) pass-by, and 19 meters for 30 km/h (18.6 mph) pass-by. The results of these computations were rounded to the nearest meter. Moore's Partial Loudness Model was then used to derive the minimum sound levels required for detection for each driving condition and one-third octave band. Levels were increased by 0.5 dB to provide a small safety factor, and were then rounded up to the nearest integer for simplicity. The resulting NPRM levels are shown in Table 10.

TABLE 10—NPRM MINIMUM SOUND LEVELS FOR DETECTION

| One-third octave band center frequency, Hz | Stationary but activated | Backing | 10 km/h | 20 km/h | 30 km/h |
|---|---|---|---|---|---|
| 315 | 42 | 45 | 48 | 54 | 59 |
| 400 | 43 | 46 | 49 | 55 | 59 |
| 500 | 43 | 46 | 49 | 56 | 60 |
| 2000 | 42 | 45 | 48 | 54 | 58 |
| 2500 | 39 | 42 | 45 | 51 | 56 |
| 3150 | 37 | 40 | 43 | 49 | 53 |
| 4000 | 34 | 36 | 39 | 46 | 50 |
| 5000 | 31 | 34 | 37 | 43 | 48 |
| Overall A-weighted SPL Measured at SAE J2889–1 PP' line | 49 | 52 | 55 | 62 | 66 |

We explained in the NPRM that while we were setting the sound pressure levels for each one-third octave band based on the distance from the vehicle at which we wanted pedestrians to be able to hear approaching vehicles, because of practical reasons we would measure sound emission for compliance purposes at a distance of 2 meters and scale the required levels accordingly. We used the following method to calculate what the sound level would need to be 2 meters from the vehicle's path to be detected within the prescribed stopping distance. Table 11 shows how the sound produced by a vehicle attenuates when measured using the procedure in SAE J2889–1.

TABLE 11—SPL ADJUSTMENT (dBA) FROM SOURCE TO SAE MICROPHONE LOCATION

| | | | |
|---|---|---|---|
| Speed, km/h | 10 | 20 | 30 |
| X source, meters | 5 | 11 | 19 |
| Y source,* meters | 2 | 2 | 2 |
| r0,** meters | 2.3 | 2.3 | 2.3 |
| r1,** meters | 5.5 | 11.2 | 19.1 |
| r doubling | 1.2 | 2.3 | 3.0 |
| Attenuation, dB | −5.8 | −12.3 | −16.8 |

* Assume effective source is at center of vehicle since propagation is forward.
** Assume Z = 1.2.

'X' represents the horizontal distance from the source to the P–P' line while 'Y' is the 45perpendicular distance from the source to the microphones in SAE J2889–1. 'Z' represents the height of the microphone in meters as specified in SAE J2889–1. The values in Table 11 were calculated using the following

[111] Moore, B.C.J., Glasberg, B.R., and Baer, T. (1997). A Model for the Prediction of Thresholds, Loudness and Partial Loudness, J. Audio Eng. Soc. 45, 224–240.

[112] American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets,* Chapter 3 Elements of Design (2004).

[113] Green (2000) How Long Does It Take to Stop? Methodological Analysis of Driver Perception-Brake Times.'' Transportation Human Factors 2(3) 195–216.

formula and assuming a value of 1.2 meters for Z:

$$r_0 = \sqrt{y^2 + z^2}$$

$$r_1 = \sqrt{x^2 + y^2 + z^2}$$

$$r_{doubling} = \log_{10}(r_1/r_0)/\log_{10}(2)$$

$$Attenuation = -6 \times r_{doubling}\ dB$$ [114]

In the NPRM, the agency also indicated its intent to conduct additional research before issuing a final rule to confirm that sounds meeting the proposed requirements would be detected as predicted by the model, and we sought comments on the following topics (NPRM pp. 2832–2833):

- What improvements would make the acoustic specifications more effective and make alert sounds more detectable?
- Should NHTSA require vehicles to emit sound that meets the four one-third octave band requirements only at 2000 Hz and above as an alternative to requirements for eight one-third octave bands?
- What is the optimum number of bands that should contain minimum sound level requirements, and what should the corresponding levels be?

In addition to requirements with minimum content in the eight one-third octave bands between 315 Hz and 500 Hz and 2000 Hz and 5000 Hz, the NPRM also considered acoustic requirements with minimum content in two one-third octave bands with a minimum requirement for the overall sound pressure level of the sound. NHTSA stated, when discussing this possible two-band approach in the NPRM, that it was seeking comment on the acoustic profile of the minimum sound requirements, as well as on the number of one-third octave bands for which the agency should establish requirements. We stated in the NPRM that the reason we were not proposing to adopt requirements for content in two one-third octave bands was that a sound with content in only two one-third octave bands would not be detectable in as many ambient noise environments as sounds with minimum content in eight one-third octave bands. On the topic of acoustic parameters for detection, the agency received a joint comment from Alliance/Global, as well as comments from OICA, Chrysler, Ford, GM, Honda, Mercedes, Nissan, Porsche, Toyota, the National Federation of the Blind, the American Council of the Blind, the World Blind Union, the National Council of State Agencies for the Blind, the Disability and Communication Access Board, the Insurance Institute for Highway Safety, Advocates for Highway and Auto Safety, Accessible Design for the Blind, and Western Michigan University. Subsequent to the NPRM comment period, NHTSA also received a late comment submitted jointly by the Alliance, Global, the NFB, and the ACB, and the agency had additional correspondence with those commenters, which is recorded in the docket.

Four main issues were discussed by the commenters relating to the acoustic parameters proposed for detection: (1) The number and level of one-third octave bands required; (2) the methods used to determine detection distances and associated sound specifications; (3) the range of frequencies used; and (4) vehicle marketability.

Fifteen of the above commenters discussed the first issue about the number and levels of one-third octave bands required. Alliance/Global [115] stated that NHTSA's proposed specification in the NPRM is too conservative. They suggested deleting the requirement for frequency content in eight one-third octave bands and replacing it with a simplified two-band approach. Specifically, they recommended using a minimum overall SPL and minimum sound levels in at least two octave bands. In their suggested approach, one band would be required in a low frequency range (less than 1000 Hz) and one band would be required in a high frequency range (1000 Hz up to 3150 Hz), separated by at least one one-third octave band. Alliance/Global suggested the following levels (Table 12) but noted that further discussion within the QRTV group that is developing a GTR is needed before these values can be fully recommended:

TABLE 12—ALLIANCE/GLOBAL RECOMMENDED TWO-BAND LEVELS

| Test condition [116] | Overall SPL | Individual band SPL (two bands) |
|---|---|---|
| Stationary/Backing. | 48 dB | 44 dB |
| 10 km/h | 53 dB | 46 dB |
| 20 km/h | 58 dB | 51 dB |

Alliance/Global stated that NHTSA's target for detectability performance can be achieved with two one-third octave bands set at the levels proposed in the NPRM, and the minimum levels for additional bands can be reduced while maintaining the same detectability performance. Alliance/Global stated that if NHTSA chooses to require in the final rule that sounds emitted by EVs and HVs must have content in more than two one-third octave bands, the agency should reduce the minimum levels for each one-third octave band according to the total number of required bands. Chrysler, GM, Honda, and Mercedes stated that they support the two-band approach suggested by Alliance/Global.

Ford argued that based on its study of this subject, not all eight one-third octave bands are needed for a sound to be detectable 5 meters away. Ford's study consisted of a human factors test where audio recordings of vehicle

[114] Attenuation rate = 4.5 dB for the first distance doubling and 6 dB per distance doubling thereafter.

[115] NHTSA–2011–0148–0251.

[116] The Alliance/Global recommendations did not include suggested minimums for 30 km/h in accordance with their comments that crossover speed should be limited to 20 km/h.

sounds were presented to participants using headphones. Sounds tested by Ford were an ICE vehicle sound, an electric vehicle without an alert sound, and three alert sounds, but those sounds did not meet all of the agency's proposed minimum one-third octave bands levels. Sounds were mixed with a 55 dB(A) masking noise. Twenty-four Ford employees and four visually impaired individuals participated in the study. Ford stated that all vehicles were detected before the 5-meter critical distance, except for the vehicle without an alert. They also reported that participants recognized the vehicles with alert sounds at least at the same rate as the ICE vehicle sound.

Nissan stated that a sound with a sound pressure level equivalent to the ICE fleet minimum with a two-peak sound profile is appropriate for detectability. Nissan stated that having one peak frequency component between 600 and 800 Hz helps detectability for aging pedestrians with high frequency hearing loss. A second peak frequency component between 2000 and 5000 Hz would provide detectability for pedestrians with normal hearing. Nissan also suggested that the required frequency content of alert sounds at around 1000 Hz (the typical frequency for road traffic noise) should be reduced to avoid additional contribution to traffic noise.

Porsche stated that the specified levels in the NHTSA proposal will lead to very loud and unpleasant alert sounds. They suggested specifying at least two bands, but allowing up to eight bands. Porsche explained that the levels to be met should be a function of the number of bands selected. They explained that if more bands are used, the levels per band can be lower to achieve the same detectability. They suggested that, for example, if eight bands are used, then the levels in each band should be reduced by 6 dB (*e.g.,* the agency's proposed minimum level of 43 dB(A) for the 500 Hz one-third octave band for the stationary condition would be reduced to 37 dB(A)), and if four bands are used, the levels in each band should be reduced by 4 dB.

Toyota supported the use of an overall level and at least two one-third octave bands, consistent with the Alliance/Global recommendation. Toyota provided results from a study that it conducted to confirm the detectability performance of the suggested approach. In that study, 33 individuals (from 20 to 49 years old) participated. The ambient noise level varied from 51 to 59 dB(A).[117] The test vehicle was a Toyota Prius V approaching at 20 km/h. The study indicated that the overall level of the test vehicle was 58 dB(A) with sound energy in multiple bands. The sound level in the 800 Hz and 2000 Hz bands were each 51 dB(A), which accounted for nearly half of the sound's acoustic energy. Toyota reported that the measured detection distance exceeded the NHTSA target detection distance in the NPRM for this operating condition.

OICA stated that the proposed specification for eight bands will force very loud devices with unpleasant sounds. They suggested that the sound specifications within the UNECE–GTR development group. They stated that NHTSA should consider requiring a specific number of tones which could be in the same one-third octave band, rather than requiring a specific number of one-third octave bands.[118]

The American Council of the Blind (ACB) stated that the most appropriate approach to the sound specifications would be to set the minimum sound level based on the levels produced by light ICE vehicles because this is the sound pedestrians currently use for safe navigation. ADB stated ''octave bands are not as great at predicting detection as overall sound levels'' based on research conducted by WMU. WMU stated that their research has shown that individual octave bands are not as useful in determining detection as is the overall sound level and that, while some regulatory direction in octave band make-up of alert sounds might be useful, there is limited justification for a requirement as restrictive as the NHTSA proposal. WMU stated that their previous research had shown a limited advantage for content in the 500 Hz band in some situations, and their statistical analysis showed significant predictive value for overall sound pressure levels rather compared to content in any particular band. WMU also commented that detecting a single approaching vehicle may not be the same as detecting quiet vehicles when other vehicles are present. In response to the request for comments on requiring vehicles to emit sound that meets only the one-third octave band requirements for 2000 Hz and above as an alternative to meeting all eight one-third octave bands, WMU stated that for a pedestrian with hearing loss content at lower frequencies is needed and that potential sounds should have a fairly broadband frequency spectrum. WMU suggested that identifying two frequency bands that are most useful for detection, similar to Nissan's approach, may be appropriate.

As mentioned above, NHTSA also received a joint letter, submitted to the docket and treated as a late comment, from the Alliance, Global, the NFB, and the ACB.[119] These commenters agreed on several technical and policy issues. They stated that the number of bands should be reduced from a minimum of eight to at least two, between 160 Hz and either 3150 or 5000 Hz, and that at least one band should be below either 1000 or 1600 Hz. Within each individual frequency band, they stated that sound levels should be revised with input from available research. They also suggested establishing limits on overall sound pressure level, but did not provide specific values.

The second main topic discussed by the commenters concerned the methods used by the agency to determine detection distances and associated sound specifications. Eleven of the commenters listed above provided comments on this topic.

In their joint comment, the Alliance, Global, NFB and ACB agreed with the detection distance methodology in the NPRM and with the values used for the deceleration rate and the brake reaction time. The World Blind Union (WBU), the National Council of State Agencies for the Blind (NCSAB), the Disability and Communication Access Board, and the Insurance Institute for Highway Safety, all agreed that the methodology used by NHTSA to set the minimum sound levels seemed reasonable and appropriate. OICA stated that the NPRM approach to establish detection distance as a function of vehicle speed is reasonable but only when applied to the overall sound pressure level.

Advocates for Highway and Auto Safety also generally agreed with specifications based on detection distance. They commented on the driver reaction time used in the detection distance computation and suggested that the 1.5 sec. used by NHTSA may be too short. They indicated that NHTSA should examine reaction times for drivers in relation to pedestrians and pedalcyclists in establishing this value.

Accessible Design for the Blind (ADB) expressed support for the NPRM approach to minimum sound levels but questioned the detection distance used in NHTSA's analysis. ADB questioned

[117] The Toyota comment did not include details about the spectral shape of the ambient, which would be important to better understand the possible masking conditions and their impact on the test vehicle alert sound acoustic profile.

[118] We note here that this suggestion could result in an alert signal with only one distinct component, for example, a single amplitude-modulated tone.

[119] NHTSA–2011–0148–0322

whether the detection distance used in NHTSA's formulation represents distances that are sufficient for pedestrians to detect, recognize, judge distance and trajectory, decide to initiate a crossing, and initiate a crossing, particularly at busy intersections. They also indicated that the specifications proposed in the NPRM are based on the detection of a single vehicle in the absence of other vehicles, which they believe is not realistic.

WMU indicated that the detection distance used in the development of the sound specification may be too short because it may not correspond to the time needed to detect a vehicle, process the information, and decide to take action. WMU explained that the detection distance formula used does not account for variability among pedestrians including those with hearing loss.

On the third issue about the range of frequencies used, the Alliance/Global, OICA and NFB provided comments. Alliance/Global said that one-third octave bands from 630 to 1600 Hz should not be excluded from the useable range as NHTSA did in the NPRM because ''these frequencies will clearly contribute to the detectability.'' OICA recommended that no sound be required above 2 kHz as they believe that is not representative of vehicle sounds. OICA stated that manufacturers should be allowed to use the range from 125 Hz to 3000 Hz and suggested that low frequencies could aid with detectability but may have cost implications. OICA recommended that low frequencies should be an option for manufacturers and if used, believe the regulatory scheme should give credit to manufacturers for using low frequencies.[120] NFB stated that manufacturers should have flexibility to create sounds that are pleasant and not annoying to vehicle occupants and requested that the agency consider not requiring sound in the lowest one-third octave bands. NFB stated that manufacturers can limit the sound inside the vehicle and meet the safety need of pedestrians without including content in each of the eight proposed one-third octave bands.

The fourth main issue raised in comments relates to vehicle marketability. These comments are addressed in section III.I of this notice.

Agency Response to Comments

Detectability Model Conclusions

After considering all comments received in response to the NPRM, and the results of agency research conducted since the NPRM was issued, we have decided to modify the proposed minimum specifications for detection of vehicles subject to this rule. While the number of one-third octave bands for which the agency is establishing requirements for minimum content and the requirements related to detection of changes in vehicle speed differ from the NPRM, the underlying analytical framework on which the minimum acoustic requirements in the final are based has not changed. The minimum acoustic requirements for each one-third octave band in the final rule remain based on the same formula used to develop the requirements proposed in the NPRM albeit with slightly different inputs to that formula. Furthermore, the overall sound pressure level and one-third octave band levels of sounds meeting the requirements of the final rule will be similar to the corresponding levels of sounds meeting the eight one-third octave band requirements in the NPRM.

After considering the comments and the agency's further evaluations conducted in response to comments, we decided to reduce the number of one-third octave bands for which we are requiring content from the eight one-third octave band requirement proposed in the NPRM to either a four one-third octave band compliance option or a two one-third octave band compliance option, the latter including an overall SPL specification.

Under the four one-third octave band compliance option, the minimum sound requirements for each band would be slightly lower than the values proposed in the NPRM, and the overall sound pressure of sounds meeting the four one-third octave band compliance option will be similar to those meeting the proposed requirements for eight bands in the NPRM. Under the two one-third octave band compliance option, the minimum sound requirements for each band are lower than those in the eight one-third octave band proposal in the NPRM for the low and mid frequency bands and higher than the minimum values in the NPRM for the high frequency one-third octave bands centered at 4000 Hz and 5000 Hz.

In the NPRM, NHTSA stated that it planned to conduct additional research once the NPRM was issued to validate the model used to develop the minimum sound requirements in the NPRM. The purpose of this research was to determine whether the model accurately predicted when sounds would be detected by human listeners at the distances predicted by the model.

Volpe conducted a human factors study to quantify differences between predicted detection levels (as indicated by Moore's Partial Loudness model) of vehicle sounds in the presence of a standardized ambient used to calculate the minimum requirements proposed in the NPRM and actual responses of participants listening to these vehicle sounds through headphones.[121] The study also evaluated the effect of several factors on detectability, including the number of one-third octave band components contained in a sound, adjacency of bands, and signal type (*e.g.,* pure tones, bands of noise). Fifty-two demographically diverse subjects were exposed to a simulation of a vehicle passing by them (as a pedestrian) at 10 km/h, in ambient noise conditions of 55 dB(A). In the study, a selection of 24 different sound signals were played back over the participants' headphones. The signals were based on synthesized and recorded sources and included pure tones, single noise bands, multiple adjacent noise bands, multiple non-adjacent noise bands, tones mixed with noise, a signal based on a recorded ICE, and signals from prototype alert systems. Signals with various numbers of bands were included in the study, ranging from one to four non-adjacent bands and from one to twenty-four continuous or semi-continuous bands. With the exception of the ICE vehicle sound, the two recorded prototype alert signals, and the three two-band samples, all signals were calibrated to just meet the NPRM specifications for safe detection in each band with signal content.[122]

The study results indicated that, except for frequency sensitivity of high frequency components, the modeling approach for determining the minimum level needed in each one-third octave band was conservative, meaning that the participants responded to signals

[120] No explanation was provided by OICA about how or why vehicle manufacturers should be given credit for using low frequencies.

[121] Hastings A.; and McInnis, C. ''Detectability of Alert Signals for Hybrid and Electric Vehicles: Acoustic Modeling and Human Subjects Experiment,'' (2015) Washington, DC: DOT/NHTSA.

[122] The NPRM did not include specifications for the one-third octave bands from 630Hz–1600Hz. Some alert signals considered by Volpe during the human factors study did include one-third octave bands in this range. Volpe derived the appropriate level for those bands the same way the minimum levels for the bands included in the NPRM were developed. For details, refer to the Volpe research report, Hastings A.; and McInnis, C. (2015). ''Detectability of Alert Signals for Hybrid and Electric Vehicles: Acoustic Modeling and Human Subjects Experiment''. Washington, DC: DOT/NHTSA.

somewhat sooner on average than the model predicted. With an understanding that the model was conservative overall but less accurate at the higher frequencies, model adjustments were made as discussed in section II.C of this preamble to provide more accurate results necessary for development of the final minimum one-third octave band levels specified in this rule.

Although not directly tested in the study, we found a general trend that the minimum one-third octave band levels as proposed in the NPRM could be reduced when increasing the number of one-third octave bands. We also found that using non-adjacent one-third octave bands instead of adjacent bands maintained the detectability of sounds more effectively while limiting the overall level. Consequently, we have incorporated non-adjacency as one of the specifications in the final rule alert requirements. We have decided not to adjust the minimum one-third octave band levels to account for the number of required bands because in this final rule we have reduced the number of required bands from eight bands to either two or four bands.

The study results also indicate that sounds with minimum content in eight, four, and two one-third octave bands were all detected by study participants prior to the two-second time-to-vehicle arrival point necessary for safety.

As discussed above, NHTSA received several comments from manufacturers and groups that represent manufacturers stating that agency should adopt the acoustic requirements with content in two one-third octave bands plus a requirement for a minimum overall sound pressure level discussed in the NPRM. These commenters believed that NHTSA's goal in the NPRM of ensuring that sounds produced by hybrid and electric vehicles are detectable to pedestrians in a variety of ambients could be accomplished by requiring minimum acoustic content in two one-third octave bands. In response to these comments and the joint comment submitted by the Alliance, Global, NFB and ACB recommending that the agency require minimum content in only two bands, NHTSA decided to conduct additional analysis to determine the likelihood that sounds with content in fewer than eight bands would be masked in different ambient environments.

The resulting analysis provided an estimate of how often a sound signal would be detected as a function of the number of one-third octave bands. Real-world ambient conditions are not consistent, and we wish to draw conclusions about detectability beyond the standardized 55 dB(A) ambient used to create the proposed requirements in the NPRM. The ambient data used in this analysis was recorded at 17 locations along Centre Street in Newton, Massachusetts.[123] Ambient samples were taken at intersections (signalized and stop-sign-controlled), one-way streets, side streets, and driveways. Samples had a mix of low, mid, and high frequencies. Some samples were dominated by low frequency content, *i.e.,* the environment had other vehicles in close proximity operating at and/or accelerating from low speeds, while other samples were dominated by high frequency content, *i.e.,* the environment had other vehicles in close proximity operating at higher constant speeds. Each ambient sample was normalized [124] to an overall sound pressure level of 55 dB(A) without affecting the spectral variation. Volpe then used the adjusted acoustic model to test how signals with different numbers of components perform across this wide variety of ambient conditions. This approach of testing signals in varying ambient conditions but at a consistent overall level allowed us to determine the performance of signals as a function of the number of components in the signal. Specifically, this method provides a measure of ''robustness'' of the signal which is the metric we use to gauge how likely it is that one or more of the signal components will be heard by pedestrians in a range of ambient conditions.

NHTSA's approach in evaluating various signals was to set the band levels for each component at the appropriate psychoacoustic thresholds according to the modified Moore's model after the model had been adjusted using the results of Volpe's human factors experiment. The adjusted acoustic model was used to measure the performance of signals having various numbers of frequency components from one up to seven one-third octave bands by evaluating how readily each signal was detected in the presence of a broad range of measured ambients normalized to the 55 dB(A) level.

[123] Ambient data were collected in 2010 (Hastings, et al. 2011). Walkthroughs were conducted with different orientation and mobility instructors; data were collected on different days of the week and time of day.

[124] Each ambient sample had to be normalized to an overall SPL of 55dB(A) to ensure a comparable analysis was conducted for detectability utilizing different numbers of one-third octave bands. As discussed in the NPRM and this final rule, a standardized 55dB(A) ambient was used to derive the minimum one-third octave band specifications. The ambient used also had a standardized one-third octave band frequency composition. To analyze the robustness of various alerts, the multiple ambients collected had various overall SPLs, either less than or greater than 55dB, and various frequency compositions. For a proper evaluation of the various ambients, each ambient's overall SPL had to be normalized, that is adjusted to 55 dB, while maintaining each individual sample's unique frequency profile. To normalize each ambient sample, the sample was broken down into its one-third octave band levels and then each level was decreased or increased the same percentage until the overall level for that particular ambient sample equaled 55dB(A). For consistent comparisons of vehicle alert sounds in these different ambients, the key data was the frequency composition, or acoustic profile, across the one-third octave bands for each ambient collected.

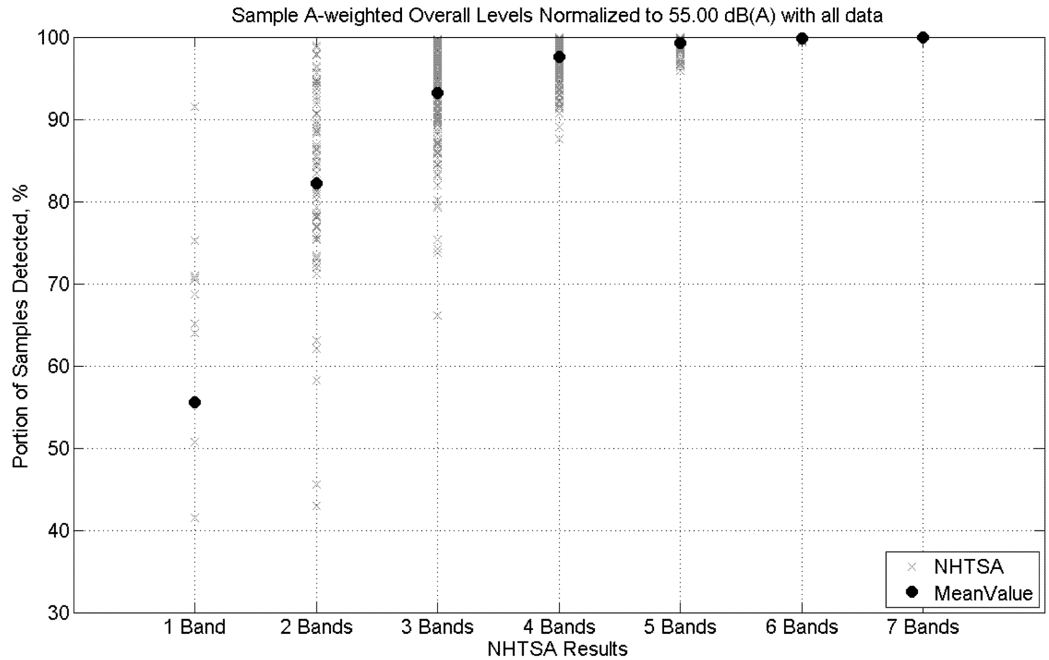


**Figure 2. Robustness of Signals Having From 1 to 7 Bands That Meet Minimum NPRM Levels**

Figure 2 shows the ''robustness'' [125] of single and multiple one-third octave band alert specifications, and includes up to seven bands because that is the maximum number that can be non-adjacent over the 315 to 5000 Hz range. This analysis shows that, on average, signals with minimum content in four one-third octave bands can be detected in 97 percent of ambient environments examined. This analysis also shows that sounds with content in only two one-third octave bands show strong resistance to masking if the minimum content is in certain bands. Additionally, this analysis shows that sounds with content in more than four one-third octave bands are only marginally more resistant to masking than sounds with four bands. Based on this analysis, NHTSA agrees with the commenters that the agency can accomplish the goals articulated in the NPRM of ensuring that sounds produced by EVs and HVs are detectable to pedestrians in a variety of ambients by requiring minimum content in fewer than eight one-third octave bands.

Given that the rationale for specifying minimum content in eight one-third octave bands in the NPRM was to ensure that sounds meeting the requirements of the NPRM were resistant to masking, NHTSA is reducing the number of bands in response to comments suggesting that requiring minimum content in eight one-third octave bands it not necessary for safety. As the latest NHTSA research demonstrated, reducing the number of bands with minimum requirements from eight to either four or two one-third octave bands would not impact the effectiveness of sounds meeting the minimum requirements of the final rule in providing alerts to pedestrians.

We believe that the four-band requirements and the two-band requirements have equivalent performance in terms of detectability by pedestrians and will be equally detectable in a variety of different ambients.

Under the four-band compliance option, the agency is requiring that the four bands used to meet the detectability requirements must be non-adjacent one-third octave bands in the frequency range from 315 Hz to 5000 Hz. This range includes the eight one-third octave bands for which we proposed requirements in the NPRM. In response to comments, NHTSA has decided that the final rule will also allow manufacturers to comply with the minimum acoustic requirements by placing acoustic content in the mid-range frequency bands excluded from the NPRM.

In order to comply, the alert signal must meet or exceed the given levels in at least four non-adjacent bands for each given vehicle operating condition. Also, the four bands must span a range of at least nine one-third octave bands. NHTSA believes that the four one-third octave band compliance option achieves the goals articulated in the NPRM of ensuring that sounds meeting this standard are detectable in a variety of ambients and responds to comments submitted to the NPRM claiming that the requirements in the NPRM were too restrictive and would require unpleasant sounds.

Because of the number of comments received on this issue, NHTSA also decided to explore allowing the two one-third octave band compliance option discussed in the NPRM. Under the two-band compliance option, minimum sound pressure levels are required in two non-adjacent one-third octave bands from 315 to 3150 Hz. One of the two bands must be below 1000 Hz and the second band must be at or above 1000 Hz. The two bands used must each meet the minimum requirements and together must also meet a specified overall SPL.

By including both a four-band specification and a two-band specification in this final rule, NHTSA is providing vehicle manufacturers with the flexibility to choose either compliance option in the new safety

[125] We use the term ''robustness'' to indicate how resistant a signal is to masking by background noise from a wide selection of different normalized ambient conditions covering a range of spectral content.

standard. We believe this approach adequately addresses a great majority of comments concerning the eight-band detectability specification proposed in the NPRM.

In addition, based on the foregoing, we have implemented slight changes to the minimum one-third octave band levels as a result of our human factors testing and acoustic model adjustments discussed above. As explained, these slight changes provide better agreement between the modeled levels and the levels indicated by the responses of the experiment participants when listening to various signals (see Figure 1) Table 13 provides the final rule minimum one-third octave band levels for each operating condition.[126]

TABLE 13—FINAL RULE MINIMUM SOUND LEVELS FOR DETECTION

| One-third octave band center frequency, Hz | Stationary | Reverse | 10km/h | 20 km/h | 30 km/h |
|---|---|---|---|---|---|
| 315 | 39 | 42 | 45 | 52 | 56 |
| 400 | 39 | 41 | 44 | 51 | 55 |
| 500 | 40 | 43 | 46 | 52 | 57 |
| 630 | 40 | 43 | 46 | 53 | 57 |
| 800 | 41 | 44 | 47 | 53 | 58 |
| 1000 | 41 | 44 | 47 | 54 | 58 |
| 1250 | 42 | 45 | 48 | 54 | 59 |
| 1600 | 39 | 41 | 44 | 51 | 55 |
| 2000 | 39 | 42 | 45 | 51 | 55 |
| 2500 | 37 | 40 | 43 | 50 | 54 |
| 3150 | 34 | 37 | 40 | 47 | 51 |
| 4000 | 32 | 35 | 38 | 45 | 49 |
| 5000 | 31 | 33 | 36 | 43 | 47 |
| Overall A-weighted SPL Range | 43–47 | 46–50 | 49–53 | 55–59 | 60–64 |

The minimum one-third octave band requirements in the final rule for the eight one-third octave bands for which the agency proposed requirements in the NPRM are slightly lower than the values proposed in the NPRM for all test conditions. Alert signals just meeting these requirements are expected to have overall levels similar to sounds meeting the proposed requirements of the NPRM, ranging from 43 to 47 dB(A) for stationary; 46 to 50 dB(A) for reverse; 49 to 53 dB(A) for 10 km/h; 55 to 59 dB(A) for 20 km/h; and 60 to 64 dB(A) for 30 km/h.

As proposed, our detectability requirements were set so that EVs and HVs are detectable in an ambient with a 55 dB(A) overall sound pressure level. It has been our understanding that pedestrians who are blind use sound for navigation in environments for which the ambient is at or below 55dB(A), and they rely on more than just sound when the ambient increases above that level.[127] The NPRM explained that, in NHTSA's development of requirements for minimum vehicle sound levels, the agency chose to use a standardized ambient[128] at a level of 55 dB(A) as an alternative to recordings of actual traffic.[129] Based partly on research conducted by Pedersen et al. 2011,[130] NHTSA selected an ambient with a 55 dB(A) noise level and a specific spectral shape (see Figure 2, p. 2818 in the NPRM) that the Pedersen research had found to be representative of many common urban ambients. Because alert sounds that are detectable in the standardized 55 dB(A) ambient also would be detectable in ambients with similar spectral shapes and lower overall sound pressure levels, the 55 dB(A) standardized ambient was appropriate for detectability computations and was utilized throughout NHTSA's development of the minimum sound levels included in this final rule.

Our approach of using human subject responses to set detection thresholds indicates how quiet alert sounds can be before they can no longer be heard and ensures that the alert sound requirements in the final rule will have the least possible impact on overall environmental noise while still providing pedestrians with the vehicle sounds they need to navigate traffic situations.

In this final rule, for the reasons discussed above, the agency has decided to reduce the eight one-third octave band requirement as proposed in the NPRM to a four one-third octave band requirement. The agency is requiring that the four bands used to meet the detectability requirements must be non-adjacent one-third octave bands in the frequency range from 315 Hz to 5000 Hz because the results of the human factors study suggests that signals with non-adjacent bands are more detectable than signals with adjacent bands. Also, these bands must span a range of at least nine one-third octave bands. This is consistent with comments made by Alliance/Global. Signal components in adjacent one-third octave bands can mask each other more effectively than signal components in non-adjacent one-third octave bands. Masking reduces the effectiveness of the alert signal. Further,

[126] These levels are based on a single one-third octave band of noise producing a detectable signal assuming a threshold of 0.079 sones per ERB for the maximum of the partial specific loudness which is the threshold value that provides the best fit between modeled detection times and those of the experiment participants. The adjustments account for model biasing for specific operating conditions, repeatability/reproducibility as discussed in section III.K of this final rule, and calculation rounding. For details see: Hastings A.; and McInnis, C. ''Detectability of Alert Signals for Hybrid and Electric Vehicles: Acoustic Modeling and Human Subjects Experiment,'' (2015) Washington, DC: DOT/NHTSA.

[127] In the NPRM we stated that we chose an ambient with a 55 dB(A) overall sound pressure level because this represented a reasonable level below the 60 dB(A) ambient in which pedestrians would no longer be able to reasonably rely on hearing to detect approaching vehicles.

[128] The standardized ambient is a ''synthetic'' background noise consisting of white noise filtered to have the same spectrum as what a pedestrian would hear in real traffic but without the variations in amplitude over time. This synthetic noise is similar to actual traffic noise but is more consistent and repeatable and thus is better suited to the acoustic research that NHTSA conducted.

[129] The NPRM included a lengthy discussion of how masking of vehicle sounds by ambient noise (also called background noise) is a fundamental factor in developing minimum vehicle sound levels. For research purposes, background noise can come from recordings of actual traffic, but such recordings are likely to include random fluctuations or peaks from transient sources like the passage of nearby traffic, construction noise, or aircraft that introduce variability when conducting human factors testing or when applying detectability models.

[130] Pedersen, *et al.* (2011). White paper on external sounds for electric cars—Recommendations and guidelines.

four components that span nine bands will be more widely spaced than four components in adjacent bands. This will increase the probability that pedestrians will be able to detect at least one signal component. This is especially true for pedestrians with age-related hearing loss. Signals in the mid-range one-third octave bands from 630 Hz to 1600 Hz, which are most strongly masked by the typical ambient conditions encountered by pedestrians, were excluded in the NPRM in an effort to reduce the overall level since components in this frequency range would need to be set at higher sound pressure levels. However, our decision to require only four bands in the final rule and to include those mid-range frequencies provides manufacturers with more flexibility and addresses comments about the exclusion of those frequencies in the NPRM. In order to comply with the four one-third octave band compliance option, the alert signal must meet or exceed the given levels in at least four non-adjacent bands for a given operating condition. Figure 3 provides an example of a four-band signal.

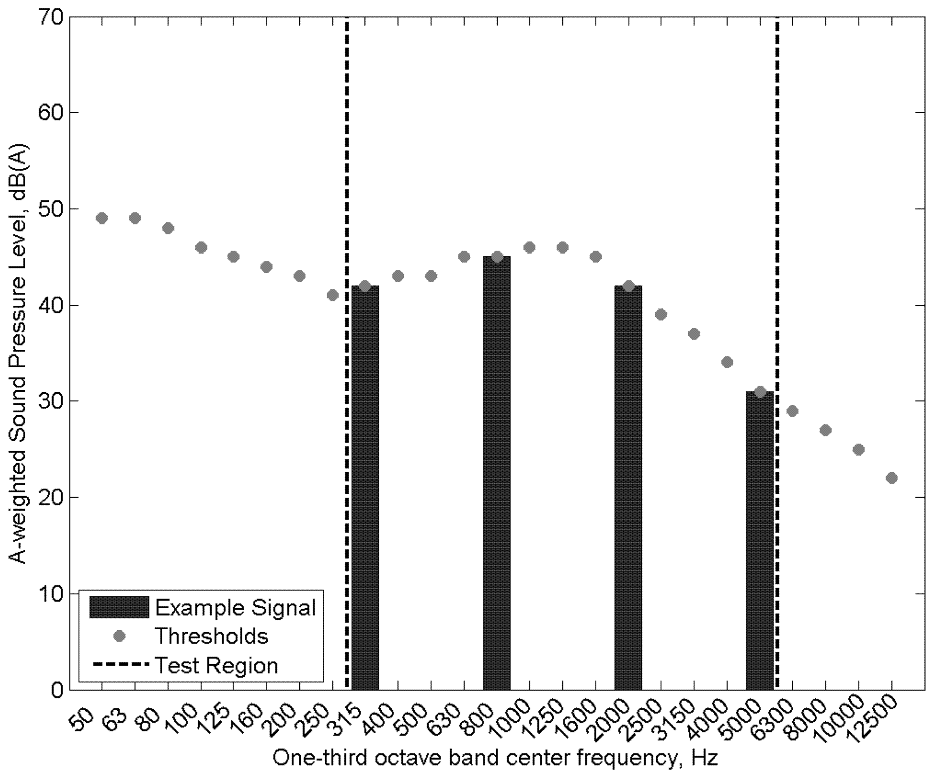


**Figure 3. Example of a Four-Component Signal at Threshold at 0 km/h**

In response to commenters who believe that sounds meeting the NPRM requirements will be too loud and will contribute to increases in environmental noise, we believe that our human factors testing has confirmed our analysis in the NPRM that sounds produced by EVs and HVs need to have content meeting the minimum thresholds we have specified to ensure detectability. At the same time, the agency has determined in its Environmental Assessment that the impact of alerts meeting the requirements of this final rule are expected to be negligible.

Several auto manufacturers also commented that sounds meeting the proposed requirements in the NPRM would intrude into vehicle interiors and be annoying to drivers. We believe that reducing the number of required bands and including frequencies from 630 Hz to 1600 Hz in the eligible range for compliance so that alert systems can utilize the entire range from 315 to 5000 Hz will provide manufacturers with the flexibility to design alert sounds that are non-intrusive and are acceptable to their customers.

Two One-Third Octave Band Compliance Option

Because of the number of commenters stating that the agency should adopt final rule with minimum content requirements in two one-third octave bands, NHTSA decided to explore a two one-third octave band compliance option in addition to the four-band compliance option discussed above. As shown in Figure 2 above, the average detectability of a vehicle sound in the presence of a range of ambients starts to decrease if there are fewer than four one-third octave bands with content at threshold levels. However, Figure 2 also shows that some of the signals with fewer than four bands at threshold levels perform well above the average and do achieve a high degree of detectability in the range of ambients. For this reason we have determined that alert sounds with content in fewer than four one-third octave bands can be acceptable choices but need additional specifications to ensure that they are as detectable as signals with content in four or more bands.

The two-band alternative that the agency is including in this rule closely matches the two-band approach suggested by commenters to the NPRM, but with a few important differences which are discussed below. By including both a four-band specification and a two-band specification in this final rule, NHTSA is providing vehicle manufacturers with the flexibility to choose either alternative for compliance with the new safety standard. In this section of today's preamble, we discuss how the agency concluded that a two-band alternative is warranted and how we developed the two-band alternative using specifications suggested in NPRM comments.

In their NPRM comments, Alliance/Global suggested an acoustic specification for HVs and EVs that consisted of a minimum overall sound level along with a minimum level in two one-third octave bands.[131] The following were the particular levels they recommended:

TABLE 14—LEVELS SUGGESTED BY ALLIANCE/GLOBAL

| | A-weighted dB | |
|---|---|---|
| | Minimum level in each of 2 Bands | Overall SPL level |
| 0 km/h, Reverse | 44 | 48 |
| 10 km/h | 46 | 53 |
| 20 km/h | 51 | 58 |

Two other criteria were part of Alliance/Global's suggested approach:

—That one of the two one-third octave bands should be in a frequency region below 1000 Hz and the other should be at or above 1000 Hz;

—That the two components of the signal should not be in adjacent one-third octave bands.

A number of other NPRM commenters, particularly vehicle manufacturers, endorsed the two-band approach as suggested by Alliance/Global.

In a follow-up letter submitted to the docket in February 2014 (treated as a late NPRM comment) a group of commenters (Alliance, Global, the National Federation of the Blind, and the American Council of the Blind) expressed their agreement on recommending a general approach of specifying two bands with an overall SPL level. In that comment letter, the suggested parameters were somewhat less specific compared to the original Alliance/Global suggestion or the compliance option discussed in the NPRM. The letter provided no minimum band levels for the two bands and left undecided the upper limit frequency (either 3150 Hz or 5000 Hz) as well as the breakpoint between the low and the high frequency (either 1000 Hz or 1600 Hz). The joint commenters indicated that further refinement of the two-band approach to finalize the levels and the frequency ranges may be needed and should be based on discussion among interested parties. They stated that those discussions should take place in the QRTV working group responsible for developing the GTR.

In developing the four-band approach that is included in today's final rule, NHTSA evaluated signals with different numbers of bands including signals with two bands. The details of that evaluation are discussed above and shown in Figure 2. As discussed, NHTSA's approach in evaluating various signals was to set the band levels for each component at the appropriate psychoacoustic thresholds according to Moore's model which was adjusted using the results of Volpe's human factors experiment. The adjusted acoustic model was used to analyze the performance of signals having various numbers of frequency components from one up to eight by predicting how readily each signal would be detected in the presence of the standardized 55 dB(A) ambient.

As discussed previously, Figure 2 demonstrates the robustness of single-band and multiple-band alerts when each band is set at the minimum threshold levels for detection based on the acoustic model the agency used. We used this same robustness methodology to evaluate the Alliance/Global two-band approach. Because their suggested approach did not specify different levels for different frequency bands, there are limitless possibilities for two-band signals that would meet the Alliance/Global method. However, the range of possible signals just meeting the requirement can be categorized according to the following four signal type scenarios:

(1) *Scenario A:* The level of the lower frequency band of the two bands is set at the suggested minimum, and the level of the higher frequency band is set such that the combination of the two bands meets the overall level (see Figure 4);

(2) *Scenario B:* The level of the higher frequency band of the two bands is set at the suggested minimum level and the level of the lower frequency band is set such that the combination meets the overall level (similar to Figure 4);

(3) *Scenario C:* The two bands both are set at the suggested minimum level, and there is low level content over many frequencies that on its own may not be audible but that, when combined with the two prominent bands, brings the signal up to the specified overall level (see Figure 5);

(4) *Scenario D:* The two bands are equal and their level is set such that the combination of the two bands meets the overall level (see Figure 6).

[131] See docket NHTSA–2011–0148–0251, Alliance/Global comment, p. 5.

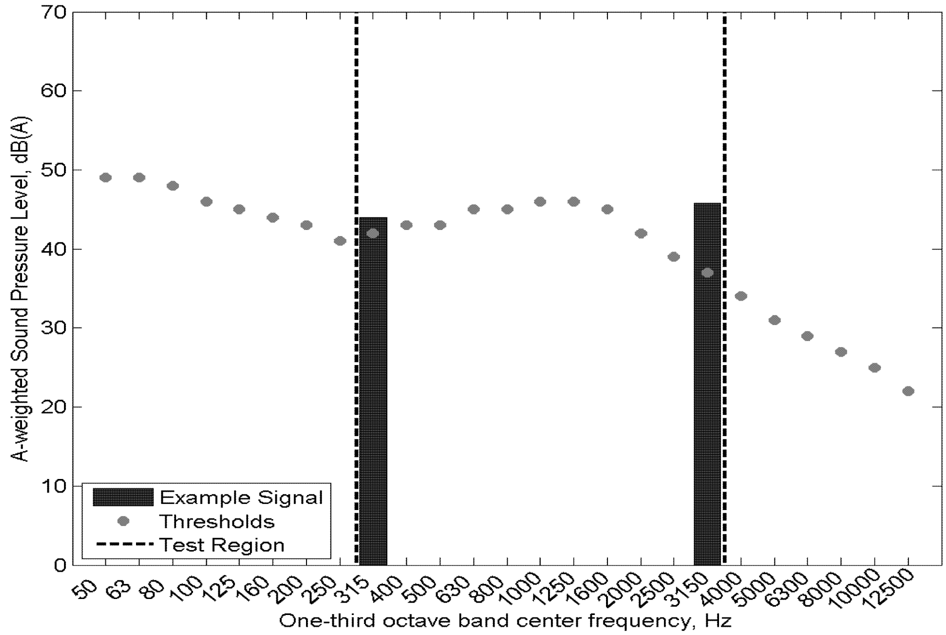


**Figure 4. Scenario A**
**Two Components with the Lower Frequency at the Recommended Minimum Level and the Higher Frequency Increased to Meet the Overall SPL Requirement for 0 km/h**

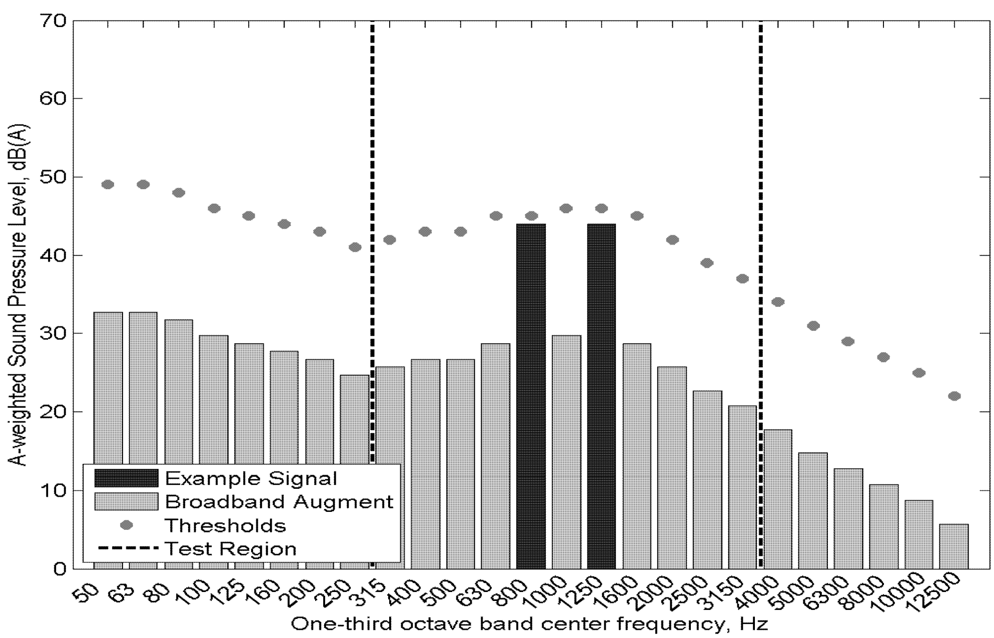


**Figure 5. Scenario C**
**Two Components at Equal Levels Plus Additional Low Level Content Adjusted to Meet Overall SPL Requirement for 0 km/h**

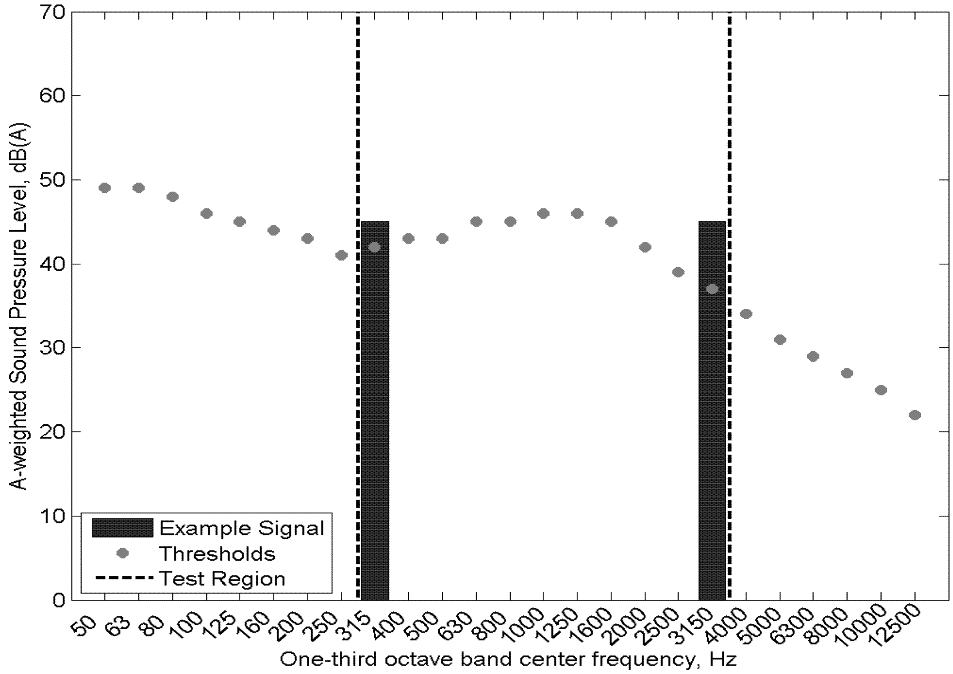


**Figure 6. Scenario D**
**Two Components at Equal Levels Adjusted to Meet Overall SPL Requirement for 0 km/h**

The range of all possible signals meeting the criteria will fall somewhere within these four signal types. For simplicity, we have considered these four types in our analysis. It is expected that the robustness of other signals will be within the range observed for these four types.

The results of our robustness analysis of two-band signals meeting the Alliance/Global suggested method are shown in Figure 7. Two-band signals are plotted according to which of the four signal categories (Scenarios A, B, C, or D, above) they fall in, with averages indicated for each category. Again, this shows the percentage of times that each signal category would be detected in the normalized sampled ambient conditions. Note that three vehicle speeds plus stationary are indicated in Figure 7. In the suggested specifications provided in the Alliance/Global comment, the minimum band values increased with increasing speed but only enough to partially account for the increase in sound level needed to maintain adequate detection time over the whole speed range. Consequently, unlike in NHTSA's acoustic specifications, the performance of the Alliance/Global approach changes at higher speeds.

From Figure 7 it can be seen that, at idle, two-band signals meeting the Alliance/Global approach are robust regardless of which type of signal is considered. However, as vehicle speed increases, robustness decreases. Figure 7 indicates that the robustness performance of certain two-band signals, particularly those in the Scenario C category, declines significantly to the point that, on average, they would be detected only about 35 percent of the time at 20 km/h in the sampled ambient conditions.[132]

[132] Figure 7 includes values plotted at 30km/h. The data depicted at 30km/h is hypothetical data derived by VOLPE because Alliance/Global's suggested alert requirements went up to only 20km/h.

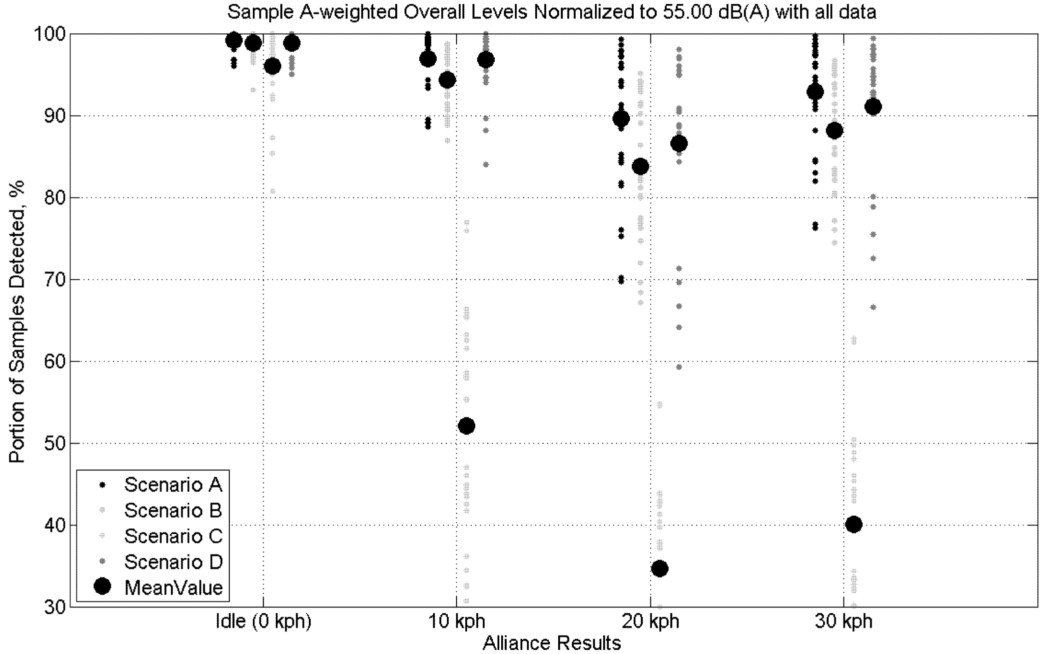


**Figure 7. Robustness of Alliance/Global Suggested Two-Band Approach**

This analysis led us to conclude that adopting the two-band Alliance/Global approach as it was suggested in their comments would allow some poor-performing alert signals to comply with the final rule. However, this analysis also led us to conclude that some two-band signals perform as well by our measures as the signals meeting the four-band requirements in this final rule, and that a two-band approach would be acceptable as long as it is specified in such a way as to exclude poor-performing two-band signals. Our analysis of two-band signals highlights two minor changes that we can make to modify the Alliance suggestion in order to increase robustness of two-band signals to that of the NHTSA four-band approach:

(1) Instead of expressing the required sound level in terms of overall SPL, we can use a *band sum* that accounts only for the sound energy in the two required bands; this criterion would negate the possibility ability to augment the two bands with acoustic energy that may not be audible, *i.e.,* that may not contribute to detectability and robustness.

(2) We can adjust the required minimum band sum to achieve robustness equal to that of the four-band specification. This provides a high degree of flexibility in signal design. For example, a system designer can make the two components equal, or can set one component at the minimum level and compensate by setting the second component high enough to reach the required minimum band sum level.

In order to optimize the Alliance/Global's suggested two-band approach using these modifications, the minimum band sum levels at each speed were iteratively determined. The results are shown in Table 15. We refer to this specification as an ''optimized'' two-band approach because it excludes two-band signals that have lower robustness (those signals that would be detectable in a lower number of ambients according to our analysis) while preserving the levels suggested by the Alliance/Global to the greatest extent possible.

TABLE 15—OPTIMIZED LEVELS FOR TWO-BAND SIGNALS

| | A-weighted dB | |
|---|---|---|
| | Minimum level in each of 2 bands | Band sum of the 2 bands |
| 0 km/h | 44 | 48 |
| 10 km/h | 46 | 55 |
| 20 km/h | 51 | 61 |
| 30 km/h | 56 | 66 |

Figure 8 shows the robustness performance of two-band signals that meet this optimized approach. Note that there now are three sound scenarios (A, B, and D) instead of the four discussed in Figure 7. Scenario C that used broadband content to enhance the two bands is no longer viable under the optimized approach. It can be seen that all two-band combinations meeting the optimized criteria will now be detectable in upwards of 97 percent of the normalized sampled ambient conditions and, on average, they reach at least the level of robustness achieved by the four-band approach.

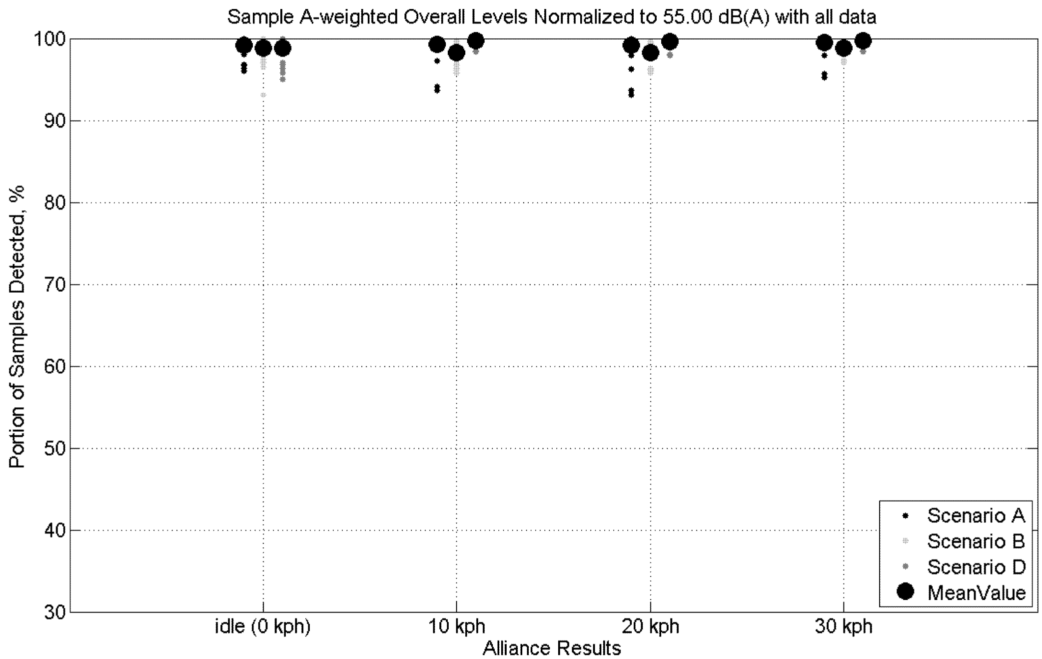


**Figure 8. Robustness of Optimized Two-Band Approach**

Also note that the optimized specification includes levels for 30 km/h because, as discussed in the crossover speed section of today's final rule (Section III.D), the agency has decided to include acoustic requirements for vehicle speeds up to 30 km/h.

The overall levels for both the optimized two-band specification and the four-band specification (''S4 Bands'') are summarized in Table 16. For comparison, Table 16 also shows the levels suggested in the Alliance/Global comment. It can be seen that for each overall SPL value given for the optimized two-band approach, the level is within the ranges for the four-band specification.

TABLE 16—OVERALL LEVELS OF THREE APPROACHES

| | Minimum level, dB(A) * | | | | |
|---|---|---|---|---|---|
| | Stationary | Reverse | 10 km/h | 20 km/h | 30 km/h |
| S4 Bands ** | 47–50 | 49–53 | 52–56 | 59–62 | 63–67 |
| Alliance/Global | 48 | 48 | 53 | 58 | NA |
| Optimized 2-band | 48 | *** 52 | 55 | 61 | 66 |

* Based on Partial Specific Loudness Threshold = 0.079 sones/ERB.
** Overall SPL depends on which four bands are selected.
*** SPL for 10 km/h with 3 dB subtracted.

For the Reverse specifications, the Alliance/Global comment set the band minimum levels and the overall level equal to the corresponding levels for the stationary operating condition. In the optimized two-band specification, to be consistent with the four-band approach and the method used in the NPRM, we are setting the band minimum and overall SPL by subtracting 3 dB from the level required at 10 km/h. That method is the same one NHTSA employed in the NPRM to set the levels for Reverse. For the band minimum, subtracting 3 dB from the 10 km/h level yields a value that is about the same as the band minimum the Alliance/Global suggested for Reverse, so the value we are adopting is the same as the one they suggested. For the overall level, subtracting 3 dB from the 10 km/h level yields a value for band sum that is somewhat higher than the overall SPL for Reverse suggested in Alliance/Global's comment, as shown in Table 16. To be consistent with the 4-band requirements and the method used in the NPRM to set Reverse requirements, we are using the higher value. This will account for the fact that sound level for Reverse operation needs to be higher than sound level in the Stationary condition, as explained in Section III.C of this preamble.

The modifications we have discussed to make two-band signals as robust as four-band signals will not make the two-band and four-band options the same in all respects. For example, the four-band option is somewhat less restrictive because the minimum levels for the one-third octave bands are lower than the levels required with the two-band option. Also, the two-band approach is more likely to result in a signal that has an individual component that exceeds minimum detection thresholds in a particular band due to the need to meet the overall SPL requirement, which would make that component relatively prominent. We note that this does not mean that environmental noise will be increased because, as shown in Table 16, the band sum levels for the two-band approach are lower at all speeds than the overall sound pressure levels that can be reached by alerts meeting the four-band approach. As discussed in Section V.D of today's final rule, our environmental assessment indicates that neither the two-band nor four-band approach would have significant environmental noise impact.

In summary, we have decided that including both compliance options in this final rule allows manufacturers the flexibility to choose the approach that best suits their design goals, while accomplishing the agency's goals in the NPRM by providing a robustly detectable signal for pedestrians without significant environmental impact. The detection requirements for compliance of alert systems designed to meet the four-band and two-band specifications are given in the regulatory text of today's final rule.

Overall Sound Pressure Level

In the NPRM, the agency specified alert requirements at the one-third octave band level and not at the overall sound pressure level. NHTSA's position was that the overall sound level may be sufficient for ICEs, which intrinsically produce sound over a broad range of frequencies at all speeds and have acoustic characteristics such as modulation that enhance detectability, but not sufficient for inherently quiet vehicles operating solely on electric motors at low speeds. The agency continues to believe that one-third octave band requirements assure that a vehicle's total sound is detectable by a broad range of pedestrians over many ambient conditions.

ADB commented that, ''octave bands are not as great at predicting detection as overall sound levels'' based on research conducted by WMU. WMU stated that its research has shown that individual octave bands are not as useful in determining detection as is the overall sound level. WMU stated that while some regulatory specification in octave band make-up of alert sounds might be useful, there is limited justification for such a restrictive requirement. WMU also stated that a pedestrian with hearing loss would need to have available content at lower frequencies and that any potential sound should have a fairly broad frequency spectrum. WMU suggested that identifying two frequency bands that are most useful for detection, similar to Nissan's approach, may be appropriate.

The agency has reviewed the research cited by ADB and conducted by WMU on the correlation between overall sound pressure level and detectability. While this research does show that overall sound level had a good correlation with detectability, it does not appear that it addressed whether specifying levels in multiple octave bands influences the detectability outcome. The agency does not believe that the cited studies adequately support the proposition that overall sound pressure level is a better metric than one-third octave band sound pressure level. Furthermore, the WMU comments about specifying low frequencies to assist with hearing loss, and about requiring a broad frequency spectrum, and also that specifying two frequency bands may be appropriate, implies that they did not conclude that an overall specification by itself necessarily would be sufficient.

During the course of developing FMVSS No. 141, the agency has carefully considered overall sound pressure levels and corresponding individual one-third octave band sound pressure levels. The agency agrees that there can be a strong correlation between overall sound pressure level and detectability. However, we also believe that regulating only the overall sound pressure level leaves open the possibility of alert signals that may be undetectable in many common situations. Agency research indicates that alert sounds with the same overall sound pressure level often do not provide the same degree of detectability or robustness. This topic is discussed in sections that follow in this preamble where we identify how the agency derived the two compliance options specified in this final rule. Through our research, the agency has determined that for an alert signal to be as ''robust'' as possible, *i.e.* for a signal to be heard by the most diverse range of pedestrians across the widest range of ambient conditions, specific combinations of one-third octave bands in different frequencies must be included in the requirements of the final rule. The requirements for one-third octave bands at various frequencies contribute to the overall sound pressure level of the sound emitted by the vehicle. Conversely, the agency maintains that minimum one-third octave band sound levels are essential to establish minimum requirements for detection, and that specifying overall sound pressure level alone would not be an acceptable approach for this final rule.

Stopping Distance

Many of the commenters agreed with the agency's approach for using stopping distance for determining detectability requirements. Two of the commenters, however, ADB and WMU, questioned the distance calculated and used. ADB and WMU questioned whether the detection distances used are sufficient for pedestrians to detect, recognize, judge distance and trajectory, decide to initiate a crossing, and initiate a crossing, particularly at busy intersections. WMU explained that the detection distance formula used does not account for variability among pedestrians including those with hearing loss.

After considering the ADB and WMU comments, we have decided to continue to follow the approach used in the NPRM where we derived stopping distance using a driver reaction time of 1.5 seconds and a deceleration rate of 5.4 $m/s^2$. The agency's main premise for the calculation of the time that should be allowed for detection of approaching vehicles was the total vehicle stopping distance needed to avoid pedestrian collisions. While the pedestrian's reaction time is important, as is providing as much time as possible for pedestrians to make crossing decisions, the critical factor is that the pedestrian should hear the alert of an approaching vehicle no later than the time and distance the driver would need in order to react and stop the vehicle before colliding with the pedestrian.

Furthermore, the alert requirements specified in the final rule include a small safety margin that will extend the timing and distance for both the driver and the pedestrian. As discussed previously, the minimum one-third octave band levels derived for detectability were increased by 0.5 dB and rounded up to the closest whole decibel. Also, because our minimum requirements are based on the levels needed to detect a signal having content in a single one-third octave band, our requirement that signals must include multiple one-third octave bands provides an additional margin of safety. We believe that requiring EVs and HVs to produce sounds with content in multiple one-third octave bands will provide an additional safety margin of time and distance due to the increased overall sound pressure level resulting from the combination of one-third octave bands. In addition, the specifications in this final rule are minimum levels for compliance. Vehicle manufacturers are likely to exceed the minimums by some amount in order to provide themselves with a margin of compliance. We believe these factors address concerns that the reaction time the agency used was insufficient.

*F. Acoustic Parameters for Recognition of Motor Vehicles*

In the NPRM, we stated that recognition includes two aspects: Recognition that the sound is emanating from a motor vehicle that may pose a safety risk to the pedestrian, and recognition of the vehicle's operating mode (acceleration, deceleration, constant speed, reverse or stationary but activated) so that the pedestrian can take appropriate measures to avoid a collision with the vehicle. The acoustic specification in the NPRM contained acoustic characteristics similar to the sounds that pedestrians associate with current ICE vehicles.

Based on our initial assessment of simulated sounds and engineering judgment, the agency determined in the NPRM that the sound emitted by the vehicle to meet the detection requirements must contain at least one tone. A component is defined as a tone if the total sound level in a critical band centered about the tone is 6 dB greater than the noise level in the band.[133] In the NPRM, we proposed requiring the sound emitted by the vehicle to have at least one tone at a frequency no higher than 400 Hz. The agency also proposed that the sound emitted by the vehicle must have content in each one-third octave band from 160 Hz to 5000 Hz.

Simulated sounds in the initial assessment were developed for the stationary but activated, constant speed pass-by, and accelerating pass-by conditions. Pass-by sounds included Doppler shifts (changes in frequency by a source moving relative to an observer) and simulated acceleration (a pitch or frequency shifting tied to a change in vehicle speed.) The sound pressure level changed as a function of speed and as a function of position relative to the microphone receiver during the pass-by simulations. During the original development of criteria for recognition, we stated that an alert signal should sound like an ICE in order to be recognizable. In order to identify qualities of the ICE vehicle, ICE sounds were evaluated in the quiet ambient conditions present during the recordings,[134] [135] which allowed low-frequency combustion related tones and wide range broadband content [136] to be audible.

The agency sought comments on the following topics related to the proposed recognition requirements:

- Suggestions for the minimum sound level of low frequency content that should be included in the agency's recognition requirements;
- Information as to whether speakers that manufacturers may wish to use to meet the requirements of the proposal are capable of producing any measurable content in the 160 Hz one-third octave band; and
- Information about the cost of a speaker system that is able to reproduce some measurable content at the 160 Hz one-third octave band versus the cost of a speaker system that is only capable of producing sound above 315 Hz.

The Agency received comments from Alliance/Global; SAE; OICA; Honda; Nissan; Porsche; Mercedes; Denso; National Federation for the Blind; Western Michigan University; Accessible Design for the Blind; The Seeing Eye, Inc.

According to Alliance/Global, bands below 500 Hz should not be required. They stated that these bands are not necessary for recognition and will add significant cost to the alert sound system. Alliance/Global also stated that isolating and measuring low frequency content under outdoor test conditions would be impracticable. Alliance/Global stated that prescribing an objective definition to recognizability using one-third octave bands is not possible because there are many ways to provide sounds that have similar acoustic characteristics. Finally, they do not recommend one-third octave band requirements in the 160 Hz band because existing speakers that are practical for alert systems cannot emit sound which contains frequencies as low as 160 Hz.

OICA stated that a tone that is pitched would simulate the sound of a machine and this in combination with the tire/road noise would be enough to recognize the sound as coming from a vehicle. They also stated that broadband band should not be required.

SAE indicated that the metric used to define 'tone' (ANSI S1.13—1995), in the proposed regulatory text, is not robust to all possible sound designs and would explicitly exclude sound characteristics identified as contributing to detection and recognition in the preamble.

Ford stated that it conducted a study to examine recognition of a given sound as the sound of a motor vehicle. The study consisted of a human factors test in which audio recordings of vehicle sounds were presented to participants using headphones. Participants were asked to assess how recognizable the sounds were in the presence of background noise. The study included 24 Ford employees and 4 blind individuals. Sounds tested included an ICE vehicle, a vehicle without an alert sound, and three alert sounds. Two tests were completed; recognition of a stationary sound and recognition of a 10 km/h pass-by. Additional tests were conducted to examine recognition of the sound as an object to avoid. Ford concluded that adding motion to the sound (pass-by vs. stationary) increased recognition as either a motor vehicle or an object to avoid. They also explained that it is not necessary to meet all proposed minimum levels in the 315 Hz, 400 Hz, and 500 Hz one-third octave bands for vehicles or alert sounds to be recognized as motor vehicles.

Honda indicated that the generation of low frequency sound is technically challenging, creates extra cost, and adds weight to the vehicle. Honda explained that the sound entering into the passenger compartment could be significant, which could cause annoyance. Honda suggested that this would require testing and an iterative design process to minimize negative effects.

Nissan stated that low frequency content alone will not ensure that a sound is recognized as a motor vehicle. Nissan suggested that requiring frequency content in this region means that either broadband or narrowband content (*e.g.* tones) could be used, which would sound quite different than an ICE.

Mercedes indicated that the proposed specification is restricting manufacturers flexibility to produce alert sounds for EVs and HVs that are effective yet pleasant to consumers and

[133] The agency explained that a component is considered to be a tone if the Tone-to-Noise ratio according to ANSI S1.13–1995[73] is greater than or equal to 6 dB.

[134] Garay-Vega, L; Hastings, A.; Pollard, J.K.; Zuschlag, M. & Stearns, M. (2010, April). Quieter Cars and the Safety of Blind. Pedestrians: Phase 1. DOT HS 811 304. Washington, DC: National Highway Traffic Safety Administration.

[135] Hastings, A., Pollard, J. K., Garay-Vega, L., Stearns, M. D., & Guthy, C. (October, 2011). Quieter Cars and the Safety of Blind Pedestrians, Phase 2: Development of Potential Specifications for Vehicle Countermeasure Sounds. DOT HS 811 496. Washington, DC: National Highway Traffic Safety Administration.

[136] Broadband content is content over a wide frequency range that could be spectrally continuous or periodic. Periodic content can be generated by engine combustion related harmonics or by periodic tire/pavement interactions, such as caused by transversely tined pavement. Continuous content can be generated by turbulence at the engine intake and exhaust ports, by non-periodically tined fan blades as well as by aerodynamic noise and random tire/pavement interactions.

expressed concerns about potential impacts to market penetration. Mercedes explained that low one-third octave frequency bands down to 315 Hz and broadband content down to 160 Hz are difficult to isolate inside the vehicle cabin and this may result in adding vehicle weight due to added insulation. Mercedes also mentioned that a speaker would need to increase in size in order to accommodate the proposed lower frequency requirements.

Porsche mentioned that pitch shifting is the most important factor to characterize motor vehicles. Porsche suggested that the number of frequencies and the frequency range be kept flexible. Porsche also indicated that broadband sound should not be required. Porsche stated that all sounds emitted by a vehicle are based on tones while broadband sound comes from tire noise. Porsche also explained that broadband sounds would require different devices and cannot be generated by the prototype control modules currently used by Porsche.

Denso requested clarification of the definition of the terms ''tone'' and ''critical band.'' Denso also mentioned that the agency did not identify sound pressure levels for the broadband requirement in the NPRM. Denso stated that the broadband requirement may not be as effective for recognition and localizability because the sound emitted by the vehicle speaker system may be masked by ambient sound if no sound level for the broadband content is specified.

NFB stated that recognition requirements were included in the PSEA to prevent excessive customization. They stated that the inclusion of pitch shifting will potentially be sufficient to insure recognition.

WMU indicated that the inclusion of tones is unlikely to enhance recognition because tones are readily masked by sounds in the environment, especially by sound from other vehicles. WMU also indicated that many blind pedestrians would not detect sound energy above 2000 Hz, especially those with hearing loss; therefore, this is not a reliable way to enhance recognition. WMU indicated that rhythmic, cyclic aspect of a sound would enhance recognition. In terms of speaker capabilities, they suggested that the cost of using speakers capable of producing sound energy in the 160 Hz range is not balanced by additional benefits. They explained that their studies have not found this low range to be useful for detection and noted that tones can be annoying.

Comments from the Accessible Design for the Blind (ADB) are consistent with WMU. ADB indicated that tones are masked by the ambient and that most people find tones to be annoying. ADB stated that added sound should be the same for all EVs and HVs. ADB explained that this would help with recognition and prompt interpretation of the sound as the sound of a vehicle. In response to the request for comments about the minimum levels of low frequency content that should be included for recognition, ADB stated that they are not aware of any research that supports the notion that adding low frequency content makes sounds more recognizable.

The Seeing Eye, Inc., stated that, for recognition purposes, it is important that all vehicles regardless of manufacturer, emit the same standardized sound.

Agency Response to Comments

After reviewing the comments and conducting additional research, we have decided to remove the requirements in paragraph S5.2 of the NPRM requiring EVs and HVs to produce sound that includes broadband content and low frequency tones. We believe these acoustic characteristics are not necessary for pedestrians to recognize artificial sounds produced by EVs and HVs as coming from a motor vehicle in operation.

During the agency's initial work to develop criteria for recognition, the agency assumed that an alert signal should sound like an ICE in order to be recognizable. In order to identify qualities of the ICE vehicle, ICE sounds were evaluated in the quiet ambient conditions present during the recordings [137] which allowed low-frequency combustion related tones to be audible. These low frequency tones make up part of the sound of a typical ICE vehicle at low speeds in quiet ambients. However, these low frequency tones are masked in many ambient conditions, and in particular the 55 dB(A) ambient used for determining the minimum sound requirements described in the NPRM.[138] In such cases pedestrians would need to use other cues to recognize a vehicle (ICE or otherwise), such as the location of the sound source (*e.g.* on the street at a stop light), the frequency and level changes caused by sound source motion (*e.g.* on the street approaching or passing the pedestrian), etc.

A recent study by NHTSA examined several alert signals in the presence of a 55 dB(A) ambient for a vehicle traveling at 10 km/h.[139] The signals included simulations based on recorded vehicles, tones, and noise components over a frequency range from 315 to 5000 Hz. Some signals had only a single component, *e.g.* a tone or a noise at 315, 630 or 2500 Hz, or multiple components, *e.g.* low frequencies (315 to 500 Hz), high frequencies (2000 to 5000 Hz), or components matching the NPRM frequencies. Participants were asked to indicate when they heard a sound that would influence their decision to cross a street. The study provides a practical indication of a pedestrians ability to recognize sounds emitted by HVs and EVs as motor vehicle sounds since recognition is required in order to respond to the detected signal in the form of making a decision regarding whether it is safe to cross a street.

All alert signals tested (with the exception of one signal that had levels below NPRM values) were detected and recognized on average by the minimum safe detection time of 2.0 seconds or greater. These results are consistent with comments by the Alliance/Global and with the study submitted by Ford. Based on these results, it appears that vehicle recognition cued by an alert signal in the presence of a ambient at 55 dB(A), which is the target ambient for detection, does not require that the alert signal contain low frequency tones. Because low frequency tones are not necessary for pedestrians to recognize sounds as vehicles sounds, could also add cost to the system, and may be annoying when not masked by the ambient, the agency is not including a requirement for low frequency tones in the final rule.

Similarly, the agency study showed that participants detected and recognized alert signals with a wide

[137] Garay-Vega, L; Hastings, A.; Pollard, J.K.; Zuschlag, M. & Stearns, M. (2010, April). Quieter Cars and the Safety of Blind. Pedestrians: Phase 1. DOT HS 811 304. Washington, DC: National Highway Traffic Safety Administration.; see also Hastings, A. et al. (2011). Quieter Cars and the Safety of Blind Pedestrians, Phase 2: Development of Potential Specifications for Vehicle Countermeasure Sounds. DOT HS 811 496. Washington, DC: National Highway Traffic Safety Administration.

[138] OICA measured stationary but activated levels are presented in Table 29 of the Phase III report. Comparing these data with the associated minimum threshold levels described in the NPRM, it can be seen that for most vehicles in Table 29 many of the measured vehicle one-third octave band levels are below the computed thresholds for the 55 dB(A) ambient used in the NPRM. Thus these components would not be reliably detectable in such an ambient.

[139] Hastings A.; and McInnis, Catherine. ''Detectability of Alert Signals for Hybrid and Electric Vehicles: Acoustic Modeling and Human Subjects Experiment'' (2015) Washington, DC: DOT/NHTSA.

range of sound characteristics including signals that do not include broadband content over the entire range from 160 Hz to 5000 Hz. For example, several signals in the study consisted of only a single pure tone or a single one-third octave band of noise and were detected and recognized at a safe distance provided the component met minimum levels as determined by the detection model. Based on these results, it appears that vehicle recognition cued by an alert signal in the presence of a 55 dB(A) ambient does not require broadband content in all one-third octave bands from 160 Hz to 5000 Hz. Given the potential costs associated with meeting the low frequency requirements of such broadband content and the fact that signals meeting the detection criteria are safely detectable, the agency is not including a broadband content requirement in the final rule specification.

Overall, the agency believes that pedestrians would use other cues to recognize a vehicle (ICE or otherwise), such as the location of the sound source (*e.g.* on the street at a stop light), and the frequency and level changes caused by sound source motion (*e.g.* on the street approaching or passing the pedestrian), etc. (See Section III.G on 'Frequency (Pitch) Shifting and Volume Change').

*G. Frequency (Pitch) Shifting and Volume Change*

The NPRM contained a requirement for frequency shifting which gives the pedestrian information about the acceleration or deceleration of an approaching vehicle. The PSEA required NHTSA to include sounds to alert pedestrians to acceleration and deceleration. As discussed in the NPRM, this information is important to the pedestrian in making a decision about whether or not to cross in front of a vehicle. The driver of an accelerating vehicle probably does not intend to stop and, according to the NPRM, ''the sound of accelerating vehicles in the parallel street indicates, for example, that the perpendicular traffic does not have the right of way and thus a crossing opportunity is available''. A decelerating vehicle on a path parallel to the pedestrian may be slowing to make a turn into the pedestrian's path if she or he were to cross the street.

The proposal required that the fundamental frequency of the sound emitted by the vehicle increase with speed by at least one percent per km/h between 0 and 30 km/h (18.6 mph). The NPRM did not include a test procedure associated with this requirement but stated that frequency shifting could be verified by comparing the fundamental frequency from the compliance tests at stationary, 10 km/h (6.2 mph), 20 km/h (12.4 mph), and 30 km/h (18.6 mph). The NPRM provided a definition for the fundamental frequency but did not specify how the fundamental frequencies at each vehicle speed should be compared.

As mentioned, the agency did not include a separate acoustic measurement procedure for frequency shifting in the NPRM, instead relying on other requirements specified and the increase in overall sound level as the vehicle increases speed (or the decrease in sound level as the vehicle decelerates) to provide enough information so that pedestrians will be able to determine when EVs and HVs are accelerating and decelerating. One reason why a separate acoustic measurement procedure was not included was due to the concerns about the feasibility of testing. The agency stated that it would be difficult for even an experienced test driver to repeatedly achieve and maintain a specific rate of acceleration or deceleration on a test track if such a test was required. Given the difficulty of ensuring a repeatable acoustic test for acceleration and the fact that information about changes in vehicle speed could be provided by varying sound pressure levels, NHTSA determined that the test procedure did not need to include a dynamic test for acceleration or deceleration.

The NPRM explained that manufacturers and their representatives, in meetings with NHTSA staff, expressed concerns that it is difficult to measure the change in frequency of a sound produced by a vehicle by measuring a complete vehicle during a pass-by test. Manufacturers requested that the agency measure frequency shifting using a component-level test, meaning that the alert system hardware is removed from the vehicle and tested as a separate unit.

In the NPRM, we said that we were hesitant to include a component-level test because we wanted the standard to be technology neutral and because we do not wish to limit technological innovation. As further explained, the agency was aware that manufacturers might use different technologies to comply with the standard, so defining the hardware components subject to the component-level test could prove difficult. The agency sought comment on including a component-level test to measure frequency shifting in the test procedure.

In the NPRM, the agency said that the proposed method for measuring frequency shifting depends on the presence of a strong tone in the sound. A tone is an acoustic component with well-defined features that make it relatively easy to recognize compared to noise. The pitch, or frequency, of an alert sound could be verified by tracking this tone as it increases in frequency for each pass-by test as the vehicle increases speed. In the proposal, we said it would be difficult to verify a sound's increase in frequency if the sound does not have any strong tones. We mentioned our concerns about identifying the tone of a sound and tracking this tone as the vehicle increases speed. The NPRM mentioned that we planned to conduct further research on this issue. We explained that if it was not possible to identify a tone to track in order to verify the increase in a sound's frequency, we may have to use a different method to verify the increase. The agency sought comments on this issue.

The agency received comments on frequency shifting from SAE, Alliance/Global, OICA, and Porsche. The agency also separately received a joint comment submitted by the Alliance, Global, the American Council of the Blind (ACB), and the National Federation of the Blind (NFB).

Several commenters stated that the NPRM did not include a test procedure to measure compliance with the proposed frequency shifting requirements. These commenters recommended that the agency use the frequency shift procedures specified in SAE J2889–1 to measure compliance with the frequency shifting requirements and that the agency allow indoor testing or component level testing to measure frequency shifting.

SAE commented that use of indoor facilities for the measurement of the frequency shift is necessary to obtain accurate results. SAE said that provisions for indoor measurement either at a component level or a simulated full-vehicle level are included in SAEJ2889–1 (May 2012). SAE also mentioned that in a December 2012 meeting with NHTSA, an alternative method of analysis was under investigation to eliminate the need for prior knowledge of the signal.

Alliance/Global mentioned that tonal tracking for frequency shifting becomes quite difficult at higher speeds (30 km/h) due the tire noise masking, particularly when testing outdoors. Alliance/Global stated they prefer an indoor component level test because they think that is the best way to ensure that the correct tones are being tracked and that noise from tires (at higher speeds), accessory equipment, or other sounds not intended for pedestrian safety, are not incorrectly counted toward the sound measurement. Alliance/Global indicated that they are not aware of a procedure that can identify these tones during whole-vehicle testing.

OICA suggested that NHTSA change the definition of ''fundamental frequency'' in S4 to read, ''[Frequency] shift frequency means, for purposes of this regulation, any frequency or frequencies used to comply with S5.1.6.''

OICA suggested requiring that the frequency of the sound shift frequency within each individual gear ratio rather than over the entire range of speeds between 0 and 30 km/h. OICA stated that this will allow for the simulation of an ICE vehicle using different gear ratios within the tested speed range. Furthermore, OICA indicated that there might be various ways to determine the frequency tone and rate and suggested that NHTSA leave the way to measure it to the individual manufacturer. OICA indicated that there is no known method to identify the proper tone in all situations without specifying the tone in advance. OICA stated that information about the signal under evaluation will be necessary.

Porsche made reference to the signal processing requirements in SAE J2889–1 (7.2.3) and stated ''The fundamental frequency is dependent on the setup of the analysis system and is typically less than two Hertz.'' Porsche also suggested that NHTSA change the definition of fundamental frequency in S4 to read . . . ''S4 Fundamental frequency means, for purposes of this regulation, any prominent frequency of a valid measurement taken in S7.''

In the joint comment submitted by Alliance/Global/NFB/ACB, those commenters agreed that at least one frequency emitted by the vehicle must vary with speed by at least an average of one percent per mph over the range from 5 mph to the crossover speed. They indicated that this frequency may also contribute to meeting the spectral and overall sound pressure level requirements.

Agency Response to Comments

After reviewing the comments and conducting additional research on the topic of frequency shifting, we have decided not to include a requirement that a vehicle's emitted sound must change in frequency as the vehicle changes speed. Although this characteristic is still considered useful and we encourage its use on hybrid and electric vehicles for enhanced detectability and recognizability, a test procedure to determine compliance with requirements for frequency shift at this time has been deemed unfeasible.

As proposed in the NPRM and finalized here, the sound pressure level in each one-third octave band changes as speed increases, leading to an increasing overall sound pressure level that corresponds to the behavior of an ICE vehicle. Thus pedestrians will be able to tell if an EV or HV is accelerating or decelerating based on the increase or decrease in sound level emitted from the vehicle, just as they would be able to in the case of an ICE vehicle. In this final rule, the agency has chosen to use the increase and decrease in sound produced by the vehicle at different speeds as an alternative to frequency shifting.

We have decided to identify this alternative method by the term ''relative volume change.'' Basically, the method of ''relative volume change'' involves summing and comparing the normalized measured one-third octave band levels for each of the operating speeds for each test vehicle. For each operating speed, the normalized sum of the measured one-third octave bands should increase by a specified minimum amount at each successive speed interval. Further details about the ''relative volume change'' method and why the agency believes the original frequency shifting requirement is not feasible are discussed below.

The agency acknowledges comments regarding the lack of a test procedure to measure frequency shifting in the NPRM. Many of the commenters requested that, in lieu of a test procedure being included in the rule, the agency adopt the frequency shifting procedure set forth in SAE J2889–1 Section S7.2. In essence, this procedure calls for identification of a frequency that has changed as a function of vehicle speed, which can be measured and can be tracked during the operating conditions specified. However, the SAE procedure, as stated in appendix B–5 of the SAE standard, requires prior knowledge of the frequencies to be tracked (''The persons conducting the test know what frequencies should be produced by the device or vehicle under measurement''). NHTSA believes that the need for prior knowledge of the frequencies precludes a readily verifiable and practicable test procedure. Also, the procedure set forth in J2889–1, Section 7.2, requires an acoustics expert to determine both the starting frequency (and/or tone) as well as the shifted frequencies as speed increases, to verify compliance. The agency believes that this contributes to a lack of objectivity in the SAE test procedure for measuring frequency shifting. The agency believes that it would be difficult to reliably and repeatably verify compliance because the frequencies identified for frequency shifting by different technicians are unlikely to always be exactly the same.

Since issuing the NPRM, the agency has conducted additional research in an attempt to develop a cohesive methodology for analyzing and verifying frequency shifting. NHTSA considers frequency shifting measurement to consist of three main steps: (1) Measurement of the signal to be used in the analysis and its conversion to the corresponding frequency domain; (2) identification of the alert sound tonal components that meet the definition of tone and that are expected to shift at each of the measured operating conditions (stationary, 10 km/h, 20 km/h, and 30 km/h); and (3) calculation of the actual magnitude of frequency shifting that has occurred from the identified tonal components. Of these steps, step one, recording the measurements and converting them to the frequency domain, is relatively routine as this is a standard signal processing technique. Also, in step three, once the proper tones and base frequencies of the vehicle alert have been identified and have been determined to be a continuous result of frequency shifting, it is relatively easy to mathematically determine the amount of frequency shifting that has occurred. From both a process basis and a calculation basis, steps one and three appear consistent with the methodology specified in SAE J2889–1.

Unfortunately, in step two above, identification and validation of tonal components is exceptionally difficult. The procedure detailed in Section S7.2 of SAE J2889–1 specifically requires that the person conducting the test know in advance what frequencies are shifting to avoid having to subjectively identify and verify the critical tones produced by the vehicle alert system. To identify and validate tonal components, the test operator first must know precisely how a tone is defined. The NPRM defined a component as a tone if the total sound level in a critical band centered about the main tonal frequency is 6 dB greater than the noise level in the band; however, the terms ''noise level'' and ''critical band'' were left undefined, and this omission was cited by the commenters. As such, the language in the NPRM was insufficient to resolve a tone in a way that would allow frequency shifting determinations.

During further research into defining a tone, NHTSA found that there are four main ways of identifying and verifying tones: By using predetermined information from manufacturers; visually, by plotting various sound data and determining an overall pattern; by utilizing a small amount of predetermined information (such as the base frequencies measured while the vehicle is in a stationary mode) and assuming a rate of frequency shifting to determine values for 10 km/h, 20 km/h, and 30 km/h; or lastly by utilizing a computer program to analyze sound data and search for tonal characteristics. Identification and verification of tones, regardless of method, is further complicated by the fact that vehicles do not generate a simple sound pattern and in general have a mixture of many tones, coupled with broadband noise as well, which is consistent with what commenters said. There are also pre-existing sound sources that have tonal and inherent frequency shifting qualities (for example, tires can produce a sound that has specific tonal qualities that will shift to a higher frequency that is proportional to the increasing speed of the wheel). These sound sources can work together to make searching for vehicle alert system tones very difficult and subjective.

NHTSA investigated using visual methods to identify tones: plotting the frequency levels versus sound levels as a function of both frequency and time as the vehicle is accelerated at a constant rate (a so-called ''run-up'' graph, presented as a spectrogram plot) where prominent frequency components can be tracked as they change due to frequency shifting; or by graphing sound levels as a function of frequency (referred to as the discrete method) for each speed condition (stationary, 10 km/h, 20 km/h, and 30 km/h) and identifying prominent frequency components which seem to be a function of frequency shifting. An example of these types of visual plots can be found in Figure B–1 of SAE J2889. Because the discrete method looks at individual test cases, there is no guarantee that the frequencies identified will be a result of continuous frequency shifting, and that the frequencies are not instead merely tonal artifacts present in the individual test case. It would be left up to the judgment of an acoustics expert to make this determination. Also, utilizing the run-up method would require the judgment of an acoustics engineer to determine the characteristics of a potential tone, identifying center frequencies, and determining if irregularities are present. Although it may be more objective than discrete visualization, this method can yield multiple interpretations of the same data, which makes it inherently subjective and unsuitable for the purposes of safety standard compliance.

The other methods for determining tones both require technical data from the manufacturer. Either the manufacturer would have to supply all of the data on frequency shifting, specifying all tones which will be used to calculate compliance, or the manufacturer would have to provide a smaller amount of information, such as the tonal components at stationary, and the agency then would have to assume a rate of frequency shifting as a function of speed and would estimate where the new tonal components should lie. Unfortunately, this process also is not objective, as the agency would be relying on information from the manufacturers and on acoustics experts to validate that information.

NHTSA also investigated the use of automated procedures utilizing ANSI S1.13: 2005, ISO 3745, and SAE J2889–1. However, NHTSA has been unable to produce a fully workable automated method. More research would be needed, but it is uncertain if the agency could ultimately develop repeatable, reliable, and objective procedures that do not require verification by an expert.

In light of the above discussion highlighting the impracticality of identifying and verifying tones without prior knowledge of the expected frequency shift, NHTSA agrees with the note 2 of Section S7.2.5.1.1 of SAE J2889 Rev DEC2014, ''. . . there is no known identification specification that can clearly identify frequencies which shift with vehicle operating conditions, primarily vehicle speed, when the frequency content of the desired signal and any background noise is unknown.'' Since no practicable test methodology consistent with the requirements of an FMVSS has been developed to date to objectively determine frequency shifting, the agency is not including a requirement for frequency shifting in the final rule.

Nevertheless, the agency encourages manufacturers to include frequency shifting in their development of alert sounds as this shifting does provide aural information to pedestrians about whether they are at risk or not and about the distance, speed, and acceleration of approaching vehicles. These are useful cues for pedestrian navigation.

In the future, should a practicable, objective method to quantify frequency shifting of vehicle alert sounds be developed, NHTSA may reconsider its decision to exclude a frequency shifting requirement from the safety standard.

Relative Volume Change

Because it is not feasible to include requirements for frequency shifting in the final rule for the reasons discussed above, the agency has decided to include in the final rule a requirement for vehicle-emitted sound level or ''volume'' rather than in frequency to increase as the vehicle increases speed. The agency has decided to include this volume change requirement as a means for pedestrians to utilize the sounds emitted by a vehicle to determine if a vehicle is accelerating or decelerating. The agency understands that the concept of ''relative volume change'' is not a direct replacement for frequency shifting, but we believe it is a reasonable alternative. While frequency shifting would be a more certain method for determining vehicle acceleration and deceleration, volume change will provide useful audible information to pedestrians about the operating state of nearby vehicles. We believe that the volume change specifications will partially compensate for the absence of pitch shifting requirements.

To better understand the concept, as a vehicle approaches a pedestrian at a constant speed, the pedestrian would hear the vehicle alert sound increase in volume, identifying that the vehicle is approaching but maybe not accelerating or decelerating. However, if the vehicle is approaching a pedestrian and accelerating (or decelerating), the alert sound will increase (or decrease) in volume more rapidly as the vehicle approaches while transitioning between 0 km/h and 10 km/h, between 10 km/h and 20 km/h, and between 20 km/h and 30 km/h. A rapid ramp up in volume as the vehicle approaches will be indicative of a vehicle accelerating, and a rapid reduction in volume as the vehicle approaches will be indicative of a vehicle decelerating.

The minimum detection thresholds which are contained in this final rule increase with speed. Consequently, vehicles that meet the minimum requirements, without exceeding them, will have an innate volume increase commensurate with the increase in speed. The minimum specifications incorporate a volume change of approximately 6 dB between stationary and 10 km/h, approximately 6 dB between 10 km/h and 20 km/h, and approximately 5 dB between 20 km/h and 30 km/h. However, manufacturers could design alert signals that have only a single sound level, such as one that meets the highest sound level requirements (those required at 30 km/h) across all speeds (thus exceeding the minimum levels at stationary, 10 km/h and 20 km/h). In this case, the alert would have no built-in volume change with increasing or decreasing speed, and the potential pedestrian cue to increasing or decreasing vehicle speed would not exist. The ''relative volume change'' requirement specified in this final rule will ensure a minimum sound level increase and decrease as a vehicle reaches each successive higher or lower speed operating condition.

In discussing the minimum acoustic requirements for the eight one-third octave bands in the NPRM, NHTSA said the minimum requirements in each one-third octave band increased as the vehicle increased in speed to give pedestrians more time to detect faster moving vehicles and to allow the pedestrian to determine whether the vehicle was accelerating or decelerating. While the minimum acoustic requirements in the NPRM increased for each test speed, the NPRM did not include maximum sound requirements for each test speed. This meant that a vehicle could comply with the requirements of the NPRM by meeting the minimum acoustic requirements for the highest test speed for all test speeds without any variation in the sound produced by the vehicle. In other words, a vehicle alert system could be designed such that it would emit the loudest required sound level in all test conditions from stationary up to 30 km/h. Under this scenario, a pedestrian would have limited ability to detect changes in vehicle speed without pitch shifting because the sound produced by the vehicle would not change as the vehicle changed speed. To eliminate this possibility, NHTSA has included the volume change requirements in the final rule to ensure that the alert sound varies produced as vehicle changes speed.

Since an alert signal's acoustic components can change from one operating condition to the next, changes in the overall SPL level will not necessarily correspond to changes in the level of individual one-third octave bands. Also, the overall sound pressure level is influenced by bands that are outside of the range of one-third octaves covered by NHTSA's specifications (*i.e.,* those greater than 5000 Hz and less than 315 Hz). Therefore, in order to evaluate changes in perceived volume level, we will consider only the one-third octave bands that account for sound energy contained in the range from 315 Hz to 5000 Hz. Normalized one-third octave band values are derived by subtracting the minimum one-third octave values specified for the stationary operating condition from each of the one-third octave band alert measurements. This normalization process allows measurements of different one-third octave bands to be compared by accounting for the differences in the minimum levels specified for each band. The logarithmic sum of the thirteen normalized one-third octave band levels is then determined (*i.e.,* the ''band sum'').

$$BANDSUM = 10 * \log_{10}\left(\sum_{13}^{i=1} 10^{\frac{Normalized\ Band\ Level_i}{10}}\right)$$

Finally, the relative volume change is calculated as the difference in these band sum values between consecutive operating speed conditions.

Evaluating the increase in band sum values from one speed to the next then provides a metric for ''relative volume change.'' This approach allows for the tracking of volume as a function of speed, as the volume is characterized by the sound pressure levels above the minimum levels required at the baseline stationary operating condition. It also allows for the rejection of one-third octave bands outside of the range of interest (315 Hz to 5000 Hz). Another key characteristic of this approach is that frequency is not tracked, which provides design flexibility because different one-third octave bands can be prominent at different speeds.

The relative volume change procedure will utilize the same vehicle measurement data collected for the determination of compliance with the minimum detection standards. That is, the volume change determination uses the average values for the thirteen one-third octave bands of the first four valid, ambient-corrected runs, from the louder side of the vehicle (left or right), for each operating condition (Stationary, 10 km/h, 20 km/h, and 30 km/h). By comparing the calculated band sum at a given operating speed with the band sum value for the next lower speed condition, a relative volume change can be computed.

An example calculation is provided in Figure 9.

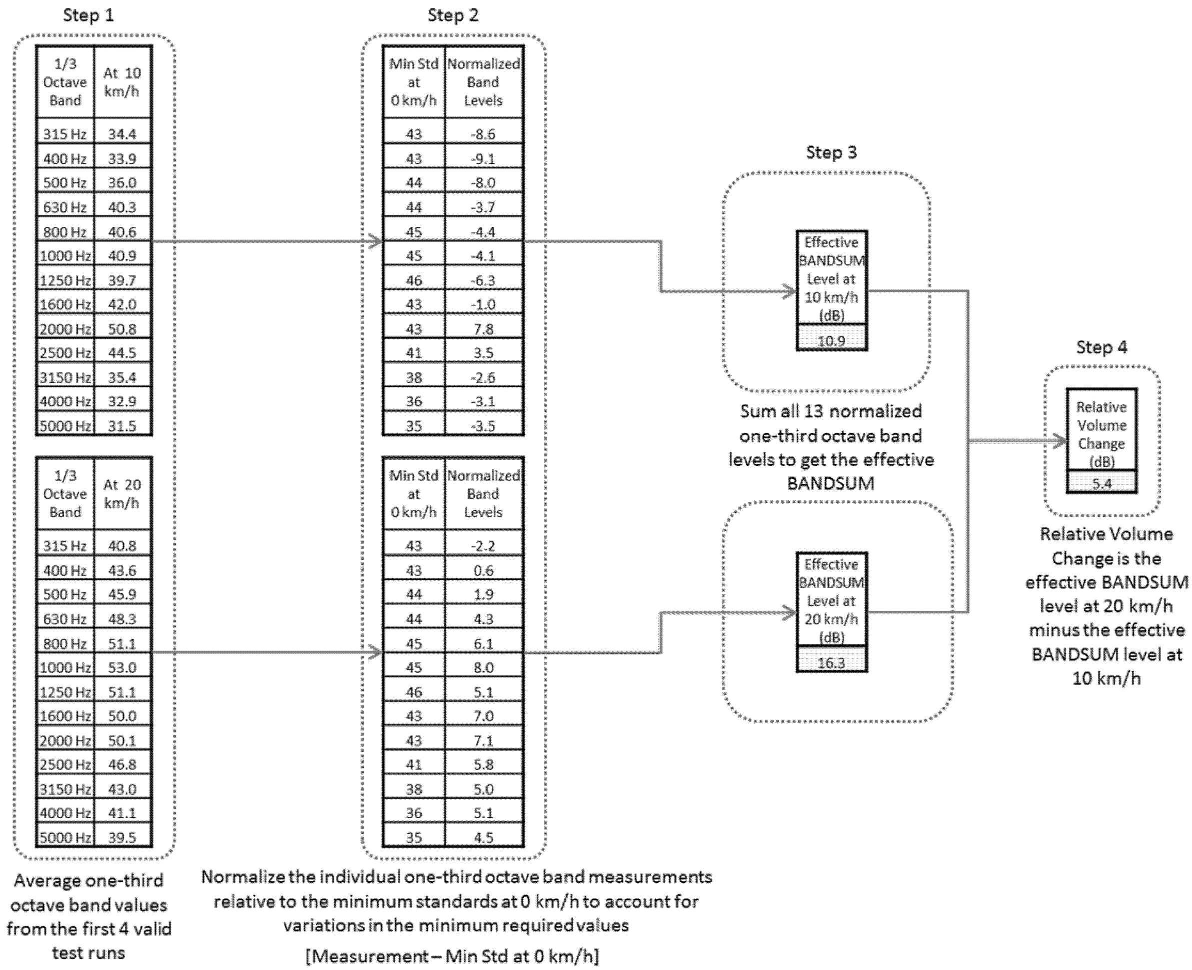


**Figure 9. Example of Relative Volume Change from 10km/h to 20 km/h**

Figure 9 illustrates the four-step procedure used to calculate the relative volume change for sample data for the 10 km/h to 20 km/h conditions as follows:

*Step 1:* Calculate the average measured one-third octave band level for each of the 13 one-third octave bands (315 Hz to 5000 Hz) using the four valid test runs identified for each of the test operating scenarios (stationary, 10 km/h (11+/− 1km/h), 20 km/h (21+/− 1km/h), and 30 km/h (31+/− 1km/h)).

*Step 2:* Calculate the normalized values for each of the 13 one-third octave bands for each of the operating scenarios, relative to the minimum SPL requirements specified for the stationary operating scenario. The normalized values are calculated by subtracting the minimum SPL values specified for the stationary operating condition from each of the one-third octave band averages calculated for each operating scenario (stationary, 10 km/h (11+/− 1km/h), 20 km/h (21+/− 1km/h), and 30 km/h (31+/− 1km/h)).

*Step 3:* Calculate the BAND SUM for each critical operating scenario (stationary, 10 km/h (11+/− 1km/h), 20 km/h (21+/− 1km/h), and 30 km/h (31+/− 1km/h)) as follows:

$$BANDSUM = 10 * \log_{10}\left(\sum_{13}^{i=1} 10^{\frac{Normalized\ Band\ Level_i}{10}}\right)$$

Where:

*i* represents each of the 13 one-third octave bands.

*Normalized Band Level$_i$* is the calculated normalized value for each of the 13 one-third octave bands.

*Step 4:* Calculate the relative volume change between each operating scenario (stationary to 10 km/h; 10 km/h to 20 km/h; 20 km/h to 30 km/h) by subtracting the BAND SUM of the lower speed test case from the BAND SUM of the next higher speed test case.

The performance specifications for the relative volume change requirement were derived based upon the minimum detection standards for each operating condition. The minimum detection standards increase with speed such that, if a vehicle just meets the minimum standards at each operating condition, its relative volume change would be approximately 6 dB between stationary and 10 km/h, approximately 6 dB between 10 km/h and 20 km/h, and approximately 5 dB between 20 km/h and 30 km/h. It is the agency's desire to ensure that vehicles equipped with compliant alert sounds are only as loud as they need to be for detection by pedestrians, and not excessively louder. To meet the relative volume change requirements, a manufacturer could simply increase the sound levels well beyond the minimum standards to achieve the required separation at each speed interval. However, we believe that manufacturers will also want to reduce alert sounds to the greatest extent possible while meeting the minimum standards in order to maximize customer satisfaction and minimize environmental noise. To accomplish the goal of minimizing excessive noise, the relative volume change values should not exceed the already established differences of 6 dB, 6 dB, and 5 dB built into the minimum operating condition specifications. The relative volume change specifications that NHTSA has decided to require are provided in Table 17.

TABLE 17—MINIMUM RELATIVE VOLUME CHANGE REQUIREMENTS

| Critical operating scenarios | Minimum relative volume change, dB |
| --- | --- |
| Between: | |
| Stationary and 10 km/h | 3 |
| 10 km/h and 20 km/h | 3 |
| 20 km/h and 30 km/h | 3 |

These performance levels were established using the following criteria. First, as explained above, to minimize alert sound levels, the maximum volume change between operating scenarios would be 6 dB, 6 dB, and 5 dB, respectively. So, as a starting point, the relative volume change requirements should not exceed these values. Second, a manufacturer might choose to design an alert signal that exceeds the minimum values at a given speed and just meets the minimum values at the next higher speed. Such a design would have a decreased relative volume change, *i.e.,* less than 5 dB or 6 dB, between operating conditions. Third, as discussed in the NPRM, the sound level change that can be discerned by an untrained observer is approximately 3 dB, so the relative volume change between each successive operating scenario should be at least 3 dB in order to be useful. Considering all these criteria, we want to target relative volume changes within the range of 3 dB to 6 dB. Within this range, we have decided to specify 3 dB as the minimum volume change requirement for the transitions between successive operating conditions. This means that the manufacturer can incorporate a 3 dB volume change or any level above 3 dB to meet the specified requirements. The minimum requirement of 3 dB between each operating condition ensures the volume change will be discernable while providing manufacturers with the greatest flexibility in the design of their alert systems.

It is NHTSA's expectation that the volume change requirement will provide pedestrians with the audible cues needed to discern vehicle acceleration and deceleration. However, we reiterate that frequency shifting still is a useful characteristic of a vehicle alert system, and we encourage system designers to incorporate frequency shifting even though this final rule does not include specific requirements for it.

Lastly, in regards to the commenters who requested that the proposed test procedure for frequency shifting be modified to allow for indoor testing and/or testing at the component level, those comments are no longer applicable since the agency has decided to exclude a frequency shifting test. In regard to comments about indoor and component testing in general, we have addressed that issue in Section III.K of today's final rule, where we have stated that NHTSA will conduct compliance testing on complete vehicles on outdoor test tracks.

*H. Sameness*

The NPRM criterion for sameness was that the alert sound of two example vehicles must have a sound pressure level within 3 dB(A) in every one-third octave band between 315 Hz and 5000 Hz. That requirement would limit the amount of variation in one-third octave bands over a range of frequencies when measured on a stationary vehicle. We proposed that requirement as an objective way to determine if the alert sounds produced by two different vehicles of the same make and model are the same.

In the NPRM, the agency interpreted the PSEA language on sameness as applying ''only to sound added to a vehicle for the purposes of complying with the NHTSA regulation'' [NPRM, p. 2804]. The proposed sameness criteria were not intended to apply to sounds generated by a vehicle's tires or body parts or by the mechanical operations of the vehicle.

In the NPRM, NHTSA stated that we interpret a vehicle ''model'' as a specific grouping of similar vehicles within a vehicle line. The *Federal Motor Vehicle Theft Prevention Standard,*[140] defines vehicle line as ''a name which a manufacturer applies to a group of vehicles of the same make that have the same body or chassis, or otherwise are similar in construction or design.'' If a manufacturer calls a group of vehicles by the same general name as it applies to another group, but adds a further description to that name (*e.g.,* Ford Fusion Hybrid, or Toyota Prius Three), the further description indicates a unique model within that line.

Also, the NPRM conveyed that the requirement for vehicles of the same make and model to have the same sound or set of sounds does not apply across model years. For example, a model year 2020 Prius Two could have a different sound than a 2019 Prius Two (same model but different model years). A 2019 Prius Two could have a different sound than a 2019 Prius Four (same model year but different models). All Prius Two's from the 2019 model year would be required to emit the same sound or set of sounds (same model and model year).

The PSEA includes language that requires ''the same sound or set of sounds for all vehicles of the same make and model.'' We interpreted this to mean that a manufacturer may choose to equip a vehicle to have different sounds for different operating modes such as forward, reverse, and stationary [NPRM, p. 2804]. Each sound would have to meet the corresponding performance requirements in each operating mode. We did not interpret this language in the PSEA to mean that a vehicle can have more than one alert sound for a given operating mode, such as a suite of sounds that a driver can select from according to personal preference.

In general, commenters from industry stated that speaker tolerances make it impossible to make all vehicles of the same year/make/model produce the same sound in accordance with the NPRM criterion, *i.e.,* to have the same sound level, within ±3.0 dB, in each of the thirteen specified one-third octave bands. Also, industry commenters favor an indoor, component-level test for sameness, rather than an outdoor test conducted on an ISO pad.

Advocacy groups that provided comments on the proposed sameness requirement generally supported it, or supported some performance-based assessment of sameness, but did not suggest specific technical criteria for such a performance test.

Alliance/Global stated on behalf of their member companies that the classification of sounds by an objective metric that would determine sameness first needs to have ''sameness'' defined. The NPRM proposal for a three decibel limit in each one-third octave band is not sufficient for the measurement uncertainty, let alone production variation, according to Alliance/Global.

[140] 49 CFR part 541.

Alliance/Global recommended that sameness be measured at a component level under indoor laboratory conditions. They stated that their only practical course of action to assure sameness between two vehicles is to compare the input signals to the speakers (the output from the signal generator or the programmed digital sound file). Alliance/Global stated that measuring sameness through microphone recordings of operating vehicles is not possible as a practical matter. Furthermore, due to the variation in production speakers, it also is not reasonable to require them to emit the same sound within the proposed three decibel specification. They acknowledged that the requirement cannot be deleted altogether because it is included in the PSEA. Alliance/Global also agreed with OICA that NHTSA should allow manufacturers the option of demonstrating compliance with the sameness requirement through comparisons of elements such as the software sound file, input to the speakers, etc.

OICA stated that the proposed sameness criterion needs revision, pointing out that industry has already shown that even 6 dB may not be a sufficient tolerance between vehicles of the same make and model. OICA stated that the measurement uncertainty is the most significant factor, and that the proposed allowance of 3 dB is not commensurate with the measurement uncertainty. OICA suggested that NHTSA should carefully consider how sameness is defined as that will drive the necessary measurement procedures. OICA noted that sound-generating devices that use the same software will inherently have the same sound, even when the sound is altered slightly through various factors such as installation into a vehicle. Using the same software also means that vehicles will produce the same sound even when the hardware is changed somewhat, according to OICA. OICA also noted that NHTSA could resolve issues with measurement of Sameness by specifying a requirement that applies to the software sound file. Citing the PSEA language, ''The Secretary shall allow manufacturers to provide each vehicle with one or more sounds that comply with the motor vehicle safety standard at the time of manufacture,'' OICA stated that vehicle manufacturers should be allowed to offer vehicles to customers with more than one alert sound and to equip vehicles with multiple alert sounds for the driver to select from during vehicle operation, as long as each of the sounds fulfils the minimum requirements defined in the safety standard. OICA suggested that the language of Section S5.3 should state that two vehicles of the same make, model, and model year must ''emit the same sound within a set of sounds,'' and that their overall sound level should be required to be within 6 dB(A).

Denso stated that this requirement is not feasible for a number of reasons. For one, there is inherent variability in vehicle sound characteristics and in speaker and amplifier characteristics and performance. When combining this variability, it is very difficult to limit the sound difference to within 3 dB(A) between two vehicles, even for vehicles having nominally identical sound systems, according to Denso. Denso stated that sound pressure levels will decrease by approximately one decibel when the ambient temperature increases from 0 to 40 degrees Celsius. Therefore, Denso suggested it is very difficult to measure the sound level within a tolerance of ±1.5 dB with good repeatability in outdoor conditions. In addition, since the perception of sound depends on ambient conditions (wind direction, wind speed, temperature, atmospheric pressure, etc.) and surrounding noise, Denso stated that ICE vehicles of the same model have up to a 3 dB and greater sound level difference. For these reasons, Denso requested that NHTSA not adopt a requirement for sameness.

The SAE stated that, although 3 dB may be an acceptable tolerance on overall SPL, it is not sufficient for one-third octave bands. SAE also stated that restricting one-third octave band variation does not guarantee sameness in any reasonable sense related to this regulation. Sounds can be filtered to meet the same one-third octave requirements, yet still could be perceived as substantially different by pedestrians. SAE provided an example of two sound files having the same overall SPL and very similar average spectral distribution, but different time signals. Despite their similarities, the two sound files were from recordings of completely different sounds. SAE stated that this demonstrates how sounds can appear to be similar based on a selected measurement criterion when in fact they might be very different in how they sound to listeners.

Honda stated the criterion for sameness in the NPRM is too stringent and cannot be complied with due to the variability of sound-producing devices. An attachment to Honda's comment graphically represented the variability in repeated testing of the same vehicles. [We note there was very little explanation of the data in Honda's comment; the graphic showed that one-third octave band measurements in repeated tests of the same vehicle appeared to vary by up to about 7 dB; but the results were quite different for the various one-third octaves and for the different test vehicles Honda tested, with variability in some instances being close to zero.] Honda suggested that NHTSA should specify an overall sound level and require that there be two peak frequencies that fall within specified frequency ranges.

Advocates for Highway and Auto Safety stated that, to ensure that different vehicles of the same make/model have the same sound, the agency must establish a test procedure for comparing different vehicles of the same make and model to ensure compliance and production uniformity along with meeting the FMVSS sound requirements.

Accessible Designs for the Blind stated that sameness should be tested at all speeds from idle up to the crossover point speed. ADB stated it does not believe that testing at idle only is appropriate for establishing the standard. ADB stated that changing a vehicle's tires or body design is likely to affect the vehicle's sound profile and therefore it is essential that the single sound specified be well documented as detectable and localizable under common traffic and ambient sound conditions by visually-impaired pedestrians who are at least 60 years of age. There will be differences in the perceived sound even if it is generated using the same wav file. The nature of the loudspeaker and where and how it is mounted will also result in differences. Perceived sound will, of course, also vary by road surface. ADB rejected the notion that a variety of sounds will be consistently and accurately recognized by pedestrians as coming from vehicles. Any added sound should be the same for all EVs and HVs in order to be maximally recognized and quickly interpreted as being a vehicular sound, according to ADB. ADB stated that having more than one sound is likely to decrease any safety benefit added sound might provide for visually-impaired pedestrians.

In a February 2014 letter to NHTSA co-signed by the Alliance, Global, the NFB, and the ACB, the co-signers jointly submitted their mutually agreed-upon position about aspects of the PSEA's sameness requirement. They stated that vehicles with the same overall sound pressure level, within a reasonable engineering and manufacturing tolerance, should be considered as having the same sound.

The joint letter said that vehicles of different model years should not be considered to be the same make and model. In other words, only vehicles of the same make, model, and model year should be required to emit the same sound.

The joint commenters also expressed their agreement about two other aspects of the PSEA Sameness requirement: First, OEMs should have flexibility to provide EV/HVs with some number of driver-selectable sounds instead of just a single sound; and second, OEMs should be allowed to install updated sounds once per model year to address any dissatisfaction that might arise on the part of vehicle owners with the alert sounds their HV/EVs are originally manufactured with. The latter would be separate from updates that OEMs might need to make to remedy a noncompliance or for conducting a recall, as provided for in the PSEA. The joint commenters believe the language of the PSEA, which uses the terms ''one or more sounds'' and also ''sound or set of sounds'' allows for driver-selectable sounds and voluntary updating of sounds.

We note that NHTSA did not receive comments specifically in response to our request for comment on the extent to which changing a vehicle's tires or body design would affect the vehicle's sound profile for the purposes of determining whether two example vehicles have the same sound.

Agency Response to Comments

In light of the comments the agency received on the NPRM sameness requirement, we have reconsidered the proposed requirement and have decided that it is not appropriate for the final rule. We agree with at least one shortcoming that was pointed out by several commenters: Even if two vehicles' alert sounds are within three dB(A) in each specified one-third octave band, the alerts would not necessarily sound the same because sounds that have identical one-third octave sound pressure levels can vary considerably in terms of how they are perceived by a listener. In fact, it is possible for completely different types of sounds to have similar one-third octave band levels, even across a wide range of frequency bands.

We now believe that the NPRM metric based on A-weighted one-third octave band sound pressure levels would be suitable only to identify ''defective'' sounds, *i.e.,* to identify when two sounds that are intended by design to sound the same are not the same, for example if a particular test vehicle had a damaged speaker. The main reason for this is that the NPRM method has relatively low resolution and would not distinguish between tonal signals and noise signals, which are different by definition but can have the same one-third octave band spectra. Consequently, even if two vehicles of the same make and model were to comply with the NPRM criterion, there would be little assurance that they in fact produce identical alert sounds.

We also acknowledge the concern expressed in comments that speakers used in alert systems have some inherent manufacturing variation. However, NHTSA has not conducted tests to verify the level of speaker variation claimed by commenters.

Regarding the Alliance/Global suggestion that overall sound pressure levels produced by two vehicles should be used to determine whether they are the same, we do not believe that method would provide a meaningful comparison. That approach would merely characterize how loudly two vehicles' alert sounds are perceived. That approach would not evaluate other acoustic characteristics that make sounds alike such as phase or spectral shape, and it normally would not distinguish between sounds that are obviously different to listeners. For example, music, construction noise, and thunder all can have the same overall A-weighted sound pressure level.

Other Sameness Metrics Considered by NHTSA

Subsequent to concluding that a requirement based on one-third octave levels is not appropriate for the final rule, the agency considered various alternatives for objectively determining that alert sounds among vehicles of the same make and model are the same.

To address issues with the NPRM approach, we considered two additional types of acoustic metrics to evaluate the similarity of the alert sounds on vehicles of the same make and model: Power Spectrum Analysis and Frequency Response Functions (FRF). These are both acoustic metrics that could be used to analyze the actual output of the alert system speaker to quantify the difference between two sound signals. Both of these metrics characterize amplitude and frequency. The FRF is sensitive to phase as well. Both metrics have higher resolution than one-third octave bands.

Power spectrum analysis generally has resolution sufficient for signals that do not change over time. However, temporal differences such as time reversal (*e.g.,* playing of a signal in reverse) and amplitude modulations which change the perceived character of a sound may not show up as significant differences in the power spectrum of two signals. For this metric to be useful for evaluating sameness, it probably would be necessary to evaluate the statistical correlation ($R^2$ value) of the power spectra of two sound signals and to specify a degree of correlation that must be achieved in order for the two sounds to be considered the same. For a variety of reasons including a lack of any established procedure using this method and also repeatability concerns, we do not know if it is feasible to develop a compliance requirement based on this method.

Frequency Response Functions would provide a better comparison. For some alert sounds, the FRF could be used to show that certain periodic variations are highly correlated between two signals. However, other signal variations may not be correlated. Additionally, an evaluation of the FRF would require a standardized method to synchronize the phase between the two signals, and the agency currently does not have any such method.

Overall, we have concluded that comparisons using Power Spectrum Analysis or Frequency Response Functions might provide a higher degree of confidence than the NPRM method that two unknown signals are the same, but developing a requirement and test procedure based on these metrics for a compliance test application may involve considerable additional agency research and testing.

Furthermore, in order for either of these metrics to be useful in a compliance test, the measurement variability of the data collected for a sameness evaluation would have to be extremely low, such that even small differences in measurements of two example vehicles could be attributed to actual differences in their alert sounds. As discussed in the Repeatability/Reproducibility section (Section III.K) of this preamble, we have determined that the variability of pedestrian alert sound measurements is on the order of several decibels when measured on a vehicle in operation (although stationary tests like those used for Sameness tend to be somewhat less variable.) Although the level of variability of the NHTSA measurement procedure promulgated in today's final rule is sufficiently low for stationary, reverse, and pass-by tests, we believe it is inadequate for a sameness evaluation using power spectra and FRFs. For these metrics to be useful for sameness, we would need to obtain a clean signal prior to its exposure to external influences like speaker tolerances and ambient noise fluctuations.

Another option would be to evaluate the alert signal at the point where it is transmitted to the alert system speaker, *i.e.,* at the speaker input. While speaker input would have very high repeatability, this approach would require that the speaker inputs must be physically accessible, which the agency has found is not always the case. For example, speakers might be integrated into a sealed module that incorporates the control electronics, making access difficult without destructive measures.

Another option is to evaluate the signal at the point where it is generated internally in the alert system. On typical alert systems, this would amount to evaluating the actual digital source of the alert sound, such as a wav file, or an equivalent digital element of the alert system from which the signal originates. NHTSA may not have the means to extract a digital file for a compliance evaluation of a test vehicle and would need the assistance of the vehicle manufacturer. At that point, a more practical option might be for NHTSA to simply request that information from the vehicle manufacturer. However, even if an OEM were to provide NHTSA with a digital source file from two vehicles of the same make and model, it is uncertain whether the agency could verify that they are identical.

Because alternative acoustic metrics have these issues, we believe they are not viable for a regulatory application, and we have decided not to adopt acoustic metrics for the sameness requirement in the final rule. Instead, as detailed later in this section, we have concluded that the final rule requirement for sameness should be based on certification by vehicle manufacturers that vehicles of the same make and model are designed to have identical alert sounds. That is, they must certify that vehicles of the same make, model, and model year are the same with respect to their alert system hardware and software components, the source of the alert sound (such as a digital file) and vehicle inputs used to vary the sound, as well as all other elements of the alert system.

Other Sameness Issues—Selectable Sounds and Mid-Year Updates

In the proposed regulatory text in the NPRM, paragraph S8 was included to prevent alert sound modifications, except in case of a vehicle recall. That section of the regulatory text also prohibited systems from being designed to allow access by anyone other than the OEM or a service provider, so that individuals would not be able to tamper with or replace the alert sound in their vehicles.

The joint comment of the Alliance, Global, the NFB, and the ACB addressed both the issue of ''selectable'' sounds and the issue of alert sounds being updated or improved after vehicles are delivered to customers. Regarding the first issue, the joint commenters stated that they believe the PSEA allows vehicles to be equipped with more than one sound for a given operating condition. This comment would mean, for example, that a particular vehicle make/model might have an alert sound X, an alert sound Y, and an alert sound Z for when the vehicle is in forward motion at a given speed, and the driver could select X, Y, or Z based on personal preference and could switch among those choices at any time. Regarding the second issue, the joint commenters stated the PSEA allows a manufacturer or dealer to provide vehicle owners with opportunities at any time during a model year to update the alert sound or sounds with which their vehicle came equipped from the factory. They contended that this allowance exists under the PSEA even in cases where the original sound is not defective or out of compliance with the safety standard, and that updates may be provided for aesthetic purposes rather than for remedy of a recalled alert system (the latter being expressly provided for in the PSEA.)

Given our understanding of the PSEA, we are not including provisions requested by these commenters that would allow for driver-selectable pedestrian alert sounds and mid-year updates of pedestrian alert sounds. As such, the provision in paragraph S8 of the NPRM regulatory text, which specifically prohibits alert sound modifications except for recall purposes and also prohibits systems designed so as to allow manipulation or modification of the alert sound by anyone other than the OEM or a service provider, is adopted in this final rule without modification. We believe that this approach is necessary to satisfy the requirements contained in the PSEA language and that allowing a means for owners to select or modify alert sounds, or to allow vehicle manufacturers, dealers, or other vehicle service entities to replace or update alert sounds outside the auspices of a recall action, would be in conflict with the language of the PSEA. Furthermore, by not allowing driver-selectable sounds, the final rule adheres more closely to the PSEA requirement that vehicles of a given make and model must have the same alert sound.

Compliance Evaluation of Sameness

After fully considering the NPRM comments on sameness and other acoustic metrics, we have concluded that the compliance requirement for sameness in this final rule should not be based on acoustic performance measurements, including the one proposed in the NPRM. The difficulties and unknowns with comparing direct measurements of acoustic metrics, as well as the potential need for more agency research in this area if we decided to use any of the metrics discussed above, leads us to conclude that, currently, the most effective and expedient way for NHTSA to evaluate sameness is to explicitly require that specific design aspects of vehicle alert systems must be the same, particularly the software and hardware that comprise the systems.

Although this approach would not be based on acoustic measurement, it would provide assurance that the design of alert systems on vehicles of a given make and model are consistent from one vehicle to the next because the vehicle manufacturer would be certifying not just that the sounds are the same but that the hardware and software components that are used to generate the alert sound are the same from vehicle to vehicle.

This approach is consistent with the comments NHTSA received in response to the NPRM. In response to NHTSA's request for comment in the NPRM regarding its proposed method of measuring whether the sound produced by two vehicles was the same, the Alliance/Global joint comment stated that the only way to verify sameness was to measure the digital signal output of the sound generator or to examine the digital sound file itself. Alliance/Global further referenced statements by OICA supporting a method of determining sameness based on the examination of the software and hardware making up the sound generation system. Alliance/Global stated in their comments that ''OICA notes that current sound generating devices that use the same software will inherently have the same sound, even when the sound is altered slightly through various factors, such as installation into a vehicle. The Alliance and Global agree with OICA that NHTSA should allow manufacturers the option of demonstrating compliance with the sameness requirement through comparisons such as: The software sound file, input to the speakers, etc.'' After reviewing the comments and its own data, NHTSA agrees that the best method for satisfying the requirement in the PSEA to require vehicles of the same make and model to make the same sound is to examine the hardware and software of the subject vehicles and to require that hardware and software to be the same.

As stated previously, we believe that the Vehicle Safety Act and PSEA requirement can be satisfied by this methodology. Aside from being a requirement in the PSEA, requiring vehicles of the same make and model to emit the same sound limits the universe of sounds produced by EVs and HVs that pedestrians, both blind and sighted, must be able to identify as vehicle sounds. This is important because pedestrians must be able to recognize the sound produced by an EV or an HV as a vehicle-emitted sound for this rule to reduce crashes between pedestrians and EVs and HVs.

If we can establish that vehicles of the same make and model are alike with respect to the hardware and software they utilize for their alert systems, that information will be sufficient to establish their sameness because the sounds they generate would be effectively the same. That is, if two vehicles are designed the same in regard to having the same software and hardware to generate alert sounds, then any overall differences in the sound produced would not be perceptible in a meaningful way to pedestrians. Thus, this approach achieves the intent of the PSEA sameness requirement.

Consistent with the NPRM, we are applying the sameness criterion only to sounds added to vehicles for the purpose of complying with this final rule. In that way, tire noise, wind noise, and any other noise associated with vehicle motion and that is not generated by the pedestrian alert system is not subject to the sameness requirement.

We note that NHTSA has taken a similar approach in other FMVSS where we have relied on manufacturer's assurance and documentation that a system is designed to comply with the safety standard. For example, when NHTSA created the safety standard for Electronic Stability Control, FMVSS No. 126, S5.6 ''ESC System Technical Documentation,'' was included for compliance of ESC systems with an understeer requirement. In NHTSA's development of FMVSS No. 126, the agency was unable to devise an understeer test that was both accurate and repeatable. The agency instead took the approach of identifying certain system design characteristics and verifying them by requesting information from the OEM. Standard No. 126 lists items such as a system diagram, a written explanation of the system operational characteristics, a logic diagram, and a discussion of processor inputs and calculations relating to vehicle understeer as examples of evidence that may be used to validate the manufacturer's certification.

In the case of pedestrian alert systems, we are taking that approach. In our development of today's final rule on FMVSS No. 141, we have not successfully devised a meaningful, accurate and repeatable test for sameness. The reasons for this are discussed previously in this section. Instead, we are including a requirement that critical aspects of the alert system design must be the same from vehicle to vehicle.

We also believe that this approach is consistent with the Vehicle Safety Act. While Congress intended that NHTSA issue performance standards when it passed the Vehicle Safety Act, courts interpreting the Vehicle Safety Act have recognized that in some instances it is necessary for NHTSA to issue a design restrictive standard in order to achieve a desired performance or to ensure safety.[141] In *Chrysler* v. *Department of Transportation,* the Sixth Circuit upheld a FMVSS issued pursuant to the Vehicle Safety Act restricting the design of headlamps. The court held that the design restriction on headlamps in the standard was consistent with the Vehicle Safety Act because it fulfilled the important safety purpose of ensuring that replacement headlamps were readily available to consumers. We believe that the provisions in this final rule requiring that certain aspects of the vehicle alert sound system be the same in all vehicles of the same make and model, in addition to fulfilling a requirement in the PSEA, fulfils the safety purpose of helping pedestrians to recognize sounds produced by EVs and HVs as vehicle emitted sounds.

To implement this approach for the sameness requirement, we are modifying the proposed regulatory text in paragraph S5.5 (was NPRM paragraph S5.3) to state that any two vehicles of the same make, model, and model year shall generate their pedestrian alert sound using the same external sound generation system including the software and hardware that are part of the system. Furthermore, we are adding a definition of Pedestrian Alert System within the regulatory text of S5.5 which lists the common components of pedestrian alert systems. In this way, by certifying that a pedestrian alert system meets S5.5, the manufacturer is explicitly certifying that the following specific hardware and software components of the system are the same from vehicle to vehicle: The alert system hardware components including speakers, speaker modules, and control modules, as evidenced by specific details such as part numbers and technical illustrations; the location, orientation, and mounting of the hardware components within the vehicle; the digital sound file or other digitally encoded source; the software and/or firmware and algorithms which generate the pedestrian alert sound and/ or which process the digital source file to generate a pedestrian alert sound; vehicle inputs including vehicle speed and gear selector position utilized by the alert system; any other design features necessary for vehicles of the same make, model, and model year to have the same pedestrian alert sound at each given operating condition specified in this safety standard.

To verify the OEM's certification of an alert system in the agency's annual compliance evaluations, NHTSA's Office of Vehicle Safety Compliance may request that the manufacturer make available to the agency specific design documentation relating to the alert system used on same make, model, and model year vehicles. The documentation that a manufacturer could provide to demonstrate that the sound produced by two vehicles of the same make and model is the same may include documents such as: A description of the source of the alert sound, such as the digital sound file; a copy of the digital file (if applicable); any algorithms for processing/ manipulating the digital file to generate an alert sound; vehicle inputs such as speed signal that are needed to process and generate the alert sound; and details such as part numbers showing that vehicles of the same make, model, and model year are consistently equipped with identical alert system components.

## I. Customer Acceptance

In the NPRM we discussed presentations provided by vehicle manufacturers regarding consumer acceptance of adding sound to vehicles to provide pedestrian detection. Nissan submitted a presentation stating that over 60 percent of Nissan Leaf owners surveyed found that added noise was acceptable if the overall sound pressure level of the sound was 55 dB–A or quieter for the forward moving condition.

The NPRM also discussed the ways in which NHTSA crafted the proposal to account for concerns about the community noise impacts of the

[141] *See Washington* v. *Dep't of Transp.,* 84 F.3d 1222, (10th Cir. 1996); *Chrysler Corp.* v. *Dep't of Transp.,* 515 F.2d 1052, 1058 (6th Cir. 1975).

proposal so that sounds complying with the requirements of the final rule would not unnecessarily contribute to noise pollution. In consideration of community noise impacts the NPRM omitted the mid-range frequencies from the proposed acoustic requirements as these are the frequencies that contribute the most to increasing the overall sound pressure level of sound.

NHTSA also conducted a draft Environmental Assessment (EA) to analyze the environmental effects of the proposed rule. The analysis in the EA most relevant to analyzing the impact of the rule on consumer acceptance is the single car pass-by analysis. This analysis is designed to show what a person standing near the road way would hear when a EV or HV emitting sound complying with the NPRM passed by. In an urban ambient with an overall sound pressure level of 55 dB(A) a listener standing near the roadway would not be able to perceive the difference between a EV/HV that did not produce added sound and an EV/HV that complied with the requirements of the NPRM.[142] In a non-urban ambient with an overall sound pressure level of 35 dB(A) the difference between the single-vehicle pass-by for EVs/HVs meeting the minimum sound requirements in the NPRM and those without the added sound would be 3.1 to 6.3 dB, depending on speed, and 10.1 dB at stationary. In the non-urban ambient a single vehicle pass by of an EV/HV meeting the minimum sound requirements of the NPRM would produce less sound than an average ICE vehicle although this difference would only be noticeable at stationary.

We received several comments in response to the NPRM that certain aspects of the proposal would be annoying to passengers or drivers or would not be accepted by consumers. We also received several comments from members of the general public stating that the whole concept of adding any sound to hybrid and electric vehicles would be annoying and would lead to decreased sales of EVs and HVs.

Alliance/Global stated in their joint comment that the loudness and frequency composition of sounds meeting the proposed requirements would be unpleasant to vehicle occupants. Specifically sounds with minimum content in eight one-third octave bands would be too loud to be accepted by consumers.

Alliance/Global further stated that because the proposed requirements did not contain requirements for mid-range one-third octave bands from 500 Hz to 2000 Hz, resulting sound would have a shrill unpleasant character. Alliance/ Global stated that, based on past experience with shrill sounds, their members fear that costumers may be unwilling to purchase EVs and HVs if they are equipped with sounds meeting the proposed requirements.

GM stated that the proposed sound levels and operating conditions are in excess of the safety needs of pedestrians and further explained that this would likely result in customer annoyance leading to customers disabling the alert sound and also affecting vehicle purchases. Chrysler and Honda also expressed concerns about marketability and customer acceptance.

Toyota also stated that sounds meeting the requirements of the NPRM would be too loud and would discourage consumers from purchasing EVs and HVs. Toyota commented that it had examined customer acceptance of sounds meeting the NPRM specifications. Toyota used a prototype speaker and included 56 Prius owners (ages 20 to 55 years old). Participants were asked to drive an alert-equipped vehicle on a specific route and then rate the sound. The operating conditions experienced during the study included slow acceleration; 40 km/h pass-by; slow deceleration; and 16 km/h pass-by. Toyota reported that 68 percent of the drivers were somewhat dissatisfied or very dissatisfied with their overall experience with the sound emitted by the test vehicle. Toyota asked the participants how the sound might affect their future vehicle purchases, and 54 percent of the drivers indicated a somewhat negative or very negative impact, while 46 percent indicated no impact or a somewhat positive impact. Toyota also mentioned that a sound meeting the proposed requirements in the NPRM resulted in an increase in the interior noise relative to the same vehicle with the alert system turned off.

WBU commented that allowing the sound to be emitted over fewer one-third octave bands may alleviate manufacturers concerns about consumer acceptance of alert systems.

Several commenters also stated that requiring a sound while the vehicle is stationary would lead to lower consumer acceptance of EVs and HVs. Nissan submitted with its comment the result of a customer survey that indicated that over 60 percent of costumers would accept an idle sound with an overall sound pressure level of 49 dB–A or less.

NHTSA also received comments from OICA stating that the requirements in the NPRM requiring that the sound produced by EVs and HVs contain tones would make sounds complying with the NPRM annoying to vehicle occupants. Mercedes expressed concern that including requirements for low one-third octave frequency bands down to 315 Hz and broadband content down to 160 Hz may affect consumer acceptance of sounds meeting the requirements of the NPRM because sounds with content in this area of the spectrum are difficult to isolate from the vehicle cabin.

Agency Response to Comments

As discussed in Section III.E of this notice, the agency made several changes to the acoustic requirements of the NPRM in this final rule. In response to comments from manufacturers, the final rule allows compliance with its acoustic requirements by placing minimum content in the mid-range one-third octave bands from 500 Hz to 2000 Hz. We believe that this change will increase manufacturer's flexibility to create sounds that are pleasing to motorists and pedestrians. NHTSA does not believe that the overall sound pressure level of sounds meeting the requirements of this final rule will discourage consumers from purchasing EVs or HVs or effect consumers acceptance of the requirements in the final rule. The overall sound pressure level of sounds meeting the requirements of the final rule for the 10 km/h pass by are between 53–56 dB(A). According to Nissan's presentation, 60 percent of consumers would accept added sound to their vehicle if the overall sound pressure level of the sound was 55 dB(A) or quieter for the forward moving condition. NHTSA believes that the Nissan study indicates that consumers will accept sounds meeting the requirements of the final rule.

While the minimum sound requirements in the final rule increase above 55 dB(a) for the 20 km/h and 30 km/h pass-by tests, sound emitted from other sources on the vehicle, such as the tires, increases as the vehicle increases speed as well. NHTSA believes that the increased sound from these other sources will limit the extent to which drivers notice, and are negatively affected by, the sound produced in compliance with this final rule at 20 km/h and 30 km/h.

NHTSA finds that it is difficult to draw conclusions about consumer acceptance of sounds meeting requirements of the final rule from the survey submitted by Toyota. The Toyota survey does not breakout the views of the participants in the survey by operating speed like the survey

[142] NHTSA, Minimum Sound Requirements for Hybrid and Electric Vehicles; Draft Environmental Assessment (2013), at 39–40.

conducted by Nissan. One of the conditions included by Toyota was a 40 km/h pass-by for which the agency did not propose requirements in NPRM. Furthermore, the Toyota study did not state the overall sound pressure level of the sound to which the participants were exposed during the test. We believe that reducing the number of required one-third octave bands to either four or two and allowing manufacturers to comply with the requirements of the final rule by placing minimum content in the mid-range one-third octave bands from 500 Hz to 2000 Hz will allow manufacturers more flexibility to create pleasing sounds.

The final EA replicates the findings of the draft EA indicating that sounds emitted by EVs/HVs in compliance with this final rule will be noticeably louder than EVs/HVs without added noise but will produce less sound than the average ICE vehicle. For this reason we do not believe that the requirements in the final rule will lead to sounds that will be so loud as to be annoying to drivers and pedestrians or to effect consumers' desire to buy these vehicles. Furthermore, according to the analysis of national annual noise caused by this final rule in the Final EA, EVs and HVs subject to the final rule would only be required to emit sound in compliance with this rule during 2.3 percent of all travel hours in urban areas.[143] Therefore, the amount of time during which drivers and pedestrians would be exposed to sounds produced in compliance with the final rule is limited which also limits the possibility for annoyance to drivers and pedestrians.

This is not the case for LSVs, however. These vehicles have top speeds of greater than 20 mph and less than 25 mph and, because final rule would require sound at speeds of up to 18.6 mph, sound is likely to be nearly constant for these vehicles. In addition, these vehicles are often open, lacking windows and, sometimes doors. For this reason, occupants of these vehicles are likely to hear the required sounds more so than occupants of other vehicles. However, we did not receive any comments indicating that consumer acceptance of sounds required by this final rule would be a greater issue for owners of LSVs than other vehicles to which this rule applies.[144]

The agency addressed comments regarding consumer acceptance of a sound at stationary in Section III.I of this notice. We note briefly here that we do not believe that the requirements in the final rule for EVs and HVs to emit a sound at stationary will substantially affect consumer acceptance of the requirements in the final rule. As indicated by the survey conducted by Nissan, 60 percent of consumers accepted a sound at stationary with an overall sound pressure level similar to the levels required by the final rule.

We note that the final rule does not contain the requirements for broadband sound, low frequency content, and tones proposed in the NPRM. In satisfying the mandate in the PSEA to establish minimum sound requirements for EVs and HVs, NHTSA has taken several steps to minimize the impacts of the requirements on drivers and pedestrians while also ensuring that these vehicles are detectable to pedestrians when operating at low speed. This includes reducing the number of required bands and removing requirements for tones and low frequency content. Given these changes from the NPRM to the final rule, NHTSA believes manufacturers will be able to design pedestrian alert sounds that will be accepted by drivers and pedestrians.

### *J. Test Conditions*

Ambient Temperature Range for Testing

In the NPRM, we proposed that, for sound measurement testing, the ambient temperature be in the range 5 to 40 °C. This proposal is consistent with SAE J2889–1. However, SAE J 2889–1 contains a note stating that testing of some vehicles may not be possible in warmer weather conditions (above 20 °C) since such things as battery cooling fans (if there is one) will always be running. Since the NPRM proposed that measurements that contain sounds emitted by any component of a vehicle's battery thermal management system be considered not valid, the NPRM stated that SAE J2889–1 note will also apply to FMVSS No. 141 sound measurement testing. Therefore, in the NPRM preamble, NHTSA requested comments on narrowing the permitted temperature range to 5 to 20 °C to improve test repeatability and to remove issues with battery cooling fans running.

We received comments from Alliance/Global and Honda regarding the ambient temperature during testing. Both commenters were opposed to narrowing the permitted temperature range to 5 to 20 °C to improve test repeatability and to remove issues with battery cooling fans running. Honda also recommended that the ambient weather conditions be measured at the specified microphone height in FMVSS No. 141 S6.4 with a tolerance of ±0.02 meters instead of the specified microphone height with a tolerance of ±0.0254 meters that was proposed in the NPRM.

Agency Response to Comments

After the NPRM was issued, NHTSA analyzed the sound measurement repeatability data that it collected in 2012 for a Ford Fusion to determine if there were systematic effects of the atmospheric conditions, particularly temperature, on measured sound pressure level for the vehicle's 10 km/h pass-by. This data consisted of 96 individual measurements taken over a six-month period from April to September of 2012. For each individual measurement the following data was recorded:

- Overall Sound Pressure Level (dBA)
- Temperature (°C)
- Wind Speed (m/s)
- Wind Direction (degrees from North)
- Atmospheric Pressure (Pa)
- Relative Humidity (%)

Analysis of variance for each variable's effect on overall sound pressure level showed no statistically significant variation (at the $\alpha = 0.05$ level) for any variable over the range of the data. Linear modeling of all terms also showed no statistically significant effect on overall sound pressure level for any variable.[145]

Since ambient temperature has no statistically significant effect on measured sound data, NHTSA agrees with the commenters that we should not restrict ambient temperatures to between 5 °C and 20 °C (however, we note that the tendency of thermal management system cooling fans to activate at higher temperatures may effectively limit testing to this temperature range). Doing so could limit compliance testing opportunities while not providing any test accuracy or repeatability benefit. We would expect a vehicle's thermal management system to operate more frequently in tests during warmer ambient conditions. As discussed in Section III.K, the agency has clarified when a test can be deemed invalid, including instances when cooling fans engage intermittently

[143] NHTSA, Minimum Sound Requirements for Hybrid and Electric Vehicles; Final Environmental Assessment (2016), at p. 56. (docket NHTSA–2011–0100).

[144] Note that the category of Low Speed Vehicles is defined in NHTSA regulations as vehicles whose top speed is more than 20 mph and not more than 25 mph. Electric vehicles with top speed of 20 mph or less, like many electric golf carts for example, are not considered LSVs and, in fact, are not regulated as motor vehicles, and thus are not subject to this final rule.

[145] For a complete analysis *see,* Garrott, W.R., Hoover, R.L., Evans, L.R., Gerdus, E., and Harris, J.R., ''2012 Quieter Vehicle Testing Report: Measured Sound Levels for Electric, Hybrid Electric, and Low Speed Vehicles'' Washington, DC, DOT/NHTSA, November 2016.

during testing. Therefore, the final rule will permit sound measurements to be made when the ambient temperature is in the range from 5 °C and 40 °C.

Honda's other recommendation was that the ambient weather conditions be measured at the specified microphone height in FMVSS No. 141, paragraph S6.1, with a tolerance of ±0.02 meters. NHTSA agrees that the ±0.02 meters tolerance instead of the proposed height tolerance of ±0.0254 meters that was proposed in the NPRM is more consistent with SAE J2889–1.

The NPRM used the microphone positions of S7.1 of SAE J2889–1 and also used the microphone height tolerance of ±0.02 meters. It seems logically consistent to use the same height tolerance of ±0.02 meters for the meteorological instrumentation. Making this change is not expected to have any impact on the stringency of the compliance test. It will merely make testing slightly easier to perform. Therefore, the final rule will have a meteorological measurement height tolerance of ±0.02 meters (±2.0 centimeters).

Tire Inflation Pressure

In the NPRM, NHTSA proposed that, prior to sound measurement testing, the vehicle's tires be inflated to the recommended tire inflation pressure listed on the vehicle's tire placard.

EMA recommended that NHTSA adopt the tire inflation pressure requirements for medium and heavy trucks in FMVSS No. 121, *Air Brake Systems.* NHTSA's proposal deviates from the test procedure in FMVSS No. 121 which states that tires will be inflated as specified by the vehicle manufacturer for its GVWR.

EMA cited two factors in support of its suggestion to harmonize the test procedures in this final rule with those contained in FMVSS No. 121 for tire fitment and inflation pressure. First, EMA pointed out that a conflict between FMVSS No. 121 and FMVSS No. 141 would add a burden to manufacturers without any safety benefit by imposing a unique tire inflation pressure specification for the new FMVSS. Second, EMA stated that ''the tire inflation pressures on a heavy-duty vehicle's certification label or tire information label may lead to inaccurate tire inflations.'' EMA stated that a heavy-duty vehicle's certification label or tire inflation pressure label contain the recommended cold inflation pressures for the tires identified on those labels; however, it is possible that the vehicle may be equipped with a tire not listed on those two labels.

Agency Response to Comments

The agency has considered EMA's comments and agrees that the correct inflation pressure should be used for all applicable vehicles. For passenger cars, multipurpose passenger vehicles, light trucks, and buses (with GVWR of 4,536 kg or less) the requirement as proposed in the NPRM is appropriate. For low-speed vehicles, the required certification label generally includes tire size and inflation pressure information. All low-speed vehicles tested to date by the agency's Compliance division have shown the requisite tire inflation pressure information on the certification label.

To address EMA's comments and ensure that all vehicles subject to the new safety standard are addressed in the language relating to recommended inflation pressure, paragraph S6.6(e) of the regulatory text has been revised.

Tire Conditioning

In the NPRM, NHTSA proposed that, prior to sound measurement testing, the vehicle's tires be conditioned by driving it around a circle 30 meters (100 feet) in diameter at a speed that produces a lateral acceleration of approximately 0.5 to 0.6 g for three clockwise laps, followed by three counterclockwise laps. This tire conditioning procedure was derived from ISO 362, ''Road Noise for Passenger Vehicle Tires.''

Honda and OICA recommended that NHTSA not require tire conditioning prior to testing unless NHTSA can show differences in measured acoustic data attributable to conditioning. OICA recommended changing the tire conditioning language to state that before sound measurements are started, the tires shall be brought to their normal operating conditions.

Agency Response to Comments

NHTSA does not have measured acoustic data showing differences that are attributable to tire conditioning. However, NHTSA's goal for tire conditioning matches the OICA recommendation that, before sound measurements are started, the tires be brought to their normal operating conditions. NHTSA also thinks that sound measurement testing with brand new tires may produce non-representative sounds due to mold vents and mold lubricant. The goal of tire conditioning is to remove sound anomalies caused by these effects. We believe that achieving this goal will require minimal effort during testing. Therefore, NHTSA will retain tire conditioning in the final rule for passenger cars, multipurpose passenger vehicles, light trucks, and buses with a GVWR of 4,536 kilograms or less, and low-speed vehicles. The final rule only specifies how NHTSA (not manufacturers) will perform compliance testing and, as with other NHTSA safety standards, manufacturers may elect not to adopt specific portions of a test procedure if they are convinced that doing so will not affect how their test results compare to the results from NHTSA compliance testing.

Self-Locking Doors

In the NPRM, NHTSA proposed that the test vehicle's doors are shut and locked for all measurements of vehicle pedestrian alert sounds.

NHTSA received comments on this topic from OICA and Alliance/Global. Commenters requested that NHTSA clarify the vehicle condition section of the final rule test procedure for self-locking doors by adding a sentence saying that in the case of self-lockable vehicles, the doors shall be locked before starting measurement.

Agency Response to Comments

NHTSA does not think that it is necessary to add clarification about vehicles with self-locking doors to the regulatory text. The applicable proposed regulatory text, as contained in the NPRM, is S6.6(b): ''The vehicle's doors are shut and locked and windows are shut.'' This seems quite clear. This text requires that all doors, whether self-locking or not, be locked prior to testing. This text is used in this final rule in re-numbered paragraph S6.6(a).

Accessory Equipment

In the NPRM, NHTSA proposed that, for sound measurement testing, all accessory equipment (air conditioner, wipers, heat, HVAC fan, audio/video systems, etc.) be turned off. We also stated that propulsion battery cooling fans and pumps and other components of the vehicle's propulsion battery thermal management system are not considered accessory equipment.

NHTSA received comments on this topic from OICA and Alliance/Global. Commenters requested that NHTSA state that accessory equipment that cannot be shut off need not be shut off. The commenters suggested that the compliance test procedure prohibit the use of any results which include sound from any vehicle systems other than those which would be constantly engaged under the specified performance conditions.

Agency Response to Comments

NHTSA's goal during compliance testing is to measure the sound produced by the vehicle when it is in its quietest state after sale to the general public. It is not to test the vehicle in some artificially quiet state that will never be attained by the driving public. These comments are in accord with NHTSA's goal for compliance testing. The point made by commenters, that accessory equipment that cannot be shut off need not be shut off, is sensible, is in the spirit of what NHTSA is trying to accomplish, and clarifies a point not addressed previously. Therefore, in the final rule we are adding the phrase ''that can be shut down'' to the proposed regulatory text of section S6.6(c) in the NPRM that dealt with accessory equipment. The re-worded requirement is in Section S6.6(b) of the final rule regulatory text.

Vehicle Test Weight

In the NPRM, we proposed that, for sound measurement testing, the vehicle test weight will be the curb weight (as defined in 571.3) plus 125 kilograms. Equipment, driver, and ballast should be evenly distributed between the left and right side of the vehicle. The vehicle test weight should not exceed the GVWR or Gross Axle Weight Ratings (GAWRs) of the vehicle.

Commenters addressed three issues related to vehicle test weight: the need for the final rule to specify vehicle test weight, the need for a vehicle test weight tolerance, and what the specified vehicle test weight should be.

Both Alliance/Global and OICA commented that vehicle test weight has no effect on measured vehicle sounds. Honda commented that, since FMVSS No. 141 testing is being conducted at relatively low vehicle speeds (a maximum of 30 km/h), small changes in vehicle test weight would have a minimal effect on measured vehicle sounds. Alliance/Global and OICA both commented that, if the final rule does specify vehicle test weight, then, for practical reasons, a vehicle test weight tolerance should be specified. Alliance/Global and Honda both recommended using the vehicle test weight specified in SAE J2889–1 (manufacturer-defined unloaded weight + one person + measurement instruments).

Agency Response to Comments

NHTSA believes that a vehicle test weight specification is necessary. While we have not conducted research in this area, we believe it is reasonable to anticipate that if a large load (relative to the curb weight of the vehicle) is placed in a vehicle (say 1,000 pounds in a passenger car's trunk or 30,000 pounds on a heavy truck), there would likely be some change in the sound produced by the vehicle during testing. Therefore, we believe it is necessary to specify vehicle test weight in the final rule.

In specifying vehicle test weight in other rules, NHTSA has not provided a weight tolerance. Organizations performing a test should make reasonable efforts to comply with the test specifications exactly as written. Therefore, we are choosing not to do so here and FMVSS No. 141 will not contain a vehicle test weight tolerance.

Since NHTSA agrees with the commenters that the sound produced by a vehicle at the relatively low test speeds being used for FMVSS No. 141 testing is not sensitive to minor changes in vehicle loading, minor deviations in vehicle test weight from the exact values specified in the rule should not have any effect.

As to what the vehicle test weight specified in final rule should be, NHTSA wants to measure sounds produced by lightly loaded vehicles. We believe that, all else being equal, the tires of a heavily loaded vehicle will produce a louder sound than will the tires of that same vehicle when it is lightly loaded.

NHTSA has identified three possible alternatives for vehicle test weight in FMVSS No. 141. These are:

1. Retain the NPRM vehicle test weight specification. This does not seem to have any particular advantages and has multiple disadvantages. Some of the disadvantages are that this test vehicle weight specification does not match that contained in SAE J2889–1; this vehicle test weight specification is not used by other FMVSS; and this vehicle test weight specification imposes weight limits on NHTSA test drivers. To elaborate on the last point, since the proposed NPRM regulatory text would require the weight above vehicle curb weight to be evenly balanced from side-to-side, the test driver for NPRM-based compliance tests cannot weigh more than 62.5 kg (138 pounds). Since a 50th-percentile adult male weighs 76 kg (168 pounds), the use of this vehicle test weight specification could create difficulties in finding drivers to perform compliance testing.

2. Specify the SAE J2889–1 vehicle test weight specification for NHTSA tests. This was the method recommended by commenters. It would harmonize with SAE J2889–1, and it has the advantage that NHTSA could use any test drivers. It has two disadvantages. First, it would mean that the weight of the test vehicle will vary with the weight of the test driver (*i.e.,* the test weight is not a precisely specified number of pounds above the manufacturer-defined unloaded weight). This may not matter since we believe that the external sounds generated by a vehicle are relatively insensitive to vehicle weight. Second, this vehicle test weight specification is inconsistent with any other FMVSS. A given NHTSA test vehicle often is tested by NHTSA and by manufacturers to determine compliance with multiple 100-series FMVSS at one time, with compliance testing for one standard being performed right after that for another. Adopting the SAE J2889–1 vehicle test weight specification would require a test vehicle undergoing such a sequence of compliance tests to be reloaded before and after FMVSS No. 141 testing slightly increasing the costs of performing such testing.

3. Specify a vehicle test weight that is specified by other NHTSA FMVSS. These test weights are different depending on vehicle class and brake system type. For pedestrian alert sound testing, a fairly lightly loaded weight would be used, not the heavier loading specified in some FMVSS. The vehicle test weight specifications used by other FMVSS are as follows:

- FMVSS No. 105 is applicable to vehicles with hydraulic or electric service brake systems and a GVWR greater than 3,500 kg (7,716 pounds). FMVSS No. 105 defines Lightly Loaded Vehicle Weight (LLVW), for vehicles with a GVWR of 10,000 pounds or less, as equal to unloaded vehicle weight plus 400 pounds including driver and instrumentation. FMVSS No. 121 is applicable to vehicles with air brake systems. FMVSS No. 121 tests at a weight equal to unloaded vehicle weight plus 500 pounds including driver and instrumentation plus not more than an additional 1,000 pounds for a roll bar structure on the vehicle (if needed).
- FMVSS No. 135 is applicable to vehicles with a GVWR of 3,500 kg (7,716 pounds) or less. FMVSS No. 135 defines Lightly Loaded Vehicle Weight (LLVW) as equal to unloaded vehicle weight plus 180 kg (396 pounds) including driver and instrumentation.
- FMVSS No. 500 is applicable to low speed vehicles. FMVSS No. 500 defines the test weight as equal to unloaded vehicle weight plus 78 kg (170 pounds) including driver and instrumentation.

NHTSA does not believe that any one of these alternatives is better for safety than any other. As was previously stated, NHTSA thinks that the sound produced by a vehicle at the relatively low test speeds being used for FMVSS No. 141 testing is not sensitive to minor changes in vehicle loading. Therefore, NHTSA's goal in selecting a test vehicle weight specification is to choose one that will minimize the economic burden of performing compliance testing. We think that this alternative is best achieved through the selection of the third alternative listed above changing to the vehicle test weights specified by other NHTSA FMVSS. Vehicle test weights will therefore be specified by vehicle type and GVWR in the final rule.

Battery Charge During Testing

In the NPRM, NHTSA proposed that, for sound measurement testing, the vehicle's electric propulsion batteries, if any, be fully charged.

NHTSA received comments on this topic from Advocates, Alliance/Global, Honda, Navistar, and OICA. Advocates requested that NHTSA either establish a battery charging procedure or require that the vehicle be charged in accordance with the manufacturer's stated charging procedure as outlined in vehicle documentation to ensure that the ICE or other vehicle non-essential systems do not start during sound testing procedures. Alliance/Global and OICA recommended using the language from the charging procedure in SAE J2889–1. OICA stated that many hybrids cannot be charged by external charge devices and that by driving the vehicle a 100-percent charge level will nearly never be reached. Honda pointed out that controlling the battery condition of a hybrid vehicle to attain a specific level of charge can be difficult. Honda recommended testing with the propulsion battery at a normal (as is) condition and deleting this requirement as being unnecessary. Navistar recommended that batteries be charged to the manufacturer's recommended full state of charge.

Agency Response to Comments

NHTSA agrees with Advocates that the battery needs to be sufficiently charged during sound measurement testing so that the ICE or other vehicle non-essential systems do not automatically activate. Provided that this condition is met, the battery's state of charge during sound measurement testing should have no impact on the safety of the vehicle. NHTSA also agrees with commenters that precisely controlling the battery condition of a hybrid vehicle to attain a specific level of charge can be difficult. However, getting the battery's state of charge during testing high enough that the ICE or other vehicle non-essential systems do not automatically activate should be feasible.

Following review of the comments, NHTSA has decided to accept the OICA and Alliance/Global recommendations and use the SAE J2889–1 language for the battery charge specifications in paragraph 7.1.2.2. This will accomplish our two objectives of (1) having a battery's state of charge during testing be high enough that the ICE or other vehicle non-essential systems do not automatically activate, and (2) specifying a practicable, achievable, battery state of charge for testing.

Battery Thermal Management Systems

In the NPRM, NHTSA proposed that measurements that included sounds emitted by any component of a vehicle's propulsion battery thermal management system are not considered valid. In addition, when testing a hybrid vehicle with an ICE that runs intermittently, measurements that contain sounds emitted by the ICE would not be considered valid measurements.

NHTSA received comments on this topic from OICA and Alliance/Global. Commenters pointed out that the battery's thermal management system might always be running when the vehicle is performing the test scenarios. Therefore, they requested that NHTSA state that a battery thermal management system that would normally be operating during the specified test conditions need not be shut down. The commenters suggested that the compliance test procedure prohibit the use of any results which include sound from any vehicle systems other than those which would be constantly engaged under the specified performance conditions.

Agency Response to Comments

NHTSA's goal during compliance testing is to measure the sound produced by the vehicle when it is in its quietest state after sale to the general public. It is not to test the vehicle in some artificially quiet state that will never be attained by members of the driving public. These comments are in accord with NHTSA's goal for compliance testing. The commenters' statement, that a battery thermal management system that would normally be operating during the specified test conditions need not be shut down, is sensible and is consistent with what NHTSA is trying to accomplish. Clarifying this will address an important test factor that was not covered in the proposed version of the regulatory text. This factor is addressed in S7.1.2 and S7.3.2 of the regulatory text in this final rule. We have modified both of these subsections by adding appropriate wording to include systems which would be constantly engaged under the specified test performance conditions (backing, stationary, forward motion at specified speeds).

*K. Test Procedure*

**Indoor Testing**

In the NPRM, the agency tentatively concluded that outdoor acoustics testing was preferable to indoor testing in hemi-anechoic chambers. The agency explained that outdoor testing was more representative of real-world vehicle-to-pedestrian interactions, and that outdoor tests, especially pass-by tests, transmit to the pedestrian not just vehicle-generated sounds (*e.g.,* engine-powertrain and pedestrian alert system), but also sounds from the vehicle body's interaction with the atmosphere (wind noise) and road test surface (tire noise). These complete sound profiles are transmitted to the pedestrian over the ''outdoor ambient'' noise. Outdoor sounds also contain a Doppler shift when the vehicle is moving relative to the pedestrian.

Conversely, the NPRM also explained, when a vehicle is tested on an indoor dynamometer in a hemi-anechoic chamber, the body of the vehicle is static and does not produce aerodynamic noise. The agency said that it was unclear how representative the tire noise generated during rotation on the curved dynamometer test rollers is of actual tire-road noise. As explained, the vehicle approach and passing of the microphones could be simulated by phasing a row of microphones next to the vehicle, and interior tire noise could be digitally replaced with exterior tire noise recordings, however, the agency has not determined the fidelity of such methods.[146] The agency voiced its concern about both the availability of repeatable specifications for all aspects of indoor testing and the availability of hemi-anechoic chambers in which to conduct compliance testing.

The NPRM mentioned the agency's belief that specifications for outdoor testing have a more detailed history of objective and repeatable performance than specifications for indoor testing. The agency noted that a substantial amount of development and refinement has gone into the test procedures and facilities used for outdoor vehicle noise testing.

The NPRM explained that SAE J2889–1 contains specifications on the cut-off frequency of the indoor hemi-anechoic test facility and requirements. However, the agency stated that it was not aware of specifications for dynamometer drum surface textures, materials, diameters, road loads coefficients (*i.e.,* to produce

[146] *see https://www.bksv.com/en/products/PULSE-analysis-software/acoustic-application-software/pass-by-noise-testing/indoor-testing-7793* (weblink last accessed 2November2016).

appropriate engine RPMs), etc. to allow comparable results between different indoor dynamometers.

Lastly, the NPRM explained that there are some advantages to testing indoors. Testing in an indoor hemi-anechoic chamber would not be influenced by weather conditions or high ambient noise levels that can affect outdoor testing. Indoor testing could be more predictable and time efficient than outdoor pass-by testing because testing time would not be limited by weather and noise conditions at the test site. The agency sought comment on the availability of hemi-anechoic facilities that could accommodate indoor pass-by testing and the desirability of including a test procedure for indoor pass-by testing in this standard.

Auto manufacturers and groups that represent them, along with SAE, stated in their comments that the agency should allow indoor testing in the compliance test procedure. According to Alliance/Global, OEMs would prefer and support the use of indoor measurement facilities meeting specifications contained in SAE J2889–1and ISO 16254. Alliance/Global [147] explained that in consideration of the practicability and repeatability of the required tests, they believe that the test conditions specified in the final rule should allow both the outdoor testing and indoor hemi-anechoic testing which are specified in SAE J2889–1. The Alliance/Global mentioned that some of its members have indoor hemi-anechoic chambers for pass-by testing and some do not, but all can gain access to them.

Honda stated it is necessary to include indoor test procedures in the final rule and requested the agency allow use of an anechoic chamber as an option for system testing. Honda stated that this option will be more practical for automakers and can yield more consistent and repeatable results without compromising the quality of the sound measurements. Honda explained that indoor chamber tests are necessary not only for pass-by tests, but for stationary vehicle tests using an artificial speed signal and component-based pitch shifting tests.

OICA stated that indoor test facilities meeting the specifications in SAE J–2889–1 are an acceptable alternative to outdoor testing. According to OICA, hemi-anechoic test facilities are widely available for testing and should be allowed but not required. OICA mentioned that some specifications for the facilities will be needed but did not elaborate further.

[147] NHTSA–2011–0148–0251.

SAE explained that to achieve the goals of practical, repeatable, and reproducible test results, the use of indoor and component level test facilities are necessary. Furthermore, SAE stated that for measuring the acoustic one-third octaves at any speed greater than zero, the use of indoor facilities will be necessary to reduce measurement uncertainty.

Agency Response to Comments

In this final rule, the agency is specifying performance requirements for vehicle-emitted sounds that are detectable and recognizable to a pedestrian as a motor vehicle in operation. All components of the vehicles' sound profile that convey the signature of a motor vehicle in operation (including aerodynamic and tire noise) up to the crossover speed are important facets of the vehicle's sound performance. Upon consideration of the above comments, and as explained further below, the agency has decided to only specify requirements for outdoor testing as proposed in the NPRM. Vehicle manufacturers may choose to test their vehicles indoors but the final rule has not added that option to the regulatory text.

As previously mentioned, the agency believes that outdoor testing is more representative of real-world vehicle-to-pedestrian interactions, and that outdoor tests, especially pass-by tests, reproduce not just vehicle sounds that are internally generated (*e.g.,* engine-powertrain and pedestrian alert system), but also sounds from the vehicle body's interaction with the atmosphere (wind noise) and road test surface (tire noise). When a vehicle is tested on an indoor dynamometer in a hemi-anechoic chamber, the body of the vehicle is static and does not produce aerodynamic noise. Additionally, the agency does not know how representative the tire noise generated during rotation on the curved dynamometer test rollers is of actual tire-road noise.

To date, the agency has had limited experience and access to testing for and measuring acoustic sound levels on dynamometers in hemi-anechoic test chambers. As we stated in the NPRM, the test setup and test execution procedures for outdoor testing have long been established.[148] As mentioned previously, a substantial amount of development and refinement has gone into the test procedures and facilities used for outdoor vehicle noise testing. Establishment of corresponding indoor procedures to be used in hemi-anechoic chambers on dynamometers requires further development and validation. SAE J2889–1 contains specifications for indoor testing but does not appear to provide the specifications for dynamometer drum surface textures, materials, diameters, road loads coefficients (*i.e.,* to produce appropriate engine RPMs), etc. to allow comparable results between different indoor dynamometers and outdoor ISO 10844 noise pads.

[148] 78 FR 2836 (Jan. 14, 2013).

The agency continues to be concerned that hemi-anechoic chambers that have four-wheel dynamometer drive capabilities are not widely available for commercial testing. The agency was able to locate a large number of outdoor 10844 noise pads in the United States, most of which were available for paid use by outside parties. As mentioned in the NPRM, one vehicle manufacturer stated that it has nine noise pads throughout its global operations and we believe the standardized outdoor noise pads have widespread commercial availability.

While indoor testing is appealing because it eliminates inclement weather and seasonal downtimes, which may provide more flexibility for manufacturers, we believe this is outweighed by the fact that outdoor testing will provide a more representative real-world condition including realistic interaction of the vehicle and vehicle alert system with the outdoor environment. The NHTSA acoustic measurement procedures incorporate strategies such as the rejection of test runs having extraneous background noise to ensure that interaction with the outdoor environment does not affect test results.

Several of the commenters explained that we should allow indoor testing as specified in SAE J2889–1. In addition to conducting indoor testing in a hemi-anechoic chamber using a dynamometer to simulate vehicle motion, it is possible to conduct pass-by testing in an indoor hemi-anechoic chamber, provided sufficient space is available to allow testing of all test conditions. SAE J2889–1 seems to allow for both methods of indoor testing. Full vehicle indoor pass-by testing in a hemi-anechoic chamber without a dynamometer (*i.e.,* an indoor track) would capture elements of the vehicle sound profile (including aerodynamic and tire noise) that contribute to the detectability of the vehicle's sound signature until the vehicle reaches the crossover speed. Therefore, indoor pass-by testing in a hemi-anechoic chamber is able to record all aspects of the vehicle's sound profile while still achieving the convenience and efficiency advantages of indoor testing. In this case, an indoor pass-by procedure, without a dynamometer, would be the same as the outdoor pass-by procedure contained in Section 7.1.5.4 of SAE J2889–1 DEC 2014 except that the 50-meter radius free of reflecting objects around the test track would not apply. The provision in SAE J2889–1 DEC 2014 that the hemi-anechoic chamber used for indoor pass-by testing comply with ISO 3745 or ISO 26101 would ensure that reflection from the test enclosure would not interfere with the vehicle's sound measurement.

The Alliance/Global [149] mentioned that some OEMs have indoor facilities large enough to execute full vehicle pass-by tests at required test speeds but did not provide corresponding details. The agency is not aware of the availability of hemi-anechoic chambers that are large enough to accommodate indoor pass-by tests and continues to believe that the existence of such facilities is limited, which would be an issue if NHTSA favored this approach as an option and wanted to conduct its own compliance testing in such an environment.

SAE stated that when measuring the acoustic one-third octaves at any speed in excess of zero, the use of indoor facilities is necessary to reduce measurement uncertainty. SAE also explained that to achieve the goals of practical, repeatable, and reproducible test results, the use of indoor and component level test facilities are necessary. NHTSA has issued a technical report presenting an analysis of its indoor test data for hybrid and electric vehicles.[150] This report includes the analysis of acoustic measurements in hemi-anechoic chambers equipped with chassis dynamometers. The analysis includes data for electric, hybrid, and internal combustion engine vehicles and examines ambient noise, repeatability and reproducibility of vehicle acoustic signals (measurements). The analysis includes a limited comparison of indoor and outdoor test data provided by Transport Canada and NHTSA in conjunction with Transportation Research Center (TRC).

Test results between two indoor test sites (General Motors Milford Proving Grounds (MPG) and International Automotive Components (IAC)) and one outdoor test site (TRC) were compared. Repeatability, as measured by standard errors for each indoor site was good. The estimated mean value was found to be within 0.5 to 0.75 dB of the true mean with 95% confidence depending on the one-third octave band being analyzed. Reproducibility of estimated means between the two indoor tests sites was about 2 dB on average; however, individual measurements had significant variation resulting in a 95% confidence interval range of +/−2.5 dB to +/−6.7 dB depending on the one-third octave band.

In addition to comparing the two indoor test facilities to one another, both facilities were also compared with outdoor measurements made at TRC. Measurement reproducibility between each indoor test facility and TRC was evaluated by comparing the average values of each vehicle at each one-third octave band for each speed at the respective sites. Results indicate that the indoor facilities tend to have higher acoustic sound levels, especially at 20 and 30 km/h. Because the differences are smaller at 10 km/h, it is not likely that the differences in acoustic reflections from the indoor floor and the outdoor pavement are causing the difference. Rather, it is likely that the tire/dynamometer interaction is producing the higher sound pressure levels. We believe that these results show that it may be necessary to conduct further studies about the tire/dynamometer interaction before any level of confidence can be established with the procedures utilizing a dynamometer. Because our research shows that the tire/dynamometer interaction could influence the repeatability of the test and because there are no specifications for dynamometer drums or other aspects of indoor testing that would increase repeatability, we believe that the procedures for indoor testing are not currently sufficient to be used by the agency for compliance testing.

Considering confidence intervals of estimated mean values for individual vehicle/speed/frequency pairs, the standard deviation between TRC and MPG was as high as 5 dB and the standard deviation between TRC and IAC was as high as 4.7 dB. Thus 95% confidence intervals would be as large as +/−9.8 and +/−9.2 dB respectively. It is important to keep in mind that these confidence intervals included not only site-to-site differences, tire/dynamometer differences, and differences as a result of using different vehicles and in some cases different model years, therefore, these confidence intervals can be considered a worst case. It is expected that confidence intervals for the same vehicles would be smaller.

In response to the SAE comment, we note the limited data available seem to demonstrate that there is measurement variability inherent in the procedures utilized indoors and outdoors. For the one-third octave bands, higher levels of variability were noted between several indoor facilities and between indoor and outdoor facilities. The variability noted may be associated with different dynamometers used and the fact that the comparison vehicles were not in all cases the exact same vehicles. The agency believes that further research and specification refinements are required to establish and properly validate indoor testing utilizing dynamometers. Further discussion on test repeatability and reproducibility is provided in Section III.K of this document.

In conclusion, after considering recent agency research and the comments received on the NPRM, the agency continues to believe outdoor testing on an ISO test pad is preferable to indoor testing in hemi-anechoic chambers with dynamometers. Section S7 of the final rule specifies the test procedures for outdoor testing.

We again note that vehicle manufacturers' testing can deviate from the procedures in an FMVSS, which communicate the method the agency will use to determine whether a vehicle complies with the requirements of that standard. Vehicle manufacturers may choose to test their vehicles indoors for the purpose of demonstrating compliance with the standard, but the final rule has not added that option to the regulatory text. The agency believes that further developments, refinements and validation are required before the indoor hemi-anechoic chambers equipped with chassis dynamometers can be specified by the agency. If further developments, data and information become available in the future the agency may decide at that time to revisit the possibility of adding the indoor testing option.

Test Surface for Compliance Testing

In the NPRM, NHTSA proposed that the test surface used during compliance testing meet the requirements of ISO 10844:2011.

NHTSA received comments on this topic from OICA, Alliance/Global, and EMA. OICA and Alliance/Global recommended that NHTSA allow compliance testing on a test surface meeting the requirements of either ISO 10844:2011 or ISO 10844:1994. They supported this recommendation by stating that they believe that surfaces meeting the requirements of ISO 10844:1994 and ISO 10844:2011 are technically equivalent.

[149] NHTSA–2011–0148–0251.

[150] See Hastings et al. ''Analysis of Indoor Test Data for Hybrid and Electric Vehicles.'' (2015) U.S. Dept. of Transportation, Washington, DC.

Agency Response to Comments

NHTSA agrees with OICA and Alliance/Global that surfaces meeting the requirements of ISO 10844:1994 and ISO 10844:2011 seem to be technically equivalent. Our understanding is that the major impetus for the 2011 update of the ISO 10844 standard was to incorporate laser profilometry technology that has recently become available which allows more precise measurements of the porosity of the surface. NHTSA's understanding is that the majority of surfaces that are within the 1994 standard should pass the 2011 standard without change. We know that this was the case for the Transportation Research Center, Inc.'s (TRC's) ISO sound pad that has been used for much of NHTSA's testing. Prior to NHTSA's testing, TRC's ISO sound pad was certified under ISO 10844:1994. At NHTSA's request, TRC recertified their sound pad under ISO 10844:2011; this required certification testing but no structural changes to the sound pad.

Thus a 1994 certified sound pad is likely to generate a sound profile equivalent to that generated on a 2011 certified surface. During the NHTSA's 2011 testing, a Ford Fusion vehicle was tested on both ISO 10844–1994 and ISO 10844–2011 surfaces and no significant difference in sound profile levels were found.

For light vehicle sound measurement, NHTSA has had no difficulties in finding sound pads certified to ISO 10844–2011 for its testing.

NHTSA prefers to harmonize FMVSS No. 141 with SAE J2889–1 absent rationale for departing from that standard. The updated version of SAE J2889–1 that was released in December 2014 specifies performing outdoor sound testing on a surface that meets the requirements of ISO 10844:1994, ISO 10844:2011, or ISO 10844:2014. Since NHTSA believes these three surfaces to be technically equivalent, we are expanding the list of test surfaces specified for FMVSS No. 141 compliance testing to include those certified to any of the above three versions of ISO 10844.

Based on the preceding discussion, all types of vehicles to which this rule applies will be tested on surfaces that meet either ISO 10844:1994, ISO 10844:2011, or ISO 10844:2014 specifications.

Vehicle Start-Up/Activation

The NPRM proposed in Section S5.1.1 that a vehicle must emit sound meeting the specifications for the stationary-but-active operating condition ''within 500 milliseconds of activation of the vehicle's starting system.'' The NPRM test procedure to measure compliance with the proposed stationary-but-active condition included a separate microphone two meters in front of the vehicle on the vehicle centerline.[151] We stated in the NPRM that this other microphone is needed in addition to the two specified in SAE J2889–1 to measure the sound that a pedestrian standing directly in front of a vehicle would hear. We wanted to ensure that there was no drop off in sound level from the side of the vehicle where the measurement is taken to the front of the vehicle, where the sound would be beneficial in warning pedestrians standing in front of the vehicle of its presence.

There were a number of comments on the proposed stationary-but-active requirement, focusing on two aspects of the regulatory language: (1) The start-up delay of 500 milliseconds for the alert to begin, and (2) the meaning of ''activation of the vehicle's starting system'' for HVs and EVs.

We note here that these two issues are directly related to the sound-at-stationary requirement which is discussed in Section III.C, ''Critical Operating Scenarios,'' in today's final rule. Many of the NPRM comments addressed start-up delay and definition of 'activation' to the extent that they opposed any requirement for an alert sound in the ''Stationary-but-Active'' operating condition. Because comments on the ''Stationary-but-Active'' operating condition were summarized in that previous section of this final rule, and we wish to avoid duplication, we are not repeating all of those comments here. Rather, we focus here on aspects of the Stationary-but-Active comments that directly relate to Start-up, the definition of Activation, and the associated measurement procedure.

Commenters, mainly OEMs, said that 500 milliseconds is too rapid to emit sound in a controlled fashion, and that it is technically unfeasible to achieve the one-third octave band levels in that short an interval.

Advocates stated that NHTSA should provide data to support the requirement that the alert sound must initiate and meet the acoustic specifications within 500 milliseconds of activation to justify that this is an appropriate amount of time to warn pedestrians. Advocates also suggested the agency should investigate the delay times of typical vehicles, *i.e.,* the delay between when a vehicle is started and when it is able to begin moving. NHTSA's analysis to support the 500 milliseconds requirement also should consider whether a lower sound level is appropriate for the parked condition.

Honda stated that NHTSA should clarify the definition and the measurement procedure of ''after the vehicle's starting system is engaged'' in the NPRM. If the definition of ''activation is the instant when the driver operates the vehicle's starting system, then it may be possible to engage the alert sound within 500 milliseconds. However, it may be difficult to consistently achieve the specified one-third octave levels in each of the eight bands as specified by NHTSA in the proposed rule.

Mitsubishi stated that the alert sound should start when a vehicle is shifted out of Park, and the 500 milliseconds interval should start at that point. Mitsubishi stated that it would be technically impracticable to meet the 500 milliseconds requirement from the moment a driver first activates the propulsion system. Mitsubishi also pointed out the need for NHTSA to define ''activation of the vehicle's starting system.''

Denso commented that 500 milliseconds is not enough time to initiate the alert sound, and that only individual vehicle manufacturers can determine how much of a delay is necessary for a given vehicle. Denso also said that the safety risk to pedestrians can be avoided if the alert sound is emitted beginning at the moment that a vehicle commences motion. In that regard, Denso suggested introducing minimum SPL requirements for a vehicle commencing-motion sound in place of the minimum SPL requirements for a vehicle at ''start-up and stationary but activated.''

WMU stated that 500 milliseconds should provide enough time from a safety standpoint because, in most cases, a driver does not initiate movement for several seconds after first starting up a vehicle. This would give any nearby pedestrian several seconds of acoustic warning.

We also received comments from Alliance/Global stating that, for testing in the stationary condition, we should amend the test procedure to eliminate the additional measurement at a point two meters in front of the vehicle on the vehicle centerline since that would have applied only to the stationary test which they were in favor of excluding from the final rule.

A number of commenters challenged the proposed requirement on the basis that 500 milliseconds is too short an interval for an alert system to become active upon vehicle start-up because

[151] The vehicle centerline is referred to as the CC' line in the test setup diagram in J2889–1.

vehicle manufacturers cannot ensure that an alert system is fully engaged and operating at the required sound level in such a short amount of time. Commenters stated that one reason for this is speaker transients, *i.e.,* once sound production begins it takes a while for it to stabilize. Therefore, while a vehicle's alert system may be capable of emitting some level of sound within 500 milliseconds, it may not achieve the specified sound pressure levels in each one-third octave band until a considerably longer time has elapsed after start-up.

Commenters also questioned how NHTSA intends to measure the lag time between starting system activation and the initiation of the alert sound. OEMs and industry groups commented that the NPRM did not define what ''activation of a vehicle's starting system'' means exactly. Without an exact definition, any attempt to measure the lag time would be subject to arbitrary selection of a starting point which could result in inconsistent measurements.

Agency Response to Comments

As a consequence of our decision discussed in Section III.C of this final rule to require sound at stationary only when a vehicle's gear selector is not in ''Park,'' and also due to the fact that vehicles are designed so that they must be in ''Park'' in order to be started, the proposed requirement for an alert to initiate within 500 milliseconds of vehicle activation is no longer applicable. Therefore, that proposed requirement is not included in this final rule.

In addition, our decision on sound-at-stationary obviates the need for NHTSA to define the term ''activation of the vehicle's starting system'' as it appeared in the proposed S5.1.1 regulatory text. Because alert system engagement will not depend on when a vehicle is started, no definition of ''activation'' is necessary.

We note that this decision does not mean that vehicles would have to be in motion before they are required to emit an alert sound. Vehicles that are not moving must emit an alert sound unless they are in a condition typical of a vehicle that may remain parked for some time. Vehicles that are stationary still would have to emit sound if they are, for example, waiting at a red traffic light (assuming the drivers do not shift to Park, in the case of automatic transmission vehicle, or apply the parking brake in the case of manual transmission vehicles). This means that vehicles that are in Park with an activated ignition and which are not in traffic, and which therefore are unable to drive off until they are put into gear, would not have to emit sound. For example, vehicles that are parked but idling so that occupants can use the heat or air-conditioning would not have to emit sound. We recognize that this will distinguish EVs/HVs from ICE vehicles since the latter emit sound whenever their engines are running, even in Park (although this may not be the case for ICE vehicles with stop-start capability.) On the other hand, an ICE vehicle could be parked with its ignition in the 'ON' position but with its engine not running.

We have decided to maintain the use of the additional front-center microphone for determining compliance with the stationary-but-active requirement. We believe this is important to ensure that pedestrians standing or passing in front of EVs and HVs are able to detect them. If the agency did not ensure that sounds produced by EVs and HVs met the minimum sound requirements in today's final rule two meters in front of the vehicle it would be possible that a pedestrian standing in front of an EV or HV would not be able to hear it within the vehicle's safe detection distance.

Vehicle Speed During Compliance Testing

In the NPRM, NHTSA proposed that the instrumentation used to measure vehicle speed during compliance testing be capable of continuous speed measurement over the entire zone from the 'AA' Line to the 'BB' Line with an accuracy of ±1.0 km/h.

NHTSA's proposal also set a speed tolerance for valid test runs. For a test run to be valid, the vehicle speed must be within ±1.0 km/h of the target speed for that run as the vehicle travels through the measurement zone from the AA' Line to the PP' Line.

NHTSA received comments on the instrumentation used to measure vehicle speed during compliance testing from Honda and Alliance/Global. Commenters requested that NHTSA allow independent,[152] as well as continuous, speed measurement during compliance testing. Honda requested that the accuracy specification for speed measurement equipment match that contained in SAE J2889–1 (± 0.5 km/h for continuous speed measurement devices or ± 0.2 km/h for independent speed measurement instrumentation). Alliance/Global also requested that the accuracy specification for independent speed measurement equipment match that contained in SAE J2889–1.

NHTSA received comments on the speed tolerance for valid test runs while the vehicle is traveling forward from Alliance/Global. They recommended changing the speed tolerance to −0.0/+2.0 km/h. Their justification for recommending this is to correct the inconsistency between the standard's performance requirement and compliance test procedure while still maintaining an overall tolerance of 2.0 km/h.

Agency Response to Comments

NHTSA wants to harmonize FMVSS No. 141 with SAE J2889–1 when feasible and consistent with the agency's focus on safety. For the instrumentation used to measure vehicle speed during compliance testing, we see no reason not to harmonize with SAE J2889–1.

Allowing independent speed measurement will not affect compliance test severity (or the safety benefits provided by this standard) because the 10 meters between the AA' Line and the PP' Line is not enough distance to permit the vehicle to vary more than minimally from the target speed.

In the most recent versions of SAE J2889–1, the accuracy specification for the continuous speed measurement instrumentation (±0.5 km/h) is tighter than the earlier SAE J2889 (Sept 2011) version and the NHTSA's proposal of ±1.0 km/h. The SAE J2889–1 continuous speed measurement accuracy specification is known to be both feasible and practical since NHTSA's commercially-purchased sound measurement equipment package includes speed measurement instrumentation with an accuracy specification of ±0.1 km/h. The SAE J2889–1 independent speed measurement accuracy specification (±0.2 km/h) is tighter than the SAE J2889–1 continuous speed measurement accuracy specification. While NHTSA does not have first-hand knowledge of independent speed measurement, we believe that the SAE J2889–1 accuracy specification should be both feasible and practical. Therefore, NHTSA accepts Honda's recommendation and will make the FMVSS No. 141 speed measurement instrumentation accuracy specification identical to that contained in the most recent version of SAE J2889–1.

Alliance/Global made a good point regarding the speed tolerance for valid test runs while the vehicle is traveling

[152] SAE J2889–1 defines independent speed measurement as being when two or more separate devices are used to measure the vehicle's speed as it crosses the AA', BB', and PP' Lines. In comparison, continuous speed measurement uses one device to measure the vehicle's speed as it travels through the entire zone from the AA'' Line to the BB' Line.

forward. NHTSA's proposal required the vehicle to emit sounds having a specified level that varied with the speed of the vehicle. The required level varied in a stepwise manner with the steps occurring at multiples of 10 km/h, *i.e.,* at 10, 20, and 30 km/h. In other words, NHTSA proposed that the vehicle emit sound with one sound pressure level at, for example, 9.9 km/h and with a different sound pressure level at 10.0 km/h. NHTSA also proposed that compliance testing be performed at multiples of 10 km/h, *i.e.,* at 10, 20, and 30 km/h. The problem is that, when testing at, for example, 10 km/h, due to the ±1.0 km/h speed tolerance, valid tests could be performed at any speed from 9.0 through 11.0 km/h, inclusive. Therefore, a test performed at 9.9 km/h would be a valid test as would a test performed at 10 km/h. However, as previously discussed, these two tests would have different required sound pressure levels.

The Alliance/Global suggestion would avoid this problem by changing the speed tolerance to −0/+2 km/h. This would mean that a valid 10 km/h test would have to have a speed in the range from 10.0 to 12.0 km/h, inclusive. Alternatively, the proposed 10 km/h pass-by compliance test would become an 11 km/h pass-by test with a ±1.0 km/h speed tolerance.

The Alliance/Global suggestion is a departure from SAE J2889–1 (which has a 10 km/h pass-by test with a ±1.0 km/h speed tolerance). However, this idea allows NHTSA to vary the required level of the sounds emitted by the vehicle in a stepwise manner with the steps occurring at multiples of 10 km/h, *i.e.,* at 10, 20, and 30 km/h. Adopting this suggestion will have only a very minor effect on the severity of FMVSS No. 141 compliance tests making them a little easier to pass since each test will now, on the average, be performed at a 1.0 km/h faster speed. Therefore, tires, aerodynamics, etc., will contribute slightly more sound thereby reducing the sound that needs to be generated by the vehicle's external sound generation system. However, the differences in sounds due to this 1.0 km/h speed up are expected to be minor.

Considering all of the preceding discussion, NHTSA has decided to adopt the Alliance/Global suggestion and change the compliance test speed tolerance to −0/+2 km/h. NHTSA will make this revised tolerance applicable to all three moving vehicle compliance tests, including the 10, 20, and 30km/h pass-by tests.

Repeatability/Reproducibility

NHTSA is addressing measurement variability in the final rule as a result of comments that were received on the NPRM, coupled with additional testing and analysis conducted by the agency which indicate that measurement repeatability and reproducibility (the latter across test facilities), may impact compliance testing results if not properly accounted for. The NPRM discussed how the agency would attempt to minimize test variability. However, adequate treatment was not given to the potential effect measurement tolerance may have on compliance testing.

A critical component of every Federal motor vehicle safety standard is a compliance test procedure that is objective, repeatable and reproducible. The test procedure must be objective such that differing parties, including OEMs and test laboratories will interpret and execute the procedures the same way. The test procedure must be repeatable and reproducible such that the results obtained are the same results from test-to-test at the same test facility and across different test facilities.

In the NPRM, the agency discussed its approach for minimizing test variability. The test procedure specified in the NPRM requires that all tests be conducted on a track with a surface that meets the requirements of ISO 10844:2011 which specifies, among other things, a very particular type of pavement to be used so as to minimize the contribution of tire noise to the sound measured. As mentioned in the NPRM, using a specified test track surface would minimize test variability.

The NPRM also contained provisions for specific environmental conditions (temperature and wind specifications), vehicle conditions (tire set-up and conditioning, door and window opening adjustments, vehicle accessory settings and vehicle loading), and track/instrumentation layout restrictions. These provisions are also important for minimizing test variability. The NPRM explained that the instruments used to make the acoustical measurements required under our proposal must meet the requirements of paragraph 5.1 of SAE J2889–1. This SAE paragraph describes procedures for calibration of the acoustical equipment. Use of such instruments and calibration procedures will ensure that test measurements can be duplicated repeatedly on the same vehicle at one facility, or at different test facilities.

In the NPRM, the agency addressed the issue of intermittent vehicle sound caused by the vehicle's battery cooling fan by requiring that any vehicle sound measurements taken while the cooling fan is operating be discarded. At the time, the agency believed that this helped address repeatability issues caused by battery cooling fans. The NPRM required that for all operating conditions, four consecutive valid measurements be within 2 dB(A). As explained, this repetition and decibel level restriction would ensure repeatability of vehicle sounds without the presence of unwanted ambient spikes, other non-vehicle sounds, or intermittent sounds the vehicle may happen to make that are not associated with its normal operating sound.

The agency received individual comments from Honda, Alliance/Global, Toyota, SAE, Nissan, and Denso. These comments generally fell into two categories: The expected variance in recorded measurements in terms of size and sources of variability; and the consequences of manufacturers taking steps to address repeatability in compliance testing.

Honda offered two comments regarding measurement variability. The first dealt with outdoor testing stating ''The Notice of Proposed Rulemaking (NPRM) requires testing of the one-third octave requirement at an outdoor site, but we are concerned that this poses practical concerns due to the low repeatability of test results which will be influenced by the presence of background noise.'' Honda also explained that it believes the ''like vehicle requirements'' are too stringent, and practically cannot be met due to the variability of sound producing devices. Honda provided an attachment with plots that indicate the differences in four tests by the same vehicle is more than 3dB.

Alliance/Global stated, ''The loudness in NHTSA's proposal is created by summing required broadband content in eight one-third octave bands when the sound in each band is already loud enough for detection purposes. The resultant sum is a sound that is, at a minimum, 6 dB louder than necessary. When a compliance margin (for repeatability and reproducibility) and production variation is added on, this proposed alert sound becomes 9–12 dB louder than necessary. The decibel sound scale is logarithmic, so this represents a doubling in the perceived sound levels.''

Alliance/Global further said that they were concerned that the run-to-run variability is greater than the levels proposed in the NPRM. They stated, ''Given the uncertainties noted by SAE for the measurement of one-third octaves proposed in the NPRM, we suggest that the tolerance should be increased to 9 dB. This applies to all measures of performance for compliance purposes.''

SAE discussed measurement uncertainties in its comments. SAE said that for the measurements of overall Sound Pressure Levels (SPL) the identified site-to-site variation at 80% confidence interval is ±1.4 dB. SAE said that the uncertainty for the measurements of one-third octave results ''has not yet been determined,'' but will be larger than the uncertainty for the overall SPL. According to SAE, for indoor measurements, the site-to-site variation of one-third octave levels at 95% confidence interval is expected to be in excess of ±2 dB. For outdoor measurements, the site-to-site variation at 95% confidence interval is expected to be in excess of ±6.0 dB. According to SAE, these estimated uncertainties should be considered when specifying tolerances for regulatory compliance. SAE also mentioned that any variation in sound output due to vehicle component production variability will be in addition to the measurements variation noted.

Denso commented on the variability of the speaker unit itself, stating ''There is inherent variability in vehicle sound characteristics and in speaker and amplifier characteristics and performance. When combining this variability, it is very difficult to limit the sound difference within 3 dB(A) between the two vehicles, even for vehicles having nominally identical sound systems.'' Denso also went on to comment that for a 40 degree rise in temperature (0 °C to 40 °C) the overall sound level would decrease by 1 dB. Nissan, similar to Denso, suggested in its comments that sound levels must be increased by the variation of speakers.

In general, comments received stated that the variability present in the vehicles sound measurement is higher than the agency accounted for in the NPRM, and that variability could be substantial even when using the measurement procedures set forth in SAE J2889–1. There was also concern expressed by the commenters that if manufacturers increase vehicle alert sound pressure levels above the minimum standards to ensure a reasonable compliance margin, the vehicle alert sound may become excessively loud.

Agency Response to Comments

Upon review and further consideration of the comments received it appears that the provisions for addressing variability included in the NPRM and discussed above are not sufficient to properly address all the test variability inherent in measuring vehicle acoustic alert sounds. To further address the issue of variability, the agency has decided to reduce the minimum standards required in this final rule by 4 dB in each one-third octave band as further discussed below. We expect sounds produced by EVs and HVs will exceed the minimum one-third octave band values in the final rule because manufacturers will design alert systems in order to ensure a margin of compliance. For this reason, we believe that vehicles complying with the final rule, the requirements of which have been reduced by 4 dB in each one-third octave band from the values provided by our revised detection model, will still emit alert sounds that are loud enough for pedestrians to safely detect EVs and HVs.

During its research, NHTSA conducted a series of tests to determine the actual level of variability in the one-third octave band measurements.[153] To do this, NHTSA analyzed data from a 2010 Ford Focus, combining over 100 individual test runs recorded at the 10 km/h test condition, including right and left side microphone recordings, that were measured at three facilities (71 test runs at Transportation Research Center in Marysville Ohio, 17 test runs at the Ford Motor Company Proving Ground in Romeo, Michigan, and 16 test runs at the Navistar test track in Fort Wayne, Indiana) over a period of 6 months. Test data were considered valid if there were no anomalies apparent in the sound recordings. The recorded files were analyzed using NHTSA's sound analysis code.

The data from the test runs were further processed using a bootstrap method [154] into three datasets, consisting of 10,000 [155] samples of eight randomly selected individual test runs, for each facility. These samples were then processed into the one-third octave bands utilizing the compliance procedure (the average of the first four valid test runs within 2 dB), generating 10,000 sets of the 13 one-third octave bands between 315 Hz and 5000 Hz. Analyzing the datasets for the individual test sites, the maximum 95% confidence interval for the individual one-third octave bands recorded on the TRC ISO sound pad was ±1.6 dB at 800 Hz and 1000 Hz. For the Ford MPG ISO test pad, the maximum value for the 95% CI of the individual one-third octave bands was ±2.0 dB at 315 Hz, and at the Navistar ISO pad it was ±1.2 dB at 400 Hz. Looking at all three sites, the overall effective maximum variation occurs in the 315 Hz one-third octave band with a 95% CI of ±2.5 dB. A summary of the results is in Table 18.

TABLE 18—COMPARISON OF MEAN AND 95% CONFIDENCE LIMIT FOR THE ONE-THIRD OCTAVE FREQUENCIES FOR THE THREE TEST SITES

| Frequency | TRC | | Ford MPG | | Navistar | | Overall effective 95% confidence limit |
|---|---|---|---|---|---|---|---|
| | Mean level recorded dB(A) | 95% Confidence limit | Mean level recorded dB(A) | 95% Confidence limit | Mean level recorded dB(A) | 95% Confidence limit | |
| 315 | 41.6 | 1.3 | 40.4 | 2.0 | 41.8 | 0.6 | 2.5 |
| 400 | 42.5 | 1.1 | 41.1 | 1.1 | 42.7 | 1.2 | 2.0 |
| 500 | 44.1 | 1.0 | 44.3 | 0.9 | 44.4 | 1.0 | 1.7 |

[153] NHTSA Technical Report '' Repeatability, Reproducibility, and Sameness of Quiet Vehicle Test Data'' (2016) Gerdus, E., Hoover, R.L., and Garrott, W.R.

[154] ''Bootstrap method'' is a statistical procedure wherein a data set consisting of a relatively small set of measurements is resampled many times over to obtain a much larger data set. This can improve statistical estimates and confidence intervals. For example, for the Ford Fusion tests on the TRC ISO sound pad at 10 km/h, NHTSA ran twelve test series, each consisting of eight runs, for a total of 96 runs. To improve our estimate of the variability in these 96 tests, we used a bootstrap method in which all of the 96 runs were consolidated into one set. Single runs then were drawn randomly from this set and the measurement values including one-third octave band levels were recorded. The run drawn was then returned to the set. This process was repeated thousands of times using the computational capability of a computer. For the Fusion data, 80,000 runs comprising 10,000 test series were drawn in this manner which made it easy to directly determine the 95% confidence interval for these vehicle tests. We used a similar procedure to evaluate vehicle measurements from the Navistar and Ford MPG test facilities, to make up three data sets (one from each of the three test facilities).

[155] The dataset size of 10,000 was selected to maximize the overall accuracy of the analysis while maintaining a reasonable total computation time.

TABLE 18—COMPARISON OF MEAN AND 95% CONFIDENCE LIMIT FOR THE ONE-THIRD OCTAVE FREQUENCIES FOR THE THREE TEST SITES—Continued

| Frequency | TRC | | Ford MPG | | Navistar | | Overall effective 95% confidence limit |
|---|---|---|---|---|---|---|---|
| | Mean level recorded dB(A) | 95% Confidence limit | Mean level recorded dB(A) | 95% Confidence limit | Mean level recorded dB(A) | 95% Confidence limit | |
| 630 | 46.1 | 1.2 | 45.6 | 1.6 | 46.5 | 0.8 | 2.2 |
| 800 | 48.4 | 1.6 | 50.4 | 1.3 | 48.3 | 1.1 | 2.3 |
| 1000 | 49.0 | 1.6 | 50.7 | 1.0 | 49.1 | 0.7 | 2.0 |
| 1250 | 48.8 | 1.4 | 50.1 | 1.1 | 48.9 | 0.6 | 1.9 |
| 1600 | 49.7 | 1.5 | 51.0 | 1.1 | 49.3 | 0.9 | 2.1 |
| 2000 | 48.6 | 1.5 | 48.7 | 1.0 | 48.0 | 0.5 | 1.9 |
| 2500 | 46.6 | 1.2 | 46.7 | 1.1 | 46.2 | 0.7 | 1.8 |
| 3150 | 45.2 | 1.2 | 45.1 | 1.0 | 44.9 | 0.9 | 1.8 |
| 4000 | 44.0 | 0.9 | 43.9 | 0.8 | 43.4 | 0.9 | 1.5 |
| 5000 | 41.9 | 0.8 | 42.0 | 1.2 | 41.5 | 0.8 | 1.6 |

Furthermore, NHTSA conducted research into the effects of speaker variability on one-third octave band repeatability using a limited sample of vehicles. Testing was performed on a group of four model-year 2014 Toyota Prius V vehicles under stationary conditions, in a hemi-anechoic chamber, with only the alert sound generator active to minimize potential variability from other sources. This testing found that when a single vehicle was tested in the chamber, run-to-run variability had a 95 CI of ±0.2 dB, operating with only the speaker active. Overall speaker variability consists of more than just the repeatability of any one individual speaker, as manufacturing tolerances will add variability when multiple speakers are tested. To estimate overall speaker variability, the agency analyzed the data across all four Prius vehicles tested. When all four vehicles were tested in the chamber, run-to-run variability increased to ±0.8 dB.[156]

Based upon the limited test data from this analysis, NHTSA estimates an overall test variability of ±3.3 dB, including both the effective test procedure variability (±2.5 dB) and the measured speaker variability (±0.8 dB). The commenters indicated that the true variability is unknown and recommended that a 3 to 9 dB increase is appropriate. To account for other, unknown sources of variability, the agency has decided to add an additional small tolerance to the variability identified during its research. Considering both the measured and the unknown variability, we have concluded that a tolerance of 4 dB adequately accounts for actual test variability.

[156] *See* NHTSA Technical Report '' Repeatability, Reproducibility, and Sameness of Quiet Vehicle Test Data'' (2016) Gerdus, E., Hoover, R.L., and Garrott, W.R.

NHTSA agrees with Alliance/Global, as well as the other commenters that manufacturers will take into account measurement variability when designing alert systems to ensure compliance with the specified performance requirements. It is possible that with this margin added, the alert sound would significantly exceed the minimum sound requirements. As such, NHTSA has decided in this final rule to reduce the minimum levels that were indicated by our detectability modeling effort. We are implementing a reduction of 4 dB in each one-third octave band for all test conditions to offset the margin of compliance that we acknowledge is needed to address test variability and that we believe OEMs will build into their alert systems. As discussed above, our repeatability analysis has shown that a 4 dB adjustment will be adequate for this purpose.

It must be made clear that the reduced minimum levels specified in this final rule, which include the 4-dB adjustment described above, are the absolute minimums allowed for safety purposes. Testing variability is not a justification for failing to meet these minimums which have been adjusted specifically to address concerns about test repeatability. The agency intends to pursue potential enforcement actions on measured levels below these minimum standards. The agency believes that by virtue of this 4-dB reduction in the level specified in each one-third octave band, manufacturers can build a reasonable margin of compliance into their alert systems while maintaining acceptable overall sound levels. We also believe this reduction, along with other changes in the final rule compared to the NPRM such as the reduction in the number of required one-third octave bands, further addresses concerns about customer acceptance, noise intrusion, and other concerns about the safety standard requiring alert sounds that are excessively loud.

Ambient Noise Correction

In the NPRM, NHTSA proposed that the ambient noise be measured for at least 30 seconds before and after a series of vehicle tests. A 10-second sample was then to be taken from these measurements and used to determine both the overall ambient noise SPL and the ambient noise level for each one-third octave band. The 10-second sample selected was to include ambient levels that were representative of the ambient levels that occurred during the actual vehicle measurement. As explained in the NPRM, it is important to know the background noise level during the test to get an accurate measurement of the sound made by the vehicle alone. Because NHTSA's proposed requirements were established using a one-third octave band basis, we stated that ambient corrections should also be calculated on a one-third octave band basis.

The NPRM explained that SAE J2889–1 contains a procedure for correcting vehicle measurements at the overall sound pressure level to account for ambient influence. In the NPRM, we also acknowledged that the variance of a signal is greater on a one-third octave band basis than at the overall level, and thus it may be difficult to apply the ambient correction procedure in SAE J2889–1 to one-third octave bands. The NPRM further stated that SAE J2889–1 requires a peak-to-peak variation of less than 2 dB in order to do a valid correction. We also pointed out that, even if the fluctuation of the overall sound pressure level of the ambient is less than 2 dB, the fluctuation in some individual one-third octave bands would likely be higher. To address this concern, we proposed a procedure that allowed one-third octave band correction within certain limits on both the peak-to-peak ambient fluctuation and the level difference between the vehicle measurement and the ambient. These criteria were provided in Table 6 in the regulatory text contained in the NPRM. They were chosen in order to provide a high degree of confidence that contamination due to an unobserved, random fluctuation would not impact the final reported level by more than about one half of one decibel. In the NPRM, we explained that increasing the acceptable peak-to-peak variability in the ambient correction procedure will allow for testing to be conducted in ambient sound environments in which the agency would expect to be able to make accurate measurements. NHTSA conveyed its position that this approach would increase flexibility in the locations and times when outdoor testing can be conducted without significantly compromising the accuracy of measurements. We sought comment on this topic.

NHTSA received comments on ambient noise correction from Alliance/Global, Honda, OICA and SAE. The comments from these organizations on this topic have been divided into three issues: Validity of applying ambient correction to one-third octave bands; a conflict in the correction procedure; and ambient measurement time interval.

All commenters stated that measured one-third octave band sound levels generated by the vehicle could not be corrected for ambient noise while maintaining adequate repeatability. As stated by Honda ''[t]he time-to-time variance of the one-third octave level of ambient noise is large and the ambient noise measurement and vehicle noise measurement are not simultaneous so that compensating by one-third octave level is not realistic for achieving repeatability.'' All four organizations therefore recommended only performing ambient noise correction for the measured overall SPL generated by the vehicle using the procedures contained in SAE J2889–1.

OICA questioned the proposed procedure to correct the measured one-third octave band sound levels generated by the vehicle for ambient noise. They pointed out that the proposed procedure contains a contradiction. It requires measurement of both the sounds generated by the test vehicle during a test and of the ambient noise at the same time and using the same equipment. The problem is that sound measurement during testing records both sounds generated by the vehicle (signal) and ambient noise. There is no objective method to disentangle the signal from the ambient noise in the recorded signal.

Finally, OICA questioned which 10 seconds should be analyzed out of each 30-second-long ambient noise measurement since NHTSA did not specify which 10 seconds.

Agency Response to Comments

NHTSA believes, based upon data collected and testing experience gained over the past several years, that measured one-third octave band sound levels generated by a vehicle can be corrected for ambient noise while maintaining adequate repeatability.

NHTSA conducted a substantial amount of vehicle sound measurement repeatability testing using a 2010 Ford Fusion (with an internal combustion engine) to develop this rule.[157] That testing included a large number of ambient noise measurements. Testing was performed on the ISO sound pad of the Transportation Research Center, Inc. in East Liberty, Ohio, and was analyzed to examine ambient noise variability. All of this testing was performed at night to minimize the ambient noise.

Analyses of NHTSA's measured ambient sound data found substantial variability. The overall ambient SPL varied over a 15.9 dB range from a low of 29.5 dB to a high of 45.4 dB. The ambient one-third octave band levels varied over a 24.4 dB range with a low of 13.6 dB and a high of 38.0 dB.[158] This ambient sound data was measured over a six month period from April to September of 2012.

NHTSA's calculations indicate that these large variations in ambient noise levels had only a minimal effect on the measured one-third octave band sound levels generated by the vehicle following ambient noise correction.

As per the procedure proposed in the NPRM, any sound generated by the vehicle at the one-third octave band level (and per SAE J2889–1 for the overall SPL) will not be corrected at all if it is more than 10 dB above the ambient noise level. NHTSA examined its vehicle sound measurement repeatability testing to see how frequently this situation occurred.

NHTSA analyzed MY2010 Ford Fusion sound data measurement repeatability for five scenarios: Stationary, reverse, 10 km/h pass-by test, 20 km/h pass-by test, and 30 km/h pass-by test. The vehicle was quietest during the stationary and reverse scenarios.

None of the Ford Fusion sound data collected during the 10 km/h pass-by test, 20 km/h pass-by test, or 30 km/h pass-by test were within 10 dB of ambient levels. Therefore, no ambient noise correction was performed for any of these tests at the overall SPL and one-third octave band level.

For the stationary scenario, 82.3 percent of tests were more than 10 dB above ambient noise levels and did not require correction. The remaining 17.7 percent of tests needed to have either the overall SPL or one or more measured one-third octave band levels corrected. However, none of these tests had measured signal levels that were less than 3 dB above ambient noise levels (the differential below which tests are considered invalid).

Electric or hybrid vehicles with an alert meeting the requirements of this rule may be quieter than is the 2010 Ford Fusion. This may result in more electric and hybrid vehicle sound tests not giving results that are 10 dB or more above ambient. Nevertheless, NHTSA believes that the effects of ambient level variability on vehicle sound measurement repeatability will be limited.

The purpose of ambient noise correction is to reduce variability in vehicle sound measurements due to variations in the ambient noise level. NHTSA uses the minimum ambient noise levels, collected before and after a test series, for ambient correction. By doing so, the ambient noise levels are expected to vary little with time during a test session. Distinct, transient loud sounds such as chirping birds, overhead planes, car doors being slammed, etc., will affect the maximum ambient noise levels but not the minimum ambient noise levels. The minimum ambient noise levels are expected to be primarily the result of more slowly varying environmental factors such as steady state wind speed, the test site geometry, and the foliage on nearby vegetation. Therefore, NHTSA believes that the minimum ambient noise levels used for correction will typically be similar before, during, and after a test series. The ambient noise correction is expected to eliminate the effects of this slowly varying ambient noise from the measured sound levels for a vehicle.

NHTSA also recognizes that distinct, louder events such as passing vehicles or wind gusts could, if they were to occur at certain times during a vehicle's operational sound measurement, increase both the measured vehicle sound and sound measurement variability. Therefore, NHTSA has

[157] Garrott, W.R., Hoover, R.L., Evans, L.R., Gerdus, E., and Harris, J.R., ''2012 Quieter Vehicle Testing Report: Measured Sound Levels for Electric, Hybrid Electric, and Low Speed Vehicles'' Washington DC, DOT/NHTSA, November 2016.

[158] Ibid.

added regulatory text in the final rule stating that measurements containing any distinct, transient, loud sounds (*e.g.,* chirping birds, overhead planes, passing trains, car doors being slammed, etc.) are considered invalid. Further discussion about determining the validity of vehicle measurements can be found in Section III.K.

In September 2014, the agency received a copy of the latest draft of ISO 16254, *Acoustics—Measurement of sound emitted by road vehicles,*[159] and in December 2014 SAE issued a revised version of SAE J2889–1.[160] Both standards are of interest to the agency because, unlike the May 2012 version of SAE J2889–1, they both attempt to address measurements at the one-third octave band level as well as overall SPL level. These standards appear to agree with the various comments, including the comments received from SAE, advising against ambient corrections at the one-third octave band level. Both standards specifically state, ''Background compensation is not permitted for one-third octave band measurements.'' Both standards also specify that when analyzing the one-third octave band measurements the level of background noise in each one-third octave band of interest shall be at least 6dB below the measurement of the vehicle under test in each respective one-third octave band. In effect, both standards state that the one-third octave bands cannot be corrected for ambient noise and that the only one-third octave bands useful for evaluation are those bands found to have at least a 6 dB difference between the vehicle measured value and the ambient measured value.

The NPRM proposed that no corrections are needed at the one-third octave band level when there is at least a 10 dB difference between the vehicle measured value and the ambient measured value. The ISO and SAE standards reduce this cut-off point for one-third octave band levels to a 6 dB difference. Based upon the earlier discussion of test data, our experience has been that very few ambient corrections are required at the 10 dB difference level. Even fewer would be required at the 6dB difference level, which has the potential to reduce the number of test runs needed for a vehicle compliance evaluation. We agree with the commenters that one-third octave bands are not viable if they are within 3 dB of the ambient, and thus it is not necessary to consider whether bands at that difference level should be corrected or not.

Accordingly, we have decided to revise the required difference between the vehicle and ambient at the one-third octave band level from 10dB as proposed in the NPRM to 6 dB, the same as in the draft ISO and revised SAE standards, as the threshold difference between when one-third octave bands should or should not be corrected for ambient conditions. Additionally, for the one-third octave bands having 3 dB to 6 dB separation between the vehicle and ambient measurements, the agency has decided to continue to correct as proposed in the NPRM. The draft ISO and SAE standards reject all the one-third octave bands with separation less than 6dB whereas now the agency's procedure considers them usable in an attempt to reduce possible test burden by rejecting fewer sound measurements. Finally, as proposed in the NPRM, any bands found to have a separation of less than 3 dB would be considered unusable. These revisions have been incorporated into the respective tables in the final rule.

Finally, based upon further consideration of the comments received, evaluation of the ambient data collected, and review of the latest ISO and SAE documents received, we have decided to make a few additional revisions to the ambient correction paragraph S6.7 in the final rule. These additional revisions to S6.7 are as follows:

- Ambient corrections may be required at the overall sound pressure level when considering which four valid test runs can be used for performance evaulation during each operating scenario. Ambient corrections at the one-third octave band level may also be required during the one-third octave band evaluations for each operating scenario. For clarification purposes Table 6 as proposed in the NPRM will be replaced with two new tables, Tables 6 and 7, one for overall SPL corrections and one for one-third octave band corrections when required. As in the NPRM, both of these tables are derived from Table 2 in SAE J2889–1.
- The first column in Table 2 of SAE J2889–1 and Table 6 in the NPRM differentiate between ambient noise levels greater than or less than 25 dB. We do not believe this differentiation is required. Table 2 in SAE J2889–1 applies to overall SPL correction. NHTSA understands that SAE J2889–1 included the 25 dB breakpoint to separate overall SPL correction because an ambient noise of less than 25 dB in an outdoor setting is extremely quiet and unlikely to occur. If such a low ambient did occur, then the overall vehicle SPL would require correction only if it was within 10 dB of the ambient noise, *i.e.,* if the overall SPL of the vehicle test was quieter than 35 dB. However, any vehicle that produces an overall SPL of less than 35 dB is very quiet and most likely would not comply with the requirements of this final rule or be heard by pedestrians. SAE J2889–1 states that in this situation, no overall SPL correction should be made. Instead, the technician conducting the test should report that the corrected overall SPL will be less than the measured signal overall SPL. NHTSA desires to correct both overall SPL and one-third octave band levels when necessary. Since overall SPL is the antilog of the logarithmic sum of all one-third octave band levels, the one-third octave band levels will, for any wide-band sound, be substantially lower than overall SPL. During NHTSA's outdoor testing, we have never seen an ambient overall SPL that is below 25 dB. However, we routinely have seen ambient one-third octave band levels below 25 dB, with some being as low as 14 dB. Furthermore, for some scenarios and one-third octave bands, NHTSA's minimum safety standard criteria are set at a level below 35 dB. NHTSA needs a robust correction procedure that is applicable when one-third octave band ambient levels are below 35 dB. If ambient is less than 25 dB in one or more one-third octave bands and the difference between ambient and vehicle measurements in those bands is less than 6 dB, we still need a way to make corrections. Therefore, NHTSA has decided to use the ambient noise correction procedure regardless of the level of ambient noise present. To accomplish this, we have removed the 25 dB limitation by deleting the first column and the last two rows from both tables.
- The second column in Table 6 of the NPRM and Table 2 of SAE J2889–1 sets peak-to-peak limits on the variability of measured ambient conditions relative to the corresponding differences measured between the vehicle alert sound profile and the measured ambient sound levels. According to the tables, the larger that difference, the larger the acceptable ambient peak-to-peak variation. OICA mentioned that the proposed procedure for ambient noise correction was confusing and contained a contradiction. According to OICA, the notes to NPRM Table 6 indicated that in some test scenarios the ambient noise levels must be measured at the same

[159] NHTSA–2011–0148–0334.

[160] In December 2014, SAE issued a revised SAE J2889–1. That version of J2889–1 contains the same proscription on background correction at the one-third octave band level as does ISO 16254.

time as the actual vehicle, *i.e.,* during the vehicle pass-by run, and using the same microphones. The NPRM did not state how this should be done. We have considered OICA's comment and agree that the notes in conjunction with the proposed Table 6 are confusing and contradictory. Ambient measurements during actual vehicle tests are not possible without subjective determination as to what sounds are ambient noise versus what are generated by the test vehicle. NHTSA does not intend to measure ambient and vehicle sounds at the same time through the same microphones. The purpose of column 2 is to ensure the validity and minimum variability of ambient sound files collected just prior to and after vehicle tests. The objective is to avoid ambient sound measurements that contain any distinct, transient, sounds (*e.g.,* chirping birds, overhead planes, car doors being slammed, etc.) for correcting vehicle sound files. We understand that column 2 is intended to provide a quantitative method for determining when distinct, transient, sounds are too loud and risk causing excessive variability in ambient sound measurements. Clearly, a high variability in ambient sound can have a compounding effect on vehicle sound pressure variability. Such variability could have a major impact on measurement repeatability. Due to ambient differences, test results from one day to another for the same vehicle might not be the same. To minimize the likelihood of ambient variability, the agency has decided, as originally proposed in the NPRM, to use the minimum ambient level instead of the maximum ambient level. Use of the minimum ambient was discussed in more detail previously in this section. Furthermore, variability of the ambient sounds measured during any vehicle test may also cause difficulties in capturing the true vehicle alert profile. To address OICA's issue we have deleted the entire second column and the associated notes from NPRM Table 6. We have also added regulatory text stating that measurements containing any distinct, transient, loud sounds (*e.g.,* chirping birds, overhead planes, car doors being slammed, etc.) are considered invalid.

- The entries in some cells in Column 4 of NPRM Table 6 and Table 2 of SAE J2889–1 are confusing. It is not clear what an entry of ''Do not correct, but report $OBL_{testcorr,j} < OBL_{test,j}$'' means in the context of a NHTSA compliance test. Since, as previously discussed, the last two rows of NPRM Table 6 have been deleted, the entry of ''Do not correct, but report $OBL_{testcorr,j} < OBL_{test,j}$'' appears in only one cell of the table. The row containing this cell will only be used when the separation between the measured vehicle sound (signal) and the ambient (either overall SPL or one-third octave band level as appropriate) is less than or equal to 3 dB. NHTSA believes that a signal- to-ambient difference of 3 dB or less is too small to ensure the ambient is not influencing the measurement. Therefore, test runs performed for which the overall measured SPL does not exceed the ambient measured SPL by more than 3.0 dB should be considered not valid and should not be used. For test runs for which the overall measured SPL exceeds the ambient measured SPL by more than 3.0 dB, it is possible that the measured sound level may not exceed the ambient sound level in one or more one-third octaves. When this happens, it is acceptable to use the data from the one-third octave bands for which the measured sound levels exceeded the ambient sound levels by more than 3.0 dB. However, the data for those particular one-third octave bands for which the measured sound level was too close to the ambient sound are considered not valid and cannot be used.

Appropriate modifications also have been made to paragraph S6.7 of the regulatory text, describing how to perform ambient noise corrections.

These decisions are clarifications and refinements that are needed for consistent compliance testing. Because they address practical issues that arise from application of the ambient correction procedures of the NPRM, which in turn are based as closely as possible on SAE J2889–1, we believe these changes are within the scope of the NPRM. In one case, we deleted a specification that doesn't apply to NHTSA testing and thus is not relevant for this final rule. Another change clears up confusion arising from a contradiction in the ambient correction table as it appeared in the NPRM. Another arises from the agency's decision to do ambient corrections at the one-third octave band level which the agency explicitly proposed in the NPRM (some commenters disagreed with that approach, and we have addressed those comments in this preamble.)

Overall, these technical changes are consistent with the SEA/ISO standard which the agency has referenced in the NPRM and which commenters urged NHTSA to adhere to. Furthermore, as we've noted, these refinements in the ambient correction procedure will have a very minimal impact on the outcomes of a small minority of tests, and they do not constitute any greater test stringency or an increase in the required sound levels over those proposed in the NPRM.

In response to OICA's question as to which 10 seconds should be analyzed out of each 30 seconds (or more), NHTSA has decided that the entire ambient noise measurement (including an interval of 30 seconds or more taken before a test series and another interval of 30 seconds or more taken after a test series) should be analyzed. Since ambient noise correction is based upon the minimum ambient noise collected before and after a test series, analyzing the entire period collected instead of two 10-second periods may result in a lower minimum ambient noise. Having a lower minimum ambient noise makes it less likely that ambient noise correction of the measured vehicle sound will be necessary. In the event that ambient noise correction is necessary, having a lower minimum ambient noise reduces the magnitude of the resulting correction resulting in a slightly easier compliance pass/fail criterion.

It is NHTSA's belief that making this change to the ambient noise correction procedures will have no effect on safety because NHTSA intends to perform compliance testing on ISO sound pads during times with as low an ambient noise as is reasonably achievable. This will minimize the need for ambient noise corrections during NHTSA compliance testing.

Conditions for Discarding Results

The NPRM discussed the agency's approach for measuring the sound produced by hybrid vehicles (HVs) without their associated internal combustion engines (ICEs) operating because of the need to measure the sound of those vehicles' in their quietest state. As explained, the proposal was designed to ensure that HVs and EVs emit a minimum level of sound in situations in which the vehicle is operating in electric mode because in that mode these vehicles do not provide sufficient sound cues for pedestrians. Therefore, we proposed to control the situation in which an ICE engine does start operating during a test by invalidating test measurements that are taken when a vehicle's ICE is operating. The proposed test procedure stated that when testing an HV with an ICE that runs intermittently, measurements that contain sounds emitted by the ICE are not considered valid.

The NPRM also discussed that tests occurring within the temperature range specified in SAE J2889–1 can produce divergent results when a vehicle is tested at different temperatures. In high ambient temperatures, the battery cooling fan, part of the thermal management system on electric vehicles, can activate intermittently while the vehicle is operating. As discussed, the agency decided to address the issue of intermittent vehicle sound caused by the vehicle's battery cooling fan by requiring that any vehicle sound measurements taken while the cooling fan is operating be discarded. While the agency believed that this would address repeatability issues caused by battery cooling fans, we noted that there may be other vehicle functions that produce inconsistent sound levels as a result of the ambient temperature. The agency tentatively concluded that we had sufficiently controlled this situation in the test procedure by invalidating measurements in which any component of the vehicle's thermal management system (*i.e.* a cooling pump or fan) is engaged. We solicited comments on other vehicle functions that produce varying noise levels at different ambient temperatures.

Furthermore, to ensure the goal of testing the vehicle in its quietest state, the NPRM specified the vehicle test condition that all accessory equipment on the vehicle should be turned off. This step was included because the vehicle's air conditioning system, heating system, and windshield wipers, for example, can all produce sound when activated which can introduce inconsistency into the acoustic measurements.

The NPRM went on to explain that for all operating conditions, the proposed test procedure (and that of SAE J2889–1) specified that four consecutive valid measurements be within 2 dB(A). This repetition and decibel level restriction are to ensure repeatability of vehicle sounds without the presence of unwanted ambient spikes, other non-vehicle sounds, or intermittent sounds the vehicle may happen to make that are not associated with its quiet operating state.

As explained in the NPRM, the agency has no preference in how manufacturers choose to comply with the minimum sound level requirements in this standard. If the agency could rely on battery cooling fans on electric vehicles or the ICEs on hybrid vehicles to be activated whenever the vehicle is turned on or is moving, this may be a satisfactory manner for a manufacturer to comply with the minimum sound level requirements. However, if the battery cooling fans and the ICEs on hybrid-electrics are only running intermittently, then sounds produced by these vehicle systems cannot be relied upon to provide sound to pedestrians for safety purposes under all conditions. While the proposed specifications requiring four valid measurements within 2 dB(A) would to some extent address repeatability issues caused by intermittent vehicle noise, the agency explained that it wanted to guard against a situation in which measurements are accepted with the battery cooling fans active on an EV or the ICE engaged on a hybrid-electric if those noise sources are intermittently engaged.

The agency also acknowledged, as discussed in the NPRM, that it may be possible that not all the HVs to which this proposal would apply are designed to be operated in EV-only mode for every operating condition for which the safety standard would specify requirements. Because the agency would be testing HVs in their quietest state, the test procedure and requirements as proposed were not designed to test a vehicle that produces added sound while its ICE is operating. Therefore, the agency stated it would not require that HVs meet the requirements of the proposal for a given operating condition if they are not capable of operating in electric-only mode in that operating condition. For example, if a vehicle is not designed to operate in electric-only mode above 25 km/h, it would not be required to meet the requirements in the proposal at any speed above that (*e.g.* at 30 km/h). The NPRM also included a provision to exclude an HV from meeting the minimum sound requirement for a given operating condition after ten consecutive tests during which the vehicle's ICE is operating during the entire test.

In response to the NPRM and the issue of invalid test results, OICA, Alliance/Global, Nissan, SAE and Advocates provided comments.

OICA recommended discarding any measurements that are influenced by the presence of vehicle functions that produce intermittent sounds. According to OICA, intermittent sound sources include cooling fans and pumps, and air conditioning components. OICA said that turning off the A/C and minimizing powertrain operation before executing a test will reduce the incursion of these sounds. OICA explained that ''experienced engineers must know what is truly an intermittent sound for a specific vehicle, and what is part of the normal vehicle emitted sound.'' OICA also asked the question about how the regulation will handle a vehicle whose thermal management system is always operational.

The comments received from Alliance/Global were similar to those provided by OICA. These commenters recommended that the agency clarify for testing purposes that all auxiliary equipment capable of being shut off actually is shut off as part of the test procedure. Alliance/Global along with OICA provided several suggested regulatory text edits to address their related concerns.

Nissan stated that given the complexity of EV and HEV technology and the expectation for future system innovation, it believes that OEMs would need to identify potential vehicle systems and components which could contribute to the overall noise measurement on a model-by-model basis.

SAE explained that the 2dB criteria was included in the SAE and ISO standards as a data quality check and was designed to provide some objective criteria to assist the user of the standard to know when unrelated transient sounds are likely to have occurred. SAE said that engineering judgment by an experienced test engineer is still required to determine when other unrelated sounds have occurred, and a decision to invalidate a measurement must be made. SAE noted that there may be certain accessories that cannot be turned off. When tested, those accessories should be in the lowest noise emission mode. SAE referred to paragraphs 7.1.2.3 and 7.1.2.4 in SAE J2889–1 May 2012 which further defines accessory loads and multi-mode operation.

Advocates for Highway Safety commented that the requirements should prohibit use of any test results which include sounds from any vehicle systems other than those which would be constantly engaged under the specified test conditions (backing, active but stationary, forward motion).

Agency Response to Comments

The agency has considered the comments received and the suggested changes to the regulatory text. Based on review of the comments, NHTSA finds general agreement with the agency's overall approach for identification of valid and invalid test runs. The goal is to identify and utilize those test runs that exhibit a vehicle's quietest operating mode. In consideration of Nissan's comments about the complexity of EV/HV technology, the agency anticipates that there will be a need to inquire about specific noise-generating technologies and systems utilized on test vehicles prior to conducting FMVSS No. 141compliance testing. We note that NHTSA uses this approach to enforce other safety standards. For example, in FMVSS No. 126; *Electronic Stability Control Systems,* there is a requirement for the vehicle manufacturer to make available technical documentation about the ESC understeer countermeasures. Similarly, in FMVSS No. 226, *Ejection Mitigation,* there is a requirement for the vehicle manufacturer to make technical information about rollover sensing systems available to NHTSA. With this information, the agency can identify which systems produce noise continuously rather than intermittently. Once this is established, test runs that include sounds from intermittent ICE operations and/or intermittent thermal management system activations can and will be deemed invalid.

Advocates recommended modifying the language to ''prohibit use of any test results which include sounds from any vehicle systems other than those which would be constantly engaged under the specified performance conditions (backing, active but stationary, forward motion up to 18 mph).'' During testing, all accessory equipment that can be physically turned off will be turned off. OICA asked about a thermal management system that is operational at all times. To address that, systems and accessories that cannot be turned off will be operated in their quietest mode. As mentioned by SAE, the agency agrees that engineering judgment by an experienced test engineer will be required to determine when other unrelated sounds have occurred, and a decision to invalidate a measurement must be made.

In consideration of the comments received and associated changes to the regulatory text that were suggested, the agency has decided to revise the regulatory text in the final rule accordingly.

The NPRM regulatory text addressed situations where the ICE ''remains active for the entire duration of the test,'' but we also need to be concerned with an ICE or thermal management system that operates intermittently. If any of these three conditions occur during ten consecutive tests the vehicle is not required to meet the applicable requirements. The agency has considered the total number of tests that may have to be executed to acquire the necessary four valid tests and has decided to include an absolute number of tests that must be attempted before the test sequence can be terminated.

The NPRM regulatory text did not specifically state that all accessories that can be physically shut off should be shut off during testing. That text has been added to the final rule.

Calculation of Results

The NPRM explained that the proposed compliance test procedure was consistent with the Society of Automotive Engineers Surface Vehicle Standard J2889–1, ''*Measurement of Minimum Noise Emitted by Road Vehicles,*'' September 2011,[161] and that several sections of the SAE standard were incorporated by reference into the proposed FMVSS regulatory text. The agency further discussed that for all pass-by operating conditions, the proposed test procedure (and that of SAE J2889–1) specified that at least four valid test trials must be completed while recording corresponding acoustic sound measurements for each operating condition, and upon completion of testing the first four valid trials with an overall SPL within 2 dB(A) of each other would be chosen for analysis. We explained that this repetition and decibel level restriction were to ensure repeatability of vehicle sound measurements without unwanted ambient disturbances, other non-vehicle sounds, or intermittent sounds the vehicle may happen to make that are not associated with its operating mode.

The proposed rule required that for each pass-by test, the sound emitted by the vehicle at the specified speed be recorded throughout the measurement zone specified in S6.4. The regulatory text specifically stated in S7.3(a), ''The test result shall be the lowest value (average of the two microphones) of the four valid pass-bys. The test result shall be reported to the first significant digit after the decimal place.'' The proposed regulatory text also stated in S7.3(b), ''The test result shall be corrected for the ambient sound level in each one-third octave band according to the procedure in S6.7 and the correction criteria given in Table 6 and reported to the first significant digit after the decimal place.''

The NPRM also explained that to ensure measurements can be duplicated repeatably on the same vehicle at one facility or at different facilities, the instruments used to make the acoustical measurements should meet the requirements of paragraph 5.1 of SAE J2889–1. Since the filter roll-off rates used affect the results of the acoustic measurements at the one-third octave band level, the NPRM explained that SAE J2889–1 requires conformance with ANSI S1.11. ANSI S1.11 specifies a wide range for filter roll-off rates, and these rates, if selected at the upper and lower extremes of the range, could produce different results. The agency sought comment on whether the test procedure should specify a maximum roll-off rate that is finite.

The agency also considered in the NPRM whether the procedures for analyzing the frequency spectrum in SAE J2889–1 were sufficient to ensure that the results of the acoustic measurements were recorded in a consistent manner. The agency asked additional questions about which filter roll-off rates have been used, if the one-third octave band analysis should be done in the frequency domain or in the time domain, and if an exponential window should be used when conducting the frequency analysis.

Several organizations including Alliance/Global (combined comment), SAE, OICA, NFB, Honda, and Toyota submitted comments regarding the need to clarify the procedures for processing the acoustic measurements used to determine vehicle compliance.

Alliance/Global stated that the NPRM was ambiguous as to what SPLs should be reported when four sets of measurements are made with two microphones. They suggested that the agency proposal was not clear if side-to-side measurements are to be averaged with the lower of the four measurements reported or if each side's four measurements are to be averaged and the lower measurement reported. Alliance/Global also stated that they do not agree with the use of the SAE J2889–1 ambient background correction procedures when applied to one-third octave band measurements as proposed because it differs from the ISO/SAE procedures which recommends correcting for ambient background only at the overall SPL level, not at the one-third octave band level. According to the Alliance/Global, its members said that they support the test procedures as specified in SAE J2889–1.

SAE commented that, ''Section S7.3(a) proposed text is unclear.'' SAE explained that the four measurement runs are to be averaged independently per side, and then the lower of the two sides is chosen to be the intermediate or final result, as applicable, in accordance with SAE J2889–1. The NFB supported the SAE comments on the proper measurement procedure. OICA said that the overall SPL values should be averaged per side and that the reported final result is from the vehicle side with the lower average overall SPL level.

Toyota stated, as mentioned in the Alliance/Global joint comment, that the

[161] The agency recognized that SAE had published an updated version of J2889–1 in May 2012. At that time we had not yet evaluated the new version, but said we intended to do so before publishing a final rule.

measurement procedure in the NPRM introduces significant variability within the results and that a more appropriate measurement procedure would be that which is specified by SAE J2889–1. Honda stated that it supports the principle of taking four measurements, averaging the lower values from each side, and reporting the calculated value, per SAE J2889–1.

In regards to roll-off filter selection for post processing acoustic files, Alliance/Global supported the use of ANSI S1.11–2004 Class 1 one-third octave filters as specified in SAE J2889–1. While they acknowledged the agency's concern regarding filter roll-off rates, they stated that the roll-off rate has a very small impact on the one-third octave results (approximately 0.15 dB). Honda also voiced concerns regarding filter roll-off rates, in that specifying a maximum and sub-infinite roll-off rate in this test procedure would represent a change to the general standard of one-third octave analysis already commonly used by automakers. Honda stated that this change would create an extra testing burden and would require additional time for development of the appropriate test instruments and test procedures.

Agency Response to Comments

It has been the agency's intention to follow the SAE J2889–1 [162] test procedures, when feasible and consistent with the agency's focus on safety. As discussed in the NPRM and in this final rule, the agency has decided to evaluate HVs and EVs for detectability and recognition at the one-third octave band level rather than at the overall sound pressure level. To do this, the agency will follow the procedures specified in SAE J2889–1 for: (1) Obtaining the ambient sound files both before and after execution of a series of test trials; (2) measuring the sound profiles for each of the first four valid test trials as appropriate for each test condition; and (3) determining which recorded sound files to use for the one-third octave band evaluation. It should be noted that the agency's final rule test procedure augments SAE J2889–1 by specifying how exactly the selected acoustic measurements will be corrected for ambient conditions and evaluated at the one-third octave band level, which is a critical step in the compliance test procedure and one that is not fully detailed in SAE J2889–1.

All of the commenters indicated that the agency's proposed ambient correction and test procedure, S6.7 and S7, do not exactly follow the procedures in SAE J2889–1. SAE specifically said that our proposed regulatory text was unclear, and the Alliance/Global stated our proposed text was ambiguous. More specifically, the commenters noted that the proposed regulatory text specified that, for each of the four consecutive valid test runs collected during the pass-by tests, the left and right microphone files are averaged together and then the one run with the lowest overall SPL value was used to evaluate the one-third octaves to determine compliance. On the other hand, the commenters noted that SAE J2889–1 clearly requires that the four data files recorded on the left side of the test vehicle are averaged, and the four data files recorded on the right side of the vehicle are averaged, and then the side of the vehicle with the lowest average overall SPL value should be selected to evaluate the one-third octave bands for compliance.

The agency has evaluated these comments and has further scrutinized the proposed text and the procedure specified in SAE J2889–1. We have decided that the regulatory text as proposed did not match that in SAE J2889–1 and agree that the text should be unambiguous. We note that the agency's intent has been to follow SAE J2889–1 as closely as possible but to expand and add the necessary details not currently specified in SAE J2889–1 for the final evaluation of the one-third octave bands.

We further considered how the recorded acoustic data files should be evaluated, and we have concluded that averaging the data files on each side of the test vehicle separately as required in J2889–1 provides the most realistic results. During a pass-by scenario, a pedestrian listening to a vehicle driving by will be positioned on either the left or right side of the vehicle. Since the pedestrian will be on one side of the vehicle or the other as it passes, the SAE J2889–1 procedures appropriately select the side of the vehicle that is found to be the quietest during the test runs. Taking an average that includes sound from both the left and right microphones as specified in the NPRM would not provide an accurate representation of what any pedestrian would hear. Therefore, the regulatory text has been revised to agree with the SAE standard.

As mentioned previously, Alliance/Global suggested that the proposed regulatory text was ambiguous in regards to the steps involved in analyzing vehicle acoustic measurements. Upon closer examination of our proposed text, we believe the text should be revised to add some clarification and additional detail. To that end, we are providing here a detailed, step-by-step explanation in conjunction with several figures to further illustrate the process. The corresponding regulatory text in this final rule has been revised accordingly to make the procedures as unambiguous as possible.

The process of executing vehicle measurements in each test condition (stationary, reverse, pass-bys), collecting necessary sound files, determining test run validity, and processing sound files to verify vehicle compliance can be broken down into five main steps, which are discussed in detail later in this section, and which can be briefly summarized as follows:

1. For a given test condition, execute test runs and collect acoustic sound files;
2. Eliminate invalid test runs and discard the corresponding sound files;
3. Identify the first four valid vehicle test runs that have overall SPLs within 2dBA of each other;
4. Take an average of the four overall SPLs from the left side of the test vehicle; separately, take an average of the four overall SPLs from the right side of the test vehicle; the lesser of these two averages will determine whether the left side or right side sound data are to be used for one-third octave band analysis.
5. Evaluate either the left side or right side sound data (whichever had the lower average in Step 4) at the one-third octave band level to determine compliance.

Each of these five steps is discussed in more detail below.

*For a given test condition, execute test runs and collect acoustic sound files:* To begin the process, multiple test runs (at

[162] In the NPRM the agency officially referenced SAE Standard J2889–1, dated September 2011, and noted that SAE had published an updated version of J2889–1 in May 2012 but that we had not evaluated that later version and intended to do so before publishing the final rule. In the May 2012 version, SAE added testing protocols for vehicle commencing motion sound and for frequency shift measurements, neither of which the agency has decided to utilize as discussed in this final rule. The May 2012 version also included paragraph updates and re-numbering. In December 2014, SAE issued another revision to J2889–1. In the final rule we have decided to update the official reference for the SAE J2889–1 standard from the September 2011 version to the December 2014 version and have updated references throughout the FMVSS No. 141 standard accordingly. A number of OEMs, including some of those that commented on the FMVSS No. 141 NPRM, are parties to the SAE committee that created J2889–1, and they presumably had a hand in subsequent updates. The agency has decided to use the Dec. 2014 version since that is the most up-to-date and since the older versions seemed to leave open some important technical details that are addressed to some extent in the latest version. Safety groups and other non-industry commenters did not address SAE recommended practices, so we assume they are indifferent about which version of the SAE standard is referenced in this final rule.

least four, but generally five to seven based on NHTSA's experience) must be completed for each test condition (stationary, reverse, pass-by) as specified in the regulatory test procedures. Immediately before and after each test condition, at least 30 seconds of ambient noise must be recorded. During each test run, a left (driver's side) and right (passenger side) acoustic sound data file must be recorded. For the stationary tests, data from a third microphone located directly ahead of the test vehicle is also recorded.

*Eliminate invalid test run acoustic sound files:* The sound files collected from each microphone during each test run are evaluated for validity. The specifics for determining validity of each test run sound file are discussed in Section III.K, *Conditions for discarding measurements.* Each test run deemed valid must be numbered sequentially based upon the chronological order in which it was executed on the test track, and each must include a left (driver's side), right (passenger side), and for the stationary test condition a front center acoustic sound file. Sound files shall be identified with, and shall retain, their test run sequence number and their association with left side and right side microphone locations.

*Identify first four valid test run sound files within 2dBA:* After a group of test run sound files have been determined as valid, further evaluation is required to identify the ''first four valid test run sound files with overall SPLs within 2dBA.'' Figure 10 identifies a flow diagram that depicts this process which is derived directly from SAE J2889–1.

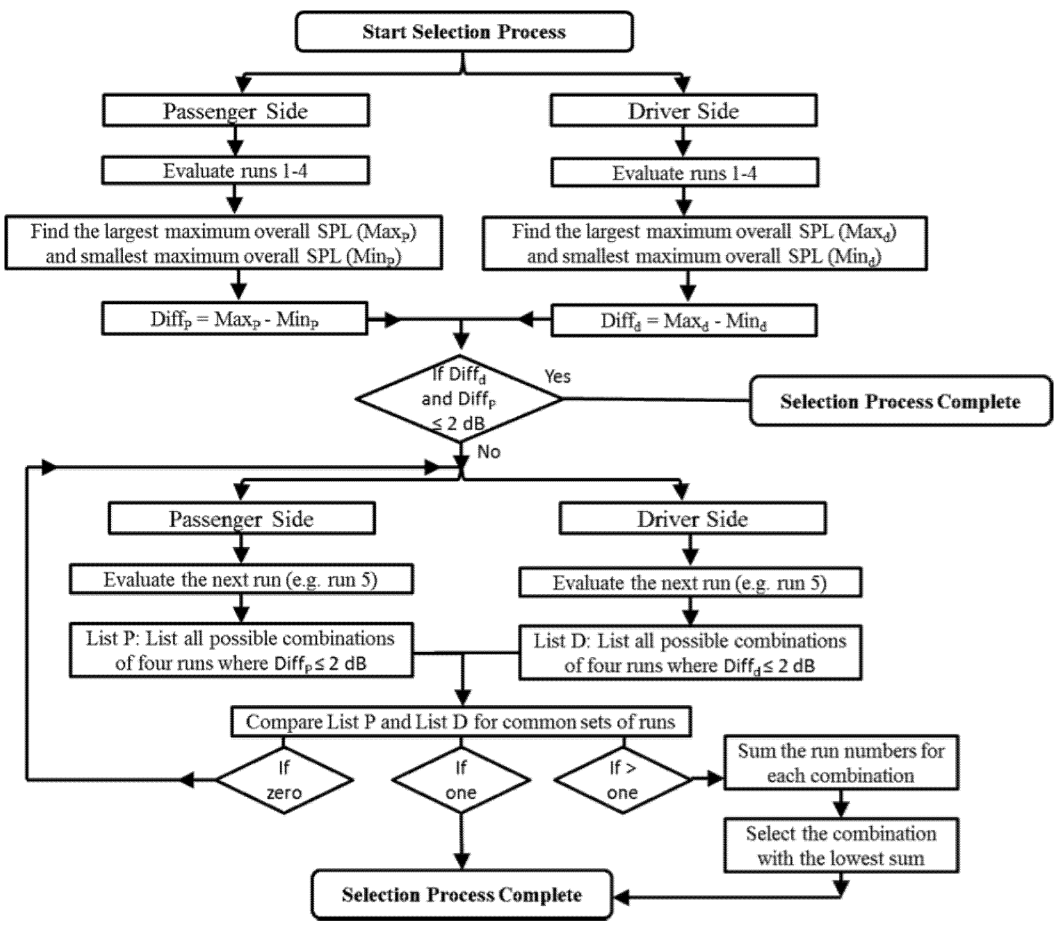


**Figure 10. Selection process to determine "first four valid test run sound files within 2dBA"**

For each test run, a valid left (driver's side) and a valid right (passenger side) sound file must exist. For each sound file the maximum overall SPL must be determined. Ultimately, the four test runs to be used for the compliance evaluation must be sequentially the first four valid test runs that have four left side files within 2.0dB(A) overall SPL and four right side files within 2.0 dB(A) overall SPL. The left and right side files must come from the same set of four test runs. This test run selection process as depicted in Figure 10 is as follows:

*Step 1:* Number each valid sound measurement test run sequentially in the chronological order it was completed on the test track– *e.g.,* Run 1, Run 2, Run 3, . . . Run N. Each test run must have a corresponding left (driver's side) and right (passenger side) acoustic sound file.

*Step 2:* Determine the maximum overall SPL value for the left and right side sound files from each of the first 4 test runs.

*Step 3:* Compare the four left side (driver's side) maximum overall SPL values. Calculate the difference between the largest and smallest of the four values. Use the same process to determine the difference between the largest and smallest of the four right side (passenger side) maximum overall

SPL values. If the difference is less than or equal to 2.0 dB(A) on both the left and right sides, then these four test runs will be used for the compliance evaluation, and the test run selection process for the given operating condition is complete. The selected runs will be considered the ''first four valid test runs within 2dBA.'' Otherwise, continue to Step 4.

*Step 4:* Add data from a fifth test run to the analysis.

*Step 5:* For the driver's side microphone, list all possible combinations of four runs for which the largest overall SPL from any of the four runs minus the smallest overall SPL from any of the four runs is less than or equal to 2.0 dB(A).

*Step 6:* For the passenger side microphone, list all possible combinations of four runs for which the largest overall SPL from any of the four runs minus the smallest overall SPL from any of the four runs is less than or equal to 2.0 dB(A).

*Step 7:* Examine the list of run combinations developed in both Step 5 and Step 6. If a set of four runs (*e.g.,* Run 1, Run 2, Run 4, and Run 5) appears in both the Step 5 and Step 6 lists, enter it into a new list (the Step 7 list).

*Step 8:* The Step 7 list can possibly contain zero, one, or more entries. If the Step 7 list has zero entries, skip to Step 10. If the Step 7 list contains exactly one entry, then that entry is the set of runs for which final data will be analyzed. For this case, terminate the run selection procedure. This set of runs will be considered the ''first four valid test run sound files within 2.0dBA.'' If the Step 7 list contains more than one entry, go to Step 9.

*Step 9:* Case for which the Step 7 list contains more than one entry. Sum the run numbers for each set of runs in the Step 7 list. For example, if an entry contains Run 1, Run 2, Run 4, and Run 5, then the sum of its run numbers would be 12 (1+2+4+5). Select the entry which has the lowest sum of run numbers. This set of runs is the set for which final data will be analyzed for compliance. At this point, terminate the run selection procedure. This set of runs will be considered the ''first four valid test run sound files within 2.0dBA.'' [Note: When there are five runs being considered, it is mathematically impossible for the sums of the run numbers for the two entries in the Step 7 list to be exactly the same. One entry will always have a lower value. However, in NHTSA's experience there have been cases in which six or seven test runs are needed to find a set of four shared by the driver's and passenger's sides that have Overall SPLs within 2.0 dB(A). It might be possible (although the agency has not yet had it happen) in these situations for the sums of the run numbers for the two entries in the Step 7 list to be exactly the same. If this occurs, our procedure will be to eliminate the combination of four runs containing the highest run number. If the highest run number is the same in both four-run combinations, we then will eliminate the combination of four runs containing the second highest run number, and so on.]

*Step 10:* Case for which the Step 7 list contains zero entries. In this situation, add data from another test run to the analysis and return to Step 5. [Note: In NHTSA's experience, there have been instances in which it was necessary to examine data from as many as seven runs to find a set of four that are shared by the driver's and passenger's sides that have Overall SPLs within 2.0 dB(A).]

Note that, although data recorded by the front microphone are not considered when determining the ''first four valid test runs within 2dB(A),'' those data are used when evaluating compliance with the directivity requirement. The front microphone data to be used for directivity are the data recorded during the ''first four valid test runs within 2dB(A)'' determined according to the procedure above.

*Average sound files on test vehicle left and right sides to determine final files for one-third octave band processing:* After the ''first four valid test runs within 2.0dBA'' have been identified, the four acoustic sound files from each side of the vehicle recorded during those four runs are analyzed to determine which side of the vehicle was the quietest during test execution. Figure 11 is a flow diagram that depicts the process used to further identify the acoustic data files on a particular side of the test vehicle that will be used to evaluate vehicle compliance at the one-third octave band level. For each of the eight acoustic sound data files (four left side files and four right side files) the maximum overall SPL value must be identified. Each of the eight acoustic data file maximum overall SPL values are then corrected for the recorded ambient conditions as specified in the final rule. Finally, the four ambient-corrected maximum overall SPL values on each side of the vehicle are averaged together for one comprehensive ambient-corrected value for each side of the vehicle. The side of the vehicle with the lowest average ambient-corrected maximum overall SPL value is the side of the vehicle that is further evaluated for compliance at the one-third octave band level. Each of the four acoustic data files on the side of the vehicle with the lowest average ambient-corrected maximum overall SPL value are then used for the one-third octave band evaluation as depicted in the flow diagram in Figure 12.

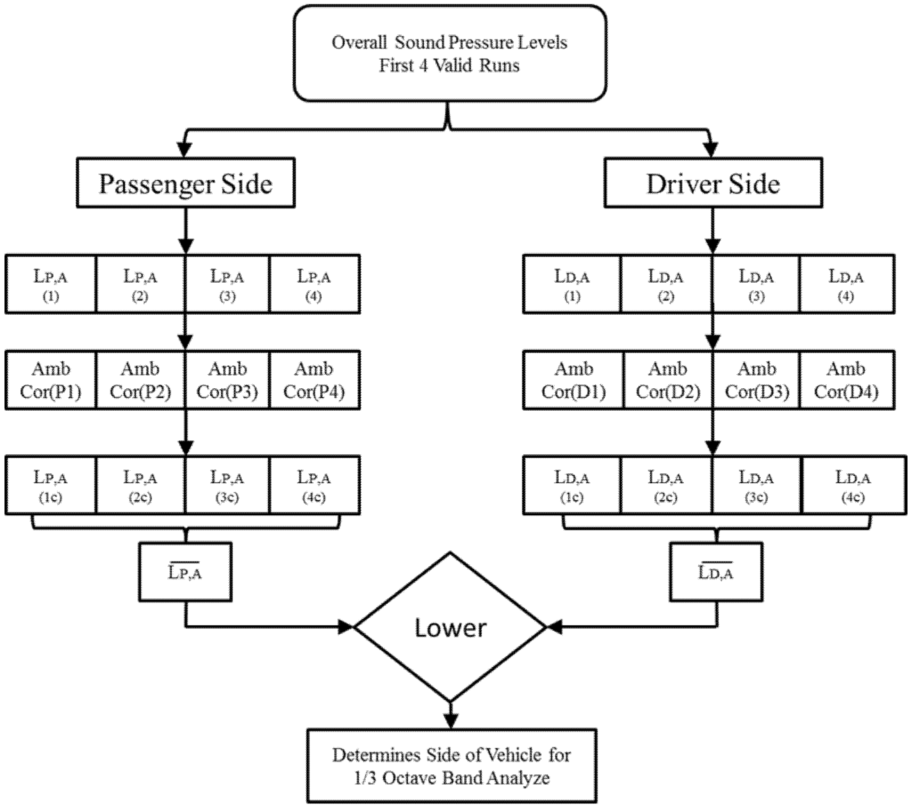


**Figure 11. Flow diagram for identification of quietest side of test vehicle to be used for one-third octave analysis**

In the event that the average corrected maximum overall SPL values for the driver's and passenger's sides are exactly equal, then the sound from the passenger's side will be analyzed.

*Evaluate final sound files at one-third octave band level for compliance verification:* Figure 12 indicates the flow process for analyzing the selected four acoustic data files for the one-third octave band analysis. As shown in Figure 11, the side of the vehicle found to have the lowest overall average and corrected SPL value is the side of the vehicle that is further evaluated for compliance verification. The side selected has four individual acoustic data files. Each file is broken down into its one-third octave band levels. The identified one-third octave band levels in each of the four files are then corrected for the measured ambient levels as specified in the final rule. The four corrected values in each one-third octave band are then averaged together to get the average corrected sound pressure level in each one-third octave band. The averaged corrected values in each one-third octave band are then compared directly to the minimum standards specified in this final rule to determine compliance.

The stationary test condition, ''first four valid test runs within 2dB(A)'' also has front microphone acoustic data. Each sound file for the front microphone is broken down into its one-third octave band levels. The identified one-third octave band levels in each of the four files are then corrected for the measured ambient levels as specified in the final rule. The four values calculated in each one-third octave band are then averaged together to get the average ambient-corrected sound pressure level in each one-third octave band. The averaged, corrected values in each one-third octave band are then compared directly to the minimum standards specified in this final rule to determine compliance.

As explained previously, the process established in this final rule augments the process specified in the SAE standard by clarifying the steps depicted in Figure 12 for processing the selected sound files for the one-third octave band analysis. The current version of SAE J2889–1 does not correct one-third octave band data, as required in this final rule.

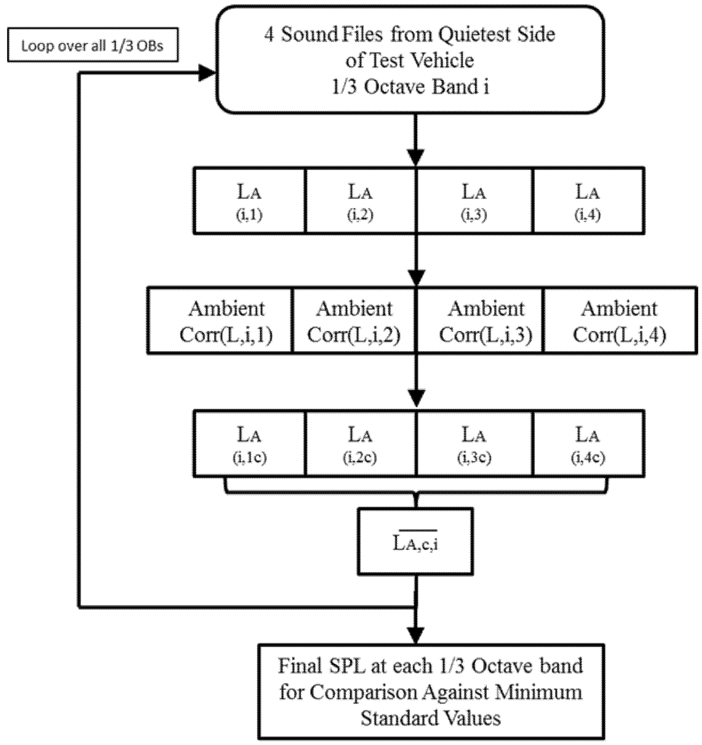


**Figure 12. Flow diagram for processing sound files at one-third octave band levels**

To address commenter issues discussed above and to add clarification, the final rule test procedure (paragraph S7) replaces in its entirety the proposed regulatory text of the corresponding section of the NPRM.

Data Post-Processing

In the NPRM, the agency sought comment on data post-processing topics including filter roll-off rates, measurement domains and type windows used for frequency analyses. Few comments were received, but the one topic that was commented on was filter roll-off rates. The commenters strongly supported using the ANSI S1.11–2004 Class 1 one-third octave filters as specified in SAE J2889–1.

We agree that the ANSI S1.11 filters should be used for processing the acoustic sound files. However, as mentioned in the NPRM, the selected filter roll-off rates could affect the results of the acoustic measurements at the one-third octave band level. Furthermore, there are other attributes (*i.e.,* sound analysis code window size, time used for exponential averaging, and the precise details of the implementation of the sound analysis code) that should also be considered for use in the data post-processing routines that can impact the final results. All of these critical attributes must be evaluated and defined to ensure an objective test procedure is specified that provides reproducible and repeatable test results.

Over the past few years, the agency has used two different sound analysis codes for processing acoustic sound files. The first code, which NHTSA licensed from Bruel and Kjaer, is the B&K Pulse Reflex™ Code (the B&K Code), and is an integral part of a commercial off-the-shelf acoustic sound measurement system. NHTSA has utilized this system and software code for much of its early research testing. The B&K Code is a data analysis software that uses preprogrammed building blocks, known as elements, to form processing chains. For the purpose of processing sound recordings two processing chains were used, one for determining the overall sound pressure levels and one for determining the 13 one-third octave sound levels.

The second analysis code that has been used by the agency is one developed by the Volpe National Transportation Systems Center (the Volpe Code). This sound analysis code was written using Matlab™. While Matlab is a proprietary engineering based technical programming language, the source code developed for acoustic data processing is the property of the United States Department of Transportation and can be made publically available. This code uses a more traditional, language based, programing structure.

The agency is aware of other acoustic measurement instrumentation and associated codes that can also be used to collect and process acoustic sound files but none of these other systems/codes have been evaluated. It is our understanding that among these codes, the two used by NHTSA and some of the other available codes function similarly. Figure 13 depicts the general process used by these various codes to derive the overall and one-third octave band sound values.

The general process involves loading the sound data file, applying the defined acoustic sound weighting, and then performing the necessary respective processing to arrive at both the overall sound pressure level and one-third octave band values. The respective processing routines will be further outlined in the following sections.

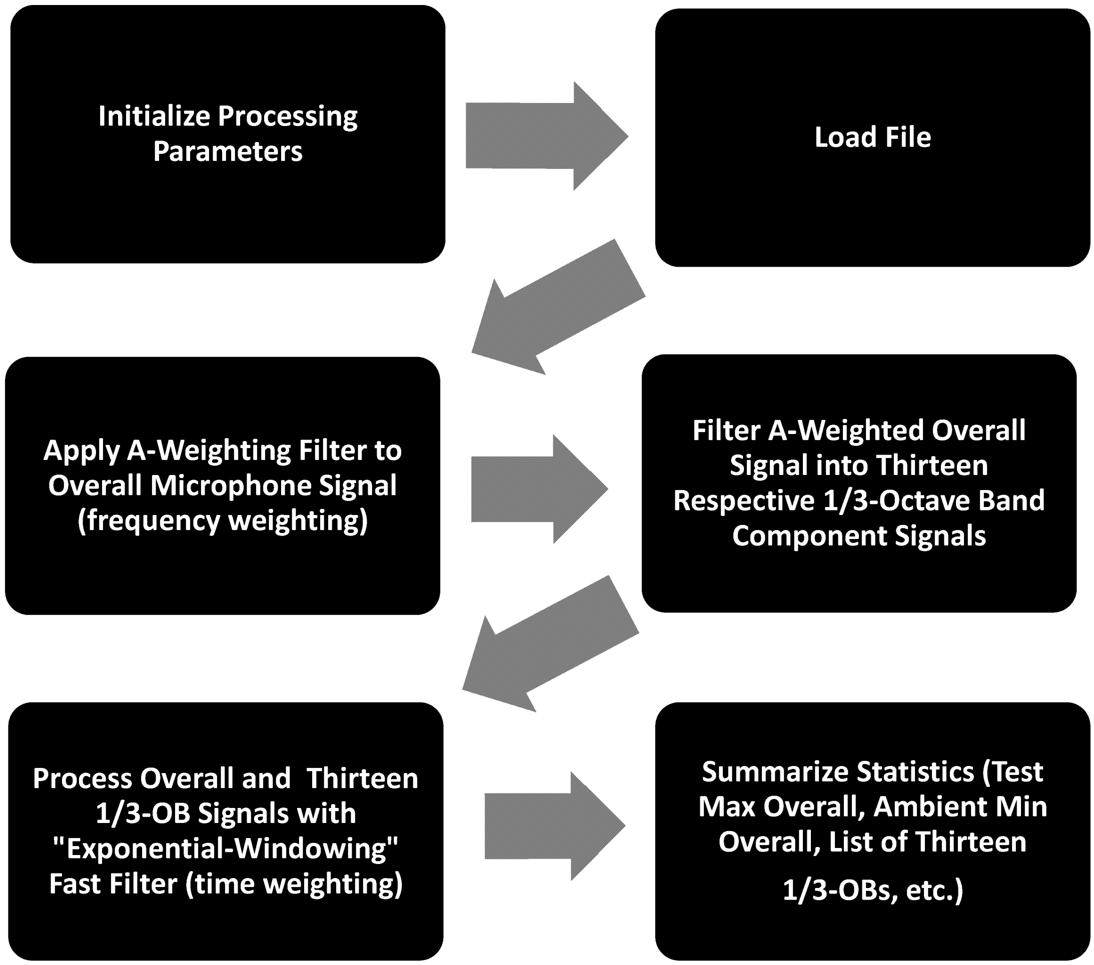


**Figure 13. General Flow Diagram for Data Processing Code**

For evaluation purposes, the sound data recorded during some test runs were analyzed using both the B&K Pulse code and the Volpe code. Some test runs were also analyzed using two different sets of user-specified parameters. Analysts looking at the results from these runs noted that there were slightly different overall sound pressure levels and one-third octave band levels for the exact same sound data depending upon the sound analysis code and the user-selectable parameters used. While the differences that were seen were not large (less than 2.0 dBA), NHTSA believed that it needed to understand the source of the differences before either code could be used in a compliance test. Therefore, NHTSA undertook further research work after publication of the NPRM to evaluate and resolve this issue.

The objective of this research was to select one sound analysis code and one set of user-selectable parameters for use in compliance testing of measured vehicle sound data. Our criteria for choosing an appropriate sound analysis code were:

- The code must generate correct results for mathematically-generated test cases for which the correct result is known.
- The code must meet all of the filter requirements for one-third octave band filters that are contained in the ANSI S1.11–2004 Class 1 standard.
- The code can be made publically available so all individuals and organizations know the exact methods, specified parameters, and filtering being used by NHTSA.

Table 19 shows the standard settings for the user definable parameters that can be set in each of the code packages that were evaluated.

TABLE 19—ANALYSIS CODE USER-SELECTABLE PARAMETERS

| Acoustic test data analysis settings | | |
|---|---|---|
| Parameter | B&K Pulse | Volpe Matlab |
| General Settings: | | |
| Sampling Frequency | 65536 Hz | 65536 Hz. |
| Processing Window | Test Scenario Dependent | Test Scenario Dependent. |
| Acoustic Weighting | A or Linear Weighting | A or Z Weighting. |
| Overall Sound Pressure Level Settings: | | |

TABLE 19—ANALYSIS CODE USER-SELECTABLE PARAMETERS—Continued

| Acoustic test data analysis settings | | |
| --- | --- | --- |
| Parameter | B&K Pulse | Volpe Matlab |
| Frequency span | 25600 Hz | 24000 Hz. |
| Overall Averaging | Linear | None. |
| Averaging time | 0.05 | None. |
| One-Third Octave Band Analysis Settings: | | |
| Bandwidth (Fractional Octave) | ⅓—Base 10 Exact | ⅓—Base 10 Exact. |
| Upper Nominal Center Frequency | 5000 Hz | 5000 Hz. |
| Lower Nominal Center Frequency | 315 Hz | 315 Hz. |
| Type of Octave Band Averaging | Exponential | Exponential. |
| Type of Time Weighting | Fast | Fast. |
| Averaging Time | ¼ seconds | ¼ seconds. |
| Tau (Time Constant) | ⅛ seconds (Fast) | ⅛ seconds (Fast). |

NHTSA began evaluating both codes by running the same vehicle sound data file through both code packages, looking to see how consistent the codes were relative to each other. The outcome was that each code gave slightly different results, even while using consistent parameter settings.

To systematically determine the differences between the two packages, both the B&K and the Volpe sound analysis codes were checked to ensure that they provided known output results for known input values. This was done through the development of test cases that were processed using each of the sound analysis codes. The test cases consist of simple pure tones which are computer-generated rather than taken from actual sound recordings, and thus they have none of the complexity of actual acoustic measurements. The test cases provide elemental inputs for which the correct outputs are known in advance. The test cases were used to evaluate the accuracy of a given code's analysis routine and to compare the outputs of the two different analysis methods.

Test Case 1 was a series of pure tones. The sound pressure of each tone as a function of time is given by a constant-amplitude, constant-frequency, single sine wave. Multiple pure tones were generated, each at a different constant-frequency. For this research, two constant-amplitudes corresponding to 40 and 60 dB sounds were used. To be certain of capturing all important effects for each of the 13 one-third octave bands of interest to NHTSA (which have nominal center frequencies ranging from 315 Hz to 5,000 Hz), the pure tones for Test Case 1, developed using Matlab™, were generated at 201 individual frequencies each corresponding to ⅛th of a one-third octave band (1⁄24th of a full octave). The frequency range over which they span is, nominally, 70Hz–22,300Hz. This range encompasses six full one-third octave bands both above, and six full one-third octave bands below, the 13 one-third octave bands of interest to NHTSA. This range was chosen to ensure a full profile of how each code responds to known inputs was generated and understood.

The following aspects of sound analysis code were checked using Test Case 1 data files:

- The correctness of the calculated amplitude, when no frequency weighting (Z-weighting) was applied, for a pure tone at a frequency corresponding to the center of each of the one-third octave bands of interest.
- The correctness of the calculated amplitude, when A-weighting was applied, for a pure tone at a frequency corresponding to the center of each of the one-third octave bands of interest.
- The correctness of the band-pass filters that split frequency-weighted sound pressure level data into 13 one-third octave bands. NHTSA and commenters want these band-pass filters to meet all of the Type 1 filter requirements for one-third octave band filters that are contained in the standard ''ANSI S1.11–2004''. The Test Case 1 frequencies include all of the frequencies listed in Table B1,'' of ANSI S1.11–2004 for the 13 one-third octave bands of interest to NHTSA.

For the second test case, Test Case 2, thirteen pure tones were superimposed to form one sound-pressure signal. These thirteen pure tones were at the frequencies corresponding to the center of each of the one-third octave bands of interest. No frequency weighting (*i.e.,* Z-weighting) was applied.

Two test runs were made using Test Case 2. The first had a 40 dB pure tone centered at each of the one-third octave bands of interest (giving an Overall SPL for this test run of 51.1394 dB). The second used thirteen pure tones at 60 dB (giving an Overall SPL for this test run of 71.1394 dB). This test case was used to check the correctness of the calculated amplitudes when no frequency weighting (Z-weighting) was applied to a complex sound data waveform.

In general, in comparing the two analysis codes using Test Case 2, NHTSA found very little or no difference between the calculated amplitudes regardless of weighting type (A- or Z-weighting) for the individual pure tones located at the center frequencies of each of the 13 one-third octave bands. Each code set gave either 40 or 60 dB at each center frequency, as expected. The results from the two analysis codes were also consistent when the overall SPL for the 13 center frequencies were combined, and both the Volpe Matlab code and the B&K Pulse code produced the correct results of 51.1 dB and 71.1 dB for the 40 dB and 60 dB inputs, respectively.

However, in looking at the test results from Test Case 1, the two analysis codes were not consistent regarding their band-pass filter function that splits frequency-weighted sound pressure data into the 13 one-third octave bands. When comparing the output of each of the 201 frequencies described in Test Case 1 to the requirements specified in ANSI S1.11–2004, NHTSA found that the B&K software tended to insufficiently attenuate the frequency bands away from the nominal one-third octave band. An example of this is shown below in Figure 14 which plots the minimum and maximum ANSI filter requirements, the output of the B&K Pulse code, and the output of the Volpe Matlab code, for the one-third octave band centered at 1000 Hz.

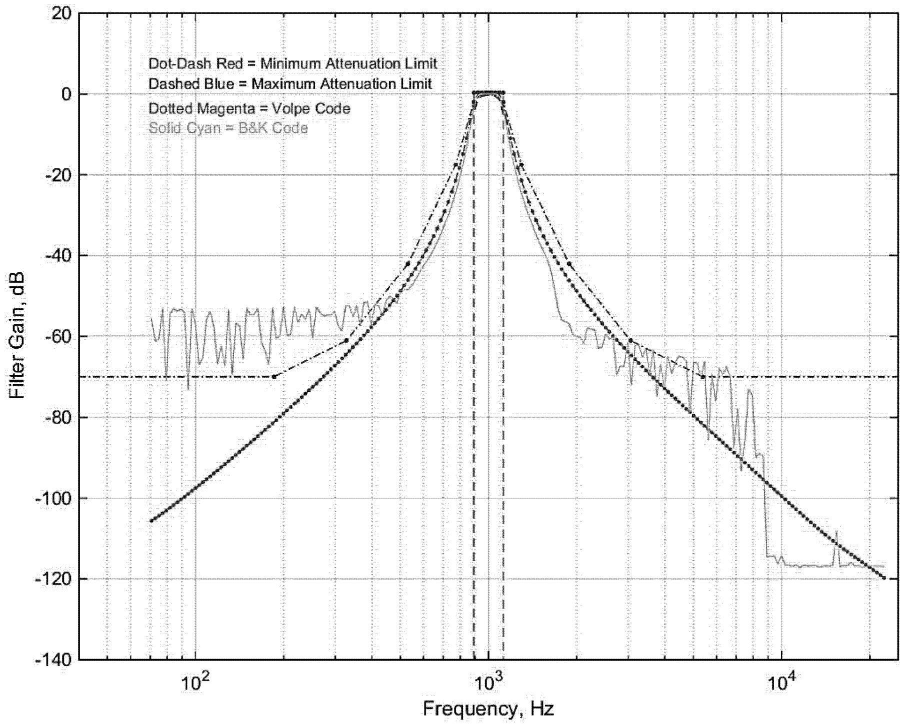


**Figure 14. One-Third Octave Band Filter Response for the 1000 Hz Band**

While some bands displayed better adherence to the ANSI S1.11 specifications, all of the 13 one-third octave bands displayed similar results as the 1000 Hz band shown above for the B&K software. On the other hand, the Volpe Matlab code processed data fell well within the filter attenuation limits specified in ANSI S1.11–2004 Class 1 across all bands. Complete results for all the individual one-third octave bands can be found in the corresponding NHTSA research report.[163]

The results of our research indicate that the two codes analyzed have different filter algorithms. This results in the two codes calculating slightly different one-third octave band levels. The exact filtering algorithm used in the B&K code is unknown because the code is proprietary. The filtering algorithm used in the Volpe code is known and can be made public. Given the results of our examination of the two post-processing methods, NHTSA has decided to use the Volpe Matlab code for the agency's future compliance testing programs. As explained above, one reason for this is that the Matlab code appears to be in full agreement with ANSI S1.11–2004 specifications and requirements. Also, the source code is not proprietary, and it can be made publically available. To resolve any potential problems with post-processing code conflicts, the agency will make the Matlab code to be used publically available, either as part of the agency's compliance test procedure, or posted on the agency's Web site. This approach will help the agency with its recent efforts to increase public communications and transparency. In reference to the other parameters that the agency inquired about in the NPRM, measurement domains and type windows used for frequency analyses, no direct comments were received so the agency has made decisions according to what it believes are technically correct. All the parameters that will be used for post processing the acoustic files will be specified in the publically available Matlab code.

**L. Phase-In of Requirements**

The PSEA directed NHTSA to establish a phase-in period to set forth the dates by which production vehicles must comply with the new FMVSS No. 141. The PSEA also stated that NHTSA must require full compliance ''on or after September 1st of the calendar year that begins three years after the date on which the final rule is issued.''

To address these requirements in the PSEA, the NPRM proposed a phase-in over three model years for new hybrid and electric vehicles produced for sale in the U.S., and full compliance of all new hybrid and electric vehicles by September 1, 2018. The three-year phase-in was based on a '30/60/90' phase-in schedule. Given that the NPRM assumed publication of a final rule in calendar year 2014, the phase-in requirements proposed in the NPRM were: 30 percent of each OEM's HV and EV production in compliance by September 1, 2015; 60 percent by September 1, 2016; 90 percent by September 1, 2017; and 100 percent by September 1, 2018. The proposed phase-in schedule was intended to be applicable to all manufacturers of HVs and EVs, except small volume and final stage manufacturers. The latter were allowed to postpone compliance until the date on which other manufacturers were required to have all their vehicles brought into compliance, *i.e.,* September 1, 2018.

The NPRM also included amendments to Part 585 Reporting Requirements to allow for OVSC verification of each manufacturer's phase-in of pedestrian alert systems.

With the exception of two advocacy groups, all commenters opposed the phase-in requirements as proposed in

[163] Dr. W. Riley Garrott, Richard, L. Hoover, Eric Gerdus, and Sughosh J. Rao, ''Selecting a Sound Analysis Code for Use With NHTSA Test Procedure to Characterize Vehicle Sound'' NHTSA Technical Report.DOT HS 812 284.

the NPRM. The NFB and NCSAB supported the phase-in schedule as proposed. The NCSAB stated that the rule should be completed by January 2014, according to the PSEA. Neither commenter suggested an alternative phase-in schedule.

All other commenters requested that NHTSA provide more lead time for compliance with the new safety standard. Some favored eliminating the phase-in altogether and establishing a single date for full compliance for all production hybrid and electric vehicles. Alternatively, commenters requested that NHTSA begin the phase-in at a later date, unless changes were made in the final rule to adopt performance requirements much less stringent than those in the NPRM. Honda and Alliance/Global requested that NHTSA allow for carry-forward credits which would give a manufacturer credit for meeting one of the phase-in stages prior to the deadline for that stage, and the manufacturer could use that credit if it did not fully meet a deadline of a later stage.

A heavy vehicle OEM commented that the proposed Part 585 phase-in reporting should not apply to a manufacturer that achieves 100 percent early compliance, and also stated that paragraph S9.5 of the NPRM, regarding phase-in for multi-stage vehicles, is unnecessary because only a final stage manufacturer would be responsible for meeting the phase-in requirements.

Porsche, a light vehicle manufacturer that produces only one hybrid model, provided proprietary production estimates through September 2018 indicating that they would not meet the 90 percent level by the third year of the proposed phase-in.

The EDTA commented that, due to the complexity of the proposal, as well as the technology needed to implement it, substantial lead time will be needed to design, develop, test and certify new alert systems. EDTA stated that it joined with Alliance/Global in recommending that, if the final rule is substantially the same as the proposal, the phase-in specified in the final rule should be limited to a single 100-percent compliance date that is set in accordance with the PSEA (*i.e.,* September 1st of the calendar year that begins three years after the date on which the final rule is issued).

Honda commented that, if the final rule must be complied with starting in September 2015, it would need more time to meet all the requirements proposed in the NPRM (modification of speakers, control unit, vehicle structural modifications, etc.). Therefore, Honda requested at least two or more years from the date that the final rule is issued before the phase-in requirements begin. As mentioned above, Honda also requested that a credit system be established as part of the phase-in.

Toyota stated that it is committed to pedestrian safety, and as such, has already equipped every hybrid and electric vehicle it produced since model year 2012 under the Toyota and Lexus brands (currently, there is no Scion HV or EV) with a pedestrian alert sound meeting the existing Japanese guidelines. However, Toyota noted that the proposed requirements of the NPRM would require significant redesign of Toyota's current production alert system, which will in turn require substantial development and test time. Therefore, Toyota recommended elimination of the phase-in requirements and suggested that NHTSA consolidate the schedule by simply requiring full compliance for all HVs and EVs by September 1, 2018 (assuming the final rule is published in calendar year 2014 or earlier).

Alliance/Global commented that it would not be possible for manufacturers to meet a phase-in beginning September 1, 2014. If the requirements of the final rule were to be substantially similar to the NPRM, they recommend foregoing the phase-in and going directly to full implementation on September 1, 2018. However, if the final rule instead were to approximate the Alliance/Global recommendations, then a phase-in period is feasible beginning with vehicles built on or after September 1, 2015, and ending with vehicles built on or after September 1, 2018 (those dates would need to be adjusted should the final rule be significantly delayed beyond the original January 2014 deadline).

Alliance/Global also commented that currently there are no EVs or HVs produced by their member companies that are capable of meeting the requirements proposed by NHTSA. They stated that several strategies had been considered, including reprogramming an existing alert sound control module. They also stated they had interviewed suppliers who currently manufacture alert systems in an effort to explore all possible solutions for meeting the NPRM. They concluded that considerably more time would be needed than a September 1, 2014 start of phase-in would allow to package/repackage components, develop new systems, source the components, and certify the new systems.

However, Alliance/Global commented that such a phase-in schedule as the one they suggested still would need assistance from carry-forward credits (including early carry-forward credits). They recommended full credits for EVs and HVs that comply with their suggested sound specifications (assuming those were implemented in the NHTSA final rule) and half-credit (*i.e.,* two vehicles equal one credit) for EVs and HVs that are equipped with pedestrian alert systems that do not meet the Alliance/Global suggested requirements, but that nevertheless comply with the spirit and purpose of the PSEA. If NHTSA specifies a phase-in, Alliance/Global stated that carry-forward credits are necessary for their member companies to avoid needless compliance expenditure on vehicle models imminently due to be phased out of production.

Alliance/Global commented that small manufacturers should not be required to comply until the end of the phase-in period. Because no current EV or HV pedestrian alert sound voluntarily implemented by vehicle manufacturers meets NHTSA's proposed requirements, if the agency proceeds to a final rule that is substantially similar to the NPRM, Alliance/Global would prefer that NHTSA does not specify a phase-in, and instead allows all manufacturers the maximum amount of time to comply with the requirements of the new safety standard.

Finally, Alliance/Global stated that phase-in language needs to clarify that requirements pertain only to vehicles described in the Applicability section of the regulation and not to every type of vehicle that a full-line manufacturer produces.

The MIC commented that, if NHTSA does decide to establish minimum sound requirements for motorcycles, it should extend the phase-in exemption for small manufacturers, including motorcycle manufacturers, indefinitely.

Nissan requested that the phase-in begin at least two years following the issuance of a final rule. Nissan also requested that NHTSA provide for the use of advanced credits for vehicles that comply before the final date for compliance.

Denso commented that vehicle manufacturers, as well as equipment suppliers, need three years of lead time before beginning phase-in of complying vehicles.

Navistar questioned how the proposed phase-in meshes with Parts 567 and 568 regarding certification of multistage vehicles.

OICA commented that the Phase-in should include only those vehicles to which the performance requirements are meant to apply, *i.e.,* certain hybrid and electric vehicles.

Agency Response to Comments

Given that this final rule is being published in calendar year 2016 and, furthermore, given that the PSEA stipulates full compliance on and after September 1st of the calendar year that begins three years after the date on which the final rule is issued, NHTSA is requiring compliance for 100 percent of HVs and EVs produced for sale in the U.S. by all manufacturers by no later than September 1, 2019. This compliance date is set forth in the Applicability section of the regulatory text of this final rule.

In addition, after review of the comments submitted, NHTSA is adopting a one-year, 50 percent phase-in. Under this phase-in, 50 percent of the total production volume of each manufacturer's hybrid and electric vehicles to which the safety standard applies, and which are produced by the manufacturer for sale in the United States., must comply by no later than September 1, 2018.

This phase-in does not apply to multi-stage and small volume manufacturers. Those manufacturers would have until September 1, 2019, to comply. This should not have any significant effect on traffic safety because of the relatively small number of vehicles they produce.

Because the phase-in period will have a duration of only one year, carry-forward credits would not be of any benefit. Therefore, NHTSA is not making any provisions in this rule for carry-forward credits.

The agency's decision on the phase-in issues is a compromise that responds to comments about reducing the phase-in or eliminating it altogether. The one year phase-in addresses the mandatory PSEA requirements and ensures that any delay in getting complying vehicles to market will be minimized. At the same time, it responds to commenters' requests for additional lead time to comply and to their suggestions that the NPRM phase-in should be consolidated and simplified. A one-year phase-in provides additional flexibility for manufacturers as to when they bring their model lines into compliance.

Furthermore, NHTSA has reviewed current model lines of vehicle manufacturers using OVSC annual compliance information and has determined that several of the OEMs that produce HVs and/or EVs have only one or two such models among their vehicle lines. This is one factor that we have considered in choosing an appropriate phase-in period. These manufacturers will benefit from a shortened phase-in schedule that provides additional lead time prior to the initial date on which the phase-in begins.

## IV. International Harmonization and Stakeholder Consultation

NHTSA is required by the PSEA to consult with the following organizations as part of this rulemaking: The Environmental Protection Agency (EPA) to assure that any alert sound required by the rulemaking is consistent with noise regulations issued by that agency; consumer groups representing visually-impaired individuals; automobile manufacturers and trade associations representing them; technical standardization organizations responsible for measurement methods such as the Society of Automotive Engineers, the International Organization for Standardization (ISO), and the UNECE World Forum for Harmonization of Vehicle Regulations (WP.29).

The agency has established three dockets to enhance and facilitate cooperation with outside entities including international organizations. The first docket (No. NHTSA–2008–0108) was created after the 2008 public meeting was held; it contains a copy of the notice of public meeting in the **Federal Register**, a transcript of the meeting, presentations prepared for the meeting and comment submissions. It also includes NHTSA's research plan, our ''Notice of Intent to Prepare an Environmental Assessment for the Pedestrian Safety Enhancement Act of 2010'' published on July 12th 2011 in the **Federal Register**, and the agency's Phase 1 and 2 research reports. (The Notice of Intent [NOI] and the agency's research are discussed more fully in other parts of this document.) The second docket (No. NHTSA–2011–0100) was created to collect comments on the NOI; it also includes a copy of that notice. The third docket (No. NHTSA–2011–0148) was created in September 2011 to include materials related to the rulemaking process (''The Pedestrian Safety Enhancement Act of 2010,'' Phase 1 and 2 research reports, statistical reports, meeting presentations, etc.), and outside comments.

On June 25, 1998, the United States signed the 1998 Global Agreement, which entered into force on August 25, 2000. This agreement was negotiated under the auspices of the United Nations Economic Commission for Europe (UNECE) under the leadership of the U.S., the European Community (EC) and Japan. The 1998 Agreement provides for the establishment of Global Technical Regulations (GTRs) regarding the safety, emissions, energy conservation and theft prevention of wheeled vehicles, equipment and parts. By establishing GTRs under the 1998 Agreement, the Contracting Parties seek to pursue harmonization in motor vehicle regulations not only at the national and regional levels, but worldwide as well.

As a general matter, governments, vehicle manufacturers, and ultimately, consumers, both here and abroad, can expect to achieve cost savings through the formal harmonization of differing sets of standards when the contracting parties to the 1998 Global Agreement implement new GTRs. Formal harmonization also improves safety by assisting us in identifying and adopting best safety practices from around the world and reducing diverging and unwarranted regulatory requirements. The harmonization process also allows manufacturers to focus their compliance and safety resources on regulatory requirements whose differences government experts have worked to converge as narrowly as possible. Compliance with a single standard will enhance design flexibility and allow manufacturers to design vehicles that better meet safety standards, resulting in safer vehicles. Further, we support the harmonization process because it allows the agency to leverage scarce resources by consulting with other governing bodies and international experts to share data and knowledge in developing modernized testing and performance standards that enhance safety.

Under the 1998 Agreement, countries voting in favor of establishing a GTR, agree in principle to begin their internal implementation processes for adopting the provisions of the GTR, *e.g.,* in the U.S., to issue an NPRM or Advanced NPRM, within one year. The ultimate decision whether or not to adopt the GTR is at each contracting party's discretion, however, based on its determination that the GTR meets or does not meet its safety needs. The UNECE World Forum for Harmonization of Vehicle Regulations (WP.29) administers the 1998 Agreement.

In 2009, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan assembled a committee to study the issue of the quietness of HVs. The committee concluded that an Approaching Vehicle Audible System (AVAS) was a realistic alternative to allow pedestrians who are blind or visually-impaired to detect quiet vehicles. In 2010, MLIT announced guidelines for AVAS based on the recommendations of the study committee. Although several vehicles were considered in the initial scope, MLIT concluded that AVAS should be installed only on HVs that can run on electric motors, EVs and fuel-cell vehicles. In terms of the activation condition, the MLIT recommended that AVAS automatically generate sound at least in a speed range from the start of a vehicle until reaching 20 km/h (12 mph) and when moving in reverse. The AVAS would not be required when a vehicle is stopped. The system may include a switch to temporarily halt the operation of the AVAS. The reason for including this switch is because the committee believes that the system is not needed on expressways where there are no pedestrians and to reduce other issues such as drivers deliberately increasing vehicle speed in order to stop the AVAS.

In its March 2011 session, WP.29 determined that vehicles propelled in whole or in part by electric means, present a danger to pedestrians and consequently adopted Guidelines covering alert sounds for electric and hybrid vehicles that are closely based on the Japanese Government's guidelines. The Guidelines were published as an annex to the UNECE Consolidated Resolution on the Construction of Vehicles (R.E.3). Considering the international interest and work in this new area of safety, the U.S. decided to lead the efforts on the new GTR, with Japan as co-sponsor, and develop harmonized pedestrian alert sound requirements for electric and hybrid-electric vehicles under the 1998 Global Agreement. Development of the GTR for pedestrian alert sound has been assigned to the Group of Experts on Noise (GRB), the group most experienced with vehicle sound emissions. GRB is in the process of assessing the safety, environmental and technological concerns to develop a GTR that leverages expertise and research from around the world and feedback from consumer groups. The U.S. is the co-chair (with Japan) of the informal working group on Quiet Road Transport Vehicles (QRTV) assigned to develop the GTR and, therefore, will guide the informal working group's development of the GTR. GRB will meet regularly and report to WP.29 until the establishment of the new GTR. NHTSA has been participating in the QRTV's meetings since its foundation and has kept the group informed about ongoing agency research activities as well as the results from completed research studies. At the time the NPRM was issued, the QRTV informal group had held five sessions to discuss development of a GTR on quiet vehicles.

NHTSA has also hosted roundtable meetings with industry, technical organizations and groups representing people who are visually-impaired for the purpose of consulting with these groups on topics related to this rulemaking. Participating in these meetings were representatives from the Alliance of Automotive Manufacturers, the Global Automakers (formerly Association of International Automobile Manufacturers (AIAM)), American Council of the Blind, The American Foundation of the Blind (AFB), the National Federation of the Blind (NFB), The International Organization for Standardizations (ISO), The Society of Automotive Engineers (SAE), the International Organization of Motor Vehicles Manufacturers (OICA), The Environmental Protection Agency (EPA) and Japan Automobile Manufacturers Association (JAMA).

Representatives of the EPA have also been included in our activities with outside organizations. They have been kept updated on our research activities and have actively participated in our outreach efforts. NHTSA has also kept up to date on EPA activities on the international front through the activities of the UNECE Working Party of Noise (GRB).

The American Foundation of the Blind, the American Council of the Blind and the National Federation of the Blind have provided NHTSA with invaluable information about visually-impaired pedestrian safety needs since the 2008 Public Meeting was held.

The Alliance of Automobile Manufacturers and Global Automakers have met separately with the agency to discuss our research findings and their ideas regarding this rulemaking. Members of both organizations have also met separately with the agency to discuss their own research findings and ideas for a potential regulatory approach to address the safety issues of interest to the agency.

Automotive manufacturers that produce EVs for the U.S. market have developed various pedestrian alert sounds, recognizing that these vehicles, when operating at low speeds, may pose an elevated safety risk to pedestrians. They have made vehicles with sound alert systems available for lease by NHTSA for research purposes. This information has been helpful in the agency decision making process.

The Society of Automotive Engineers (SAE) established the Vehicle Sound for Pedestrians (VSP) subcommittee in November 2007 with the purpose of developing a recommended practice to measure sounds emitted by ICE vehicles and alert sounds for use on EVs and HVs. Their efforts resulted in recommended practice SAE J2889–1, *Measurement of Minimum Noise Emitted by Road Vehicles.* The agency had been sending a liaison to VSP meetings starting in 2008. SAE is the U.S. technical advisory group to the International Organization for Standardization (ISO), and they both have cooperated in the development of the industry safety standard. The ISO document (ISO/NP 16254, *Measurement of Minimum Noise Emitted by Road Vehicles*) and the SAE document are technically identical. The agency used SAE J2889–1 and ISO 16254 as references in the NHTSA test procedure development. Other international organizations, such as the International Organization of Motor Vehicle Manufacturers (OICA) and Japan Automobile Manufacturers Association (JAMA) have provided NHTSA with research findings and also have attended various quiet vehicle meetings.

In the NPRM, the agency concluded that the voluntary guidelines adopted by the Japanese government, and subsequently by the UNECE WP.29 Committee, did not have the level of detail necessary for NHTSA to establish objective minimum performance requirements for creation of an FMVSS. We did not believe that the agency would be able to tell if a sound fell within one of the exclusions by means of an objective measurement, nor would we be able to adequately ensure that sound levels would be detectable by pedestrians or provide manufacturers with a set of requirements that they would be able to meet. The NPRM noted that the WP.29 QRTV work was scheduled to be completed in 2014, and a draft GTR adopted in November 2014.

OICA, EU, Chrysler, EDTA, VW, and Alliance/Global all suggested delaying the development of a U.S. regulation on minimum noise levels until WP.29 has had sufficient time to develop a globally harmonized set of regulations via the GTR process. They stated that establishment of separate requirements that may or may not be harmonized with the recommendations under negotiation through WP.29 would harm development of electric drive vehicles globally and constrain the growth of the market as a whole.

OICA, EU, VW, and Alliance/Global commented that the PSEA statute does not provide enough time for WP.29 to address all remaining technical issues in development of a globally harmonized standard that the U.S. could then adopt. EU commented that if the agency is unable to delay publication of a final rule that would harmonize with the international community, it should at a minimum ensure that any U.S. regulations are consistent with the recommendations of the WP.29 Informal

Working Group on Quiet Road Transport Vehicles.

The EU questioned to what extent NHTSA had taken into consideration the conclusions and results of the QRTV–IWG. They believed a delay in the NPRM process and the finalization of the new FMVSS until the new GTR has been drafted would contribute towards a common approach and an overall consensus at the international level with respect to EVs and HEVs.

VW and Alliance/Global commented that if NHTSA is unable to delay the enactment based on statutes within the PSEA, NHTSA should inform the United States Congress that additional time to complete this rulemaking is required in order to allow for completion of the GTR so that a harmonized regulation can be achieved.

Alliance/Global commented that in accordance with the QRTV Terms of Reference, the development of the GTR should be concluded in the fall of 2014, with status reports provided along the way so that the public can monitor the status of the activity. Alliance/Global explained that the benefits of having consensus on a global technical regulation are enormous and any potential downside related to allowing an accelerated GTR process to conclude prior to finalizing the NHTSA regulation will be negligible given that a majority of current production EVs and HVs are already voluntarily equipped with audible pedestrian alert systems.

EU, VW, Chrysler, and Alliance/Global all supported using the GTR process to finalize any remaining technical issues towards a globally harmonized standard.

WBU and MB supported using the NPRM as a basis for development of the WP.29 GTR.

Agency Response to Comments

The NPRM stated that the recommendations of the QRTV informal working group do not include objective criteria with which the agency could ensure vehicles comply with an FMVSS. The agency maintains that this is still the case. Further, as discussed above, the agency has determined that a crossover speed of 30 km/h is necessary because our conclusion from the data we have acquired to date from all sources (*i.e.,* from commenters and from our own vehicle evaluations) is that some hybrid and electric vehicles continue to need sound enhancement at speeds above 20 km/h in order to ensure that they are adequately detectable.

Most of the commenters recommended that the agency wait until the WP.29 World Forum can complete development of a GTR for minimum sound levels, or, at a minimum, work closely with the QRTV in development of requirements that could be recognized globally. The agency, through its leadership role in the QRTV informal group, continues to work with the international community in development of criteria that are technically sound and objective. We note that the WP.29 QRTV work has been extended until late 2015, at the earliest, with expected eventual adoption of a GTR on minimum noise requirements for electrically driven vehicles. Adoption of the GTR is only the beginning of the process of regulating minimum noise levels by signatories of the 1998 UN agreement. After a GTR on minimum noise requirements is adopted, NHTSA would still need to issue an NPRM or an SNPRM (Supplemental Notice of Proposed Rulemaking) to begin the process of adopting the GTR as an FMVSS. This could result in several additional years of delay before an FMVSS mandating sound for EVs and HVs could be issued. We do not believe that a delay of this length is justified from a safety perspective. We believe the agency's approach in development of this final rule to be consistent with both the mission and safety goals of the agency and with the PSEA and Safety Act.

We agree with WBU and MB that development of U.S. regulations for minimum noise levels might aid WP.29 in addressing some of the technical issues that hinder development of a global regulation that is both measurable and enforceable. We note that the leadership role of the U.S. delegation in development of a global regulation for minimum noise levels is consistent with the comments regarding using the GTR process to refine a harmonized regulation. In that light, we believe that development of a U.S. regulation would aid WP.29 in drafting a global regulatory framework that is both measureable and enforceable.

The agency has also continued to actively monitor the work that has been done internationally by SAE and ISO. The SAE recently issued an updated version of J2889–1 dated December 2014. The ISO recently submitted the latest draft of ISO 16254 to the agency's docket.[164] The agency has taken into consideration these documents to the extent possible for the development of this final rule.

[164] NHTSA–2011–0148–0334.

**V. Analysis of Costs, Benefits, and Environmental Effects**

*A. Benefits*

As stated above in the discussion of the statistical analysis of safety need done for this rulemaking (see Section II.B), the data from 16 states cannot be used to directly estimate the national problem size. Also, an analysis of pedestrian fatalities rather than injuries is not appropriate for this rulemaking. The target population analysis will therefore focus on injuries only.

The PSEA directs NHTSA to establish minimum sound requirements for EVs and HVs as a means of addressing the increased rate of pedestrian crashes for these vehicles. In calculating the benefits of this rulemaking we have assumed that adding sound to EVs and HVs will bring the pedestrian crash rates for these vehicles in line with the pedestrian crash rates for ICE vehicles because the minimum sound requirements in the proposed rule would ensure that EVs and HVs are at least as detectable to pedestrians as ICE vehicles. This approach assumes that EVs and HVs have higher pedestrian crash rates than ICE vehicles because of the differences in sound levels produced by these vehicles. Therefore, the target population for this rulemaking is the number of crashes that would be avoided if the crash rates for hybrid and electric vehicles were the same as the crash rate for ICE vehicles.

No quantifiable benefits are estimated for EVs because we assume that EV manufacturers would have added alert sounds to their cars in the absence of this proposed rule and the PSEA.

NHTSA was not able to directly measure the safety differences between hybrids with and without sound. Although there are now some hybrids in the market that produce sounds to alert pedestrians and pedalcyclists, the agency is unable to directly measure the effectiveness rate of sound by using data from these new hybrid vehicles because there is not sufficient crash data on new model hybrid vehicles with sound to be able to make a statistically significant comparison to hybrids without sound. The agency's data base for low speed injuries is a sample, and data on crashes involving hybrid vehicles that emit sound is limited. Furthermore, the data set used to analyze differences in crash rates for this rulemaking consists of crash data from 16 states. At this time, only half of the states have submitted data for the 2012 or later calendar years. Since we believe that most hybrid vehicles have been equipped with some type of alert sound only since 2012, any effect that voluntary adoption would have on pedestrian crash rates would not be captured by this data set. In addition, none of the recently introduced hybrids with sounds were designed to meet all of the requirements in this rule. Therefore, any change in crash rate between original quiet HVs and these voluntarily-equipped HVs would not necessarily be indicative of the full safety benefits of compliant sounds.

NHTSA has also been unable to directly measure the pedestrian and pedalcyclist crash rates per mile travelled for HVs and EVs to the rates for ICEs because the agency does not have data on VMT for HVs and EVs. To calculate the difference in crash rates between HVs and ICEs NHTSA computes the ratio of the number of pedestrian and pedalcyclist crashes involving HVs to the number of other types of accidents involving HVs and compares it to a similar ratio for ICEs. While this is a standard technique in analyzing crash risk, it does raise a problem in this case because NHTSA was not able to control for VMT. NHTSA assumes that any difference in these ratios is attributable to the lack of sound in HVs. However, it is possible that there are other explanations for differences. For example, there may be reasons other than sound for why HVs have higher numbers of pedestrian and pedalcyclist accidents. Or there may be reasons why ICEs have higher numbers of other types of accidents.[165] This could result in a lower ratio for ICEs even if the two types of vehicles had similar pedestrian and pedalcyclist crash rates.

The first step in NHTSA's analysis was to use injury estimates from the 2006–2012 National Automotive Sampling System—General Estimates System (NASS–GES) and both 2007 and 2008–2011 Not in Traffic Surveillance (NiTS) database to provide an average estimate for combined in-traffic and relevant not-in-traffic crashes. In order to combine the GES and NiTS data in a meaningful way, it was assumed that the ratio of GES to NiTS will be constant for all years 2006 to 2012.

Because both the GES and NiTS databases rely on police-reported crashes, these databases do not accurately reflect all vehicle crashes involving pedestrians because many of these crashes are not reported to the police. The agency estimates that the number of unreported crashes for pedestrians is equal to 100.8 percent of the reported crashes. That is to say, for every 100 police-reported pedestrian crashes, there exist 100.8 additional unreported pedestrian crashes.

Table 20 shows the reported and unreported crashes by injury severity. Only injury counts will be examined for the purpose of benefits calculations and, as such, fatalities and uninjured (MAIS 0) counts are not included.

TABLE 20—ESTIMATED ANNUAL QUIET CARS TARGET POPULATION INJURIES REPORTED (GES 2006–2012, NITS 2007, 2008–2011) AND UNREPORTED PEDESTRIANS AND PEDALCYCLISTS, BY VEHICLE

| MAIS level | 1 | 2 | 3 | 4 | 5 | TOTAL 1–5 |
|---|---|---|---|---|---|---|
| **Reported (GES+NiTS) and Unreported Injured Pedestrians** | | | | | | |
| Passenger Car (PC) | 69,453 | 11,093 | 2,249 | 529 | 214 | 83,538 |
| Light Trucks & Vans (LTV) | 47,604 | 7,852 | 1,629 | 387 | 156 | 57,626 |
| Total Light Vehicles (PC+LTV) | 117,056 | 18,945 | 3,877 | 916 | 370 | 141,164 |
| **Reported (GES+NiTS) and Unreported Injured Pedalcyclists** | | | | | | |
| MAIS level | 1 | 2 | 3 | 4 | 5 | TOTAL 1–5 |
| Passenger Car (PC) | 42,943 | 6,148 | 1,082 | 239 | 84 | 50,495 |
| Light Trucks & Vans (LTV) | 26,932 | 3,957 | 715 | 160 | 56 | 31,820 |
| Total Light Vehicles (PC+LTV) | 69,875 | 10,105 | 1,796 | 400 | 140 | 82,315 |

The estimates in Table 20 are based on the current make-up of the fleet for all propulsion types. Next, we make the assumption that because the hybrid and electric vehicles pose a higher risk of pedestrian collisions, each hybrid and electric vehicle is producing more injuries per year than their ICE counterparts. Thus, while the 2006–2012 time period resulted in 141,164 pedestrian injuries annually, this injury count is the result of the mixed hybrid/electric/ICE fleet during that period. Based on the odds ratios from our crash analysis, we can calculate what size of theoretical ICE-only fleet would have been needed to generate as many injuries during that same time period.

The estimated injuries in Table 21 and Table 22 are created by combining the estimated percentage of annual sales of hybrid and electric vehicles for MY2020 from Table 23 with the odds ratio of 1.18, representing the increased risk of an HV being involved in a pedestrian crash, and the odds ratio of 1.51, representing the increased risk of an HV being involved in a pedalcyclist crash.[166] Thus, when considering pedestrians injured by MY2020 vehicles and assuming these pedestrian crashes occurred because the pedestrians failed to detect these vehicles by hearing, the rulemaking applies to the 877 injury difference between that theoretical ICE-only fleet (140,663 injuries) and the estimated lifetime injuries from the MY2020 fleet (141,567). Given the effectiveness assumption of 97 percent, the rulemaking addresses 850 of those 877 injuries. When considering pedalcyclists injured by MY2020 vehicles, the rulemaking is applied to the 1,514 injury difference between that theoretical fleet (81,455 injuries) and the estimated lifetime injuries from the MY2020 fleet (83,015). Given our assumption that the pedestrian and pedalcyclists crash rates for LSVs without sound is similar to that for other types of light vehicles without sound, the rule would also reduce pedestrian injuries by 4 over the lifetime of the MY2020 fleet of LSVs and

[165] For example, HLDI compared overall rates of injury for hybrid vehicles and their ICE non-hybrid twins and found that crash rates are lower for hybrids. HLDI concluded that the heavier weight of hybrids was an important factor in this lower overall crash rate for hybrids. Highway Loss Data Institute. ''Injury Odds and Vehicle Weight Comparison of Hybrids and Conventional Counterparts.'' HLDI Bulletin 28(10). Arlington, VA, 2011.

[166] Wu, J. (2015). Updated Analysis of Pedestrian and Pedalcyclist Crashes by Hybrid Vehicles with Larger Samples and Multiple Risk Factors. Washington, DC: National Highway Traffic Safety Administration.

pedalcyclist injuries by 7 over the lifetime of the MY2020 fleet of LSVs.

TABLE 21—ENHANCED INJURY RATE (EIR) FOR PEDESTRIANS FOR 2020 MODEL YEAR [167]

| | Mild hybrids (%) | Strong hybrids (%) | EVs + fuel cell (%) | ICEs (%) | Total (%) | Injuries assuming 100% ICE fleet | Injuries assuming predicted fleet | Injury difference | Benefits |
|---|---|---|---|---|---|---|---|---|---|
| Passenger Car | 6.94 | 6.86 | 0.21 | 87.02 | 101.03 | 83,101 | 83,953 | 853 | 827 |
| Light Trucks & Vans | 7.97 | 0.59 | 0.08 | 91.45 | 100.09 | 57,563 | 57,614 | 51 | 50 |
| Total | | | | | | 140,663 | 141,567 | 904 | 877 |

TABLE 22—ENHANCED INJURY RATE (EIR) FOR PEDALCYCLISTS FOR 2020 MODEL YEAR [168]

| | Mild hybrids (%) | Strong hybrids (%) | EVs + fuel cell (%) | ICEs (%) | Total (%) | Injuries assuming 100% ICE fleet | Injuries assuming predicted fleet | Injury difference | Benefits |
|---|---|---|---|---|---|---|---|---|---|
| Passenger Car | 6.94 | 8.80 | 0.21 | 87.02 | 102.97 | 49,737 | 51,215 | 1,479 | 1,434 |
| Light Trucks & Vans | 7.97 | 0.76 | 0.08 | 91.45 | 100.26 | 31,719 | 31,800 | 81 | 79 |
| Total | | | | | | 81,455 | 83,015 | 1,560 | 1,514 |

As discussed in the Final Regulatory Impact Analysis (FRIA), MAIS injury levels are converted to dollar amounts. The benefits across passenger cars, LTVs, and LSVs of reducing 2,401 pedestrian and pedalcyclist injuries, or 32 undiscounted equivalent lives saved (19.80 equivalent lives at the 7-percent discount rate and 25.64 at the 3-percent discount rate), is estimated to be $320 million at the 3-percent discount rate and $247.5 million at the 7-percent discount rate.

The agency calculated the benefits of this rule by calculating the ''injury differences'' between ICE vehicles and HVs. The ''injury differences'' assume that the difference between crash rates for ICEs and non-ICEs is explained wholly by the difference in sounds produced by these two vehicle types of vehicles and the failure of pedestrians and pedalcyclists to detect these vehicles by hearing. It is possible that there are other factors responsible for some of the difference in crash rates, which would mean that adding sound to hybrid and electric vehicles would not reduce pedestrian and pedalcyclist crash rates for hybrids to that of ICE vehicles. Based on research conducted by NHTSA's VOPLE Center,[169] NHTSA also assumes the sound added to hybrid and electric vehicles will be 97-percent effective in providing warning to pedestrians as the sound produced by a vehicle's ICE.

In addition to the benefits in injury reduction due to this rule, there is also the benefit to blind and visually impaired individuals of continued independent mobility. The increase in navigational ability resulting from this rule is hard to quantify and thus this benefit is mentioned but not assigned a specific productivity or quality of life monetization. By requiring alert sounds on hybrid and electric vehicles, blind pedestrians will be able to navigate roads as safely and effectively as if the fleet were entirely ICE vehicles. The benefit of independent navigation leads to the ability to travel independently and will, therefore, also lead to increased employment and the ability to live independently.

*B. Costs*

Based on Ward's Automotive Yearbook 2014,[170] there were 597,035 hybrid engine installations in light vehicles (96 percent were in passenger cars and 4 percent were in light trucks) sold in MY2013, which accounts for 3.5 percent of the total 17.2 million MY2013 light vehicles. There were a smaller number of MY2013 electric vehicles: 17,480 passenger cars and 1,046 LTVs, representing 0.1 percent of the overall sales. The Annual Energy Outlook (AEO) for 2014 provides future estimates of the fleet broken down into hybrid and electric vehicles.[171] The number of vehicles that the agency projects will be required to meet the standard is shown in Table 23.

TABLE 23—ESTIMATED/PREDICTED HYBRID AND ELECTRIC VEHICLE SALES PROPOSED TO BE REQUIRED TO PROVIDE AN ALERT SOUND

| | Estimated 2013 sales source: Ward's | Predicted 2020 sales source: AEO & NHTSA |
|---|---|---|
| Low-Speed Vehicles | 1,500 | 2,500 |

[167] Table values may not add up to the correct total due to rounding.

[168] Table values may not add up to the correct value due to rounding.

[169] See ''Robustness'' discussion in Section III.E.

[170] *Ward's Automotive Yearbook CD.* Path: \2014 YB CDROM\5. North America\c. U.S. Auto Industry\3. Engines\Engines by Type.xls

[171] In calculating the costs of this rule the agency only included those vehicles that can operate solely via the vehicle's electric motor. The agency did not included ''micro hybrids'' whose ICE is always running when the vehicle is motion when calculating the costs of this rule.

TABLE 23—ESTIMATED/PREDICTED HYBRID AND ELECTRIC VEHICLE SALES PROPOSED TO BE REQUIRED TO PROVIDE AN ALERT SOUND—Continued

| | Estimated 2013 sales source: Ward's | Predicted 2020 sales source: AEO & NHTSA |
|---|---|---|
| Light Vehicles Electric | 18,526 | 15,020 |
| Light Vehicles Fuel Cells | 0 | 5,606 |
| Light Vehicles Hybrid | 597,035 * | 506,701 |
| *Light Vehicles subtotal* | 594,061 | 527,327 |
| Total Sales | 602,061 | 561,327 |

* **Note**—This estimate of vehicle sales includes micro-hybrids which the rule does not apply to. This overestimation of hybrid vehicle sales is addressed in the MY2020 column, where propulsion source is provided by AEO.

The Nissan Leaf and other fully electric vehicles come equipped with an alert sound system. Based on what manufacturers have voluntarily provided in their fully electric vehicles, the agency assumes that fully electric vehicles and hydrogen fuel-cell vehicles will provide an alert sound system voluntarily and, therefore, for costing purposes we assumed a small upgrade cost in order to bring these existing systems up to compliance. In addition, we assume that some hybrid light vehicles, particularly those manufactured by Toyota, come equipped with some form of speaker system, similar to the ones expected to be found on electric vehicles. Furthermore, *www.energy.gov* data indicates that these partially-equipped light vehicles make up about 67% of the hybrids that fall under the rule. Thus, the number of light vehicles that have to add (or upgrade) an alert sound system for costing purposes for MY2020 is 561,327 vehicles.

Based on informal discussions with suppliers and industry experts, in addition to confidential documents provided to the agency, we estimate that the total consumer cost for a system that produces sounds meeting the requirement of this rule is $125.34 per hybrid light vehicle. In cases where a sound system already exists on a light vehicle (hybrid vehicles voluntarily equipped, electric vehicles, and fuel cell vehicles), we assume a cost of $50.49. This estimate includes the cost of a dynamic speaker system that is packaged for protection from the elements and that is attached with mounting hardware and wiring in order to power the speaker(s) and receive signal inputs, and a digital signal processor that receives information from the vehicle regarding vehicle operating status (to produce sounds dependent upon vehicle speed, for example.) We assume there will be no other structural changes or installation costs associated with complying with the rule's requirements. We believe the same system can be used for both LSVs and light vehicles. We estimate that the added weight of the system would increase fuel costs for light vehicles by about $4 to $5 over the lifetime of the vehicle. Average vehicle costs reflect the different installation costs determined by propulsion source and vehicle make as described above.

TABLE 24—COST SUMMARY (IN $M, 2013 ECONOMICS)

| | 3% Discount rate ($) | 7% Discount rate ($) |
|---|---|---|
| Per vehicle costs: | | |
| Passenger Cars, Per Vehicle * | $79.06 | $78.16 |
| Light Trucks, Per Vehicle * | 77.27 | 76.17 |
| Low Speed Vehicles (LSVs), Per Vehicle * | 78.91 | 77.99 |
| Total Cost by Vehicle Type:. | | |
| Passenger Cars | 38.2M | 37.8M |
| Light Trucks | 3.6M | 3.5M |
| Light Vehicles, PCs + LTVs Subtotal | 41.8M | 41.3M |
| Low Speed Vehicles (LSVs) | 0.3M | 0.3M |
| Total (PC + LTV + LSV) | 42.1M | 41.6M |

In addition to the quantifiable costs discussed above, there may be a cost of adding sound to quiet vehicles to owners who value quietness of vehicle operation and to society at large. NHTSA is not aware of a method to quantify the value of quietness for a driver's own vehicle. Some sound from these systems may intrude into the passenger compartment. The use of multiple speakers with directional characteristics might mitigate these costs. Sound insulation also can counteract interior noise, and a sensitivity analysis for sound insulation cost is provided in the accompanying FRIA.

As explained further in the Environmental Assessment (EA), we expect that the increase in noise from the alert sound will be no louder than that from an average ICE vehicle and that aggregate sound from these vehicles will not create an appreciable increase over current noise levels. Given the low increase in overall noise caused by this rule, we expect that any costs that may exist due to added sound will be minimal. NHTSA has not found any way to value the increase in noise to society at large, and, thus it is a non-quantified cost.

*C. Comparison of Costs and Benefits*

Comparison of costs and benefits expected due to this rule provides a savings of $0.4 million per equivalent life saved to a cost of $0.04 million per equivalent life saved across the 3-percent and 7-percent discount levels. This falls under NHTSA's value of a statistical life of $10.8 million, (for MY2020) and therefore this rulemaking is assumed to be cost beneficial. Since the lifetime monetized benefits (VSL+Economic) of MY2020 light vehicles (and LSVs) is expected to be between $197.6M and $244.9M, the net impact of the rule on light vehicles and LSVs is a positive one, even with the estimated $46 million required to install speakers [172] and $3 million in lifetime fuel costs.

TABLE 25—DISCOUNTED BENEFITS (PC+LTV) MY2020, 2013$

| | Total PED + CYC | |
|---|---|---|
| | Total Monetized Benefits | Total ELS |
| 3% discount | | |
| (PC) | $301,146,801 | 24.25 |
| (LTV) | 17,381,812 | 1.39 |
| Total | 318,528,614 | 25.64 |
| 7% discount | | |
| (PC) | 233,031,924 | 18.74 |
| (LTV) | 13,258,335 | 1.06 |
| Total | 246,290,259 | 19.80 |

TABLE 26—TOTAL COSTS (PC+LTV) 2013$

| | Total cost/veh | Total costs |
|---|---|---|
| 3% discount | | |
| (PC) | $79.06 | $38,223,782 |
| (LTV) | 77.27 | 3,587,400 |
| Total | 78.91 | 41,811,182 |
| 7% discount: | | |
| (PC) | 78.16 | 37,788,667 |
| (LTV) | 76.17 | 3,536,329 |
| Total | 77.99 | 41,324,996 |

TABLE 27—NET IMPACTS (PC+LTV) 2013$

| | Net impact/veh | Net impact | Net costs/ELS (in $M) |
|---|---|---|---|
| 3% Discount | | | |
| (PC) | $543.83 | $262,923,019 | −0.1 |
| (LTV) | 297.12 | 13,794,413 | 0.93 |
| Total | 522.22 | 276,717,432 | −0.04 |
| 7% Discount | | | |
| (PC) | 403.84 | 195,243,258 | 0.33 |
| (LTV) | 209.40 | 9,722,005 | 1.67 |
| Total | 386.81 | 204,965,263 | 0.4 |

The net impact of this rule on LSVs is also expected to be positive. The net benefits of the minimum sound requirements for these vehicles is $1,023,934 at the 3-percent discount rate and $788,953 at the 7-percent discount rate. Thus, the total net impact of the rule considering both the MY2016 light vehicle and LSV fleet is positive.

[172] Based on the assumption in this analysis that manufacturers will install speakers to meet the rule.

TABLE 28—COSTS AND SCALED BENEFITS FOR LSVS, MY2020 [173]

| Discount rate | Sales ratio LSV to light vehicle | Sales | Scaled costs | Scaled injuries (undisc.) | Scaled ELS | Scaled benefits | Scaled benefits minus scaled costs |
|---|---|---|---|---|---|---|---|
| 3% | 0.47% | 2,500 | $197,264 | 11.28 | 0.1210 | $1,189,469 | $1,305,543 |
| 7% | 0.47% | 2,500 | 194,970 | 11.28 | 0.0934 | 848,651 | 967,019 |

*D. Retrospective Review*

NHTSA has been unable to directly compare pedestrian and pedalcyclist crash rates for hybrids with and without sound because sufficient data is not yet available. As a result, we have not been able to directly determine whether lack of sound is the cause of the difference in pedestrian and pedalcyclist crash rates between hybrids and ICEs. For this reason, we intend conduct an expedited retrospective review of this rule once data are available. Although some hybrid manufacturers began putting alert sound in their vehicles around 2012, the state data from this period needed for our analysis is just starting to become available. While these voluntarily equipped vehicles will not be fully compliant with this rule, within the next four years we will conduct a preliminary study to determine whether adding sound eliminates some pedestrian and pedalcyclist crashes should we have sufficient data for such analysis. It will take several more years until data from fully compliant vehicles are available for analysis. Therefore, we expect to complete our retrospective review of this rule within eight years of when this rule is finalized. For LSVs, sufficient data may not be available and it may be necessary to use a Special Crash Investigation to determine whether adding sound makes these types of vehicles safer than those without sound should we be able to identify any such crashes.

*E. Environmental Assessment*

The agency has prepared an Environmental Assessment (EA) to analyze and disclose the potential environmental impacts of a reasonable range of minimum sound requirements for HVs and EVs, including a preferred alternative. The alternatives the agency analyzed include a No Action Alterative, under which the agency would not establish any minimum sound requirements for EVs/HVs, and two action alternatives. Under Alternative 2 (the final rule), the agency would require a sound addition at speeds at or below 30 km/h and would require that covered vehicles produce sound at the stationary but active operating condition. Under Alternative 3, the agency would require a minimum sound pressure level of 48 A-weighted dB for speeds at or below 20 km/h; there would be no sound requirement when the vehicle is stationary.

In order to determine the potential environmental impacts of the alternatives, NHTSA estimated the amount of travel covered by vehicles and changes in sound level projected to occur under each of the alternatives. NHTSA separately analyzed the projected environmental impacts of each of the three alternatives in both urban and non-urban environments because differences in population, vehicle speeds, and deployment of EVs/HVs in these areas could affect the potential environmental impacts. The EA calculates the potential noise impacts of the alternatives in two different ways.

In one analysis, NHTSA analyzed the potential for change in sound levels experienced by an individual listener near a roadway as a result of the final alternatives by single vehicle passes by. In the second analysis, NHTSA compared the sound levels experienced by a single listener among sets of vehicles with varying percentages of EVs/HVs when these vehicles were assumed to have no minimum sound requirement versus when producing the sound level specified under each of the action alternatives. For this analysis, NHTSA calculated the difference in sound perceived by a person standing either 7.5 or 15 meters (25 or 50 feet, respectively) away from the source to replicate the difference in sound between the alternatives experienced by a person standing near a busy roadway.

Our first analysis for both action alternatives suggest that in urban environments, a single listener would not perceive a noticeable difference in sound when standing 7.5 meters from the roadway compared to the no action alternative. In a non-urban environment, a single listener would not perceive a noticeable difference under Alternative 3, but under the Preferred Alternative a single listener would perceive a noticeable difference in sound level when standing 7.5 meters from the roadway compared to the no action alternative.

The results from second analysis show that changes in overall sound levels near a busy roadway for either action alternative compared to the No Action Alternative would not exceed 3 dB, the commonly used threshold for noticeability by human listeners, even assuming that up to 20% of vehicles on the road are EVs/HVs, which is nearly three times the deployment level currently projected for 2035. When non-urban or urban ambient sound levels are taken into account, the perceived sound level change is further reduced to well under the 3 dB threshold.

In addition to analyzing the projected impact of the action alternatives on an individual listener, NHTSA computed the magnitude of the change in sound levels nationally as a result of the alternatives. This analysis takes into account the National Household Travel Survey (NHTS) distribution of trip miles, the Annual Energy Outlook (AEO) forecast of the deployment of EVs/HVs, and Environmental Protection Agency (EPA) drive cycle speed distributions. Because the action alternatives would only affect specific vehicles in certain operating conditions, this analysis calculates the total U.S. vehicle operations affected by the action alternatives as a proportion of total U.S. vehicle operations, and analyzes the overall change in sound levels projected to occur as a result of the action alternatives.

Based on this analysis of national impacts, NHTSA projects that under the Preferred Alternative, 2.3 percent of all urban U.S. light duty vehicle hours travelled and 0.3 percent of all non-urban U.S. light duty vehicle hours travelled potentially would be impacted by the minimum sound requirement. Under Alternative 3, NHTSA projects that 0.9 percent of all urban U.S. light duty vehicle hours and 0.1 percent of all nonurban U.S. light duty vehicle hours potentially would be impacted by the minimum sound requirement.

[173] Scaled benefits and costs for low speed vehicles are estimated to be directly proportional to light vehicles based on sales. Scaled costs include both installation costs for the system and fuel costs.

Given the extremely small percentage of vehicle hours travelled impacted by this rule and the fact the sounds under the final rule would only be noticeable to a single listener standing 7.5 meters from the roadway under the single vehicle pass by condition, the environmental impacts of the final rule are expected to be negligible. In addition, the EA anticipates no or negligible additional impacts on wildlife; topography, geology, and soils; hazardous materials, hazardous waste, and solid waste; water resources; historical and archeological resources; farmland resources; air quality and climate; and environmental justice populations.

## VI. Regulatory Notices and Analyses

*Executive Order (E.O.) 12866 (Regulatory Planning and Review), E.O. 13563, and DOT Regulatory Policies and Procedures*

The agency has considered the impact of this rulemaking action under E.O. 12866, E.O. 13563, and the Department of Transportation's regulatory policies and procedures. This action was reviewed by the Office of Management and Budget under E.O. 12866. This action is ''significant'' under the Department of Transportation's regulatory policies and procedures (44 FR 11034; February 26, 1979).

This action is significant because it is the subject of congressional interest and because it is a mandate under the PSEA. The agency has prepared and placed in the docket a Final Regulatory Impact Analysis.

We estimate the total fuel and installation costs of this rule to the light EV, HV and LSV fleet to be $41.8M at the 3-percent discount rate and $41.3M at the 7-percent discount rate. We estimate that the impact of this rule in pedestrian and pedalcyclist injury reduction in light vehicles and LSVs will be 30.69 equivalent lives saved at the 3-percent discount rate and 24.75 equivalent lives saved at the 7-percent discount rate. The benefits of applying this rule to light EVs and HVs are estimated to be $260.1 million at the 3-percent discount rate and $209.5 million at the 7-percent discount rate. Thus, this action is also significant because it has an annual economic impact greater than $100 million.

*Executive Order 13609: Promoting International Regulatory Cooperation*

The policy statement in Section 1 of Executive Order 13609 provides, in part:

> The regulatory approaches taken by foreign governments may differ from those taken by U.S. regulatory agencies to address similar issues. In some cases, the differences between the regulatory approaches of U.S. agencies and those of their foreign counterparts might not be necessary and might impair the ability of American businesses to export and compete internationally. In meeting shared challenges involving health, safety, labor, security, environmental, and other issues, international regulatory cooperation can identify approaches that are at least as protective as those that are or would be adopted in the absence of such cooperation. International regulatory cooperation can also reduce, eliminate, or prevent unnecessary differences in regulatory requirements.

We received several comments regarding the impact of the rulemaking schedule on the development of GTR of this topic. As discussed in Section IV of this notice, given the deadlines for issuing a final rule provided in the PSEA, the agency did not think that it would be feasible to delay issuing a final rule until after the GTR is completed.

NHTSA also received comments regarding the approach taken in guidelines developed by the UNECE and Japan regarding the crossover speed and whether HVs and EVs should be required to produce sound when they are not in motion. For the reasons discussed in Section III.D of this notice, we believe that a crossover speed of 30 km/h is necessary to ensure that blind, visually-impaired, and sighted pedestrians can safely detect EVs and HVs operating at low speeds. For the reasons discussed in Section III.C of this notice, we believe that EVs and HVs must produce sound when stationary with their gear selector is in any position other than park to prevent collisions and because of the language of the PSEA.

*National Environmental Policy Act*

Concurrently with this final rule, NHTSA is releasing a Final EA, pursuant to the National Environmental Policy Act, 42 U.S.C. 4321–4347, and implementing regulations issued by the Council on Environmental Quality (CEQ), 40 CFR part 1500, and NHTSA, 49 CFR part 520. NHTSA prepared the EA to analyze and disclose the potential environmental impacts of the requirements of the proposed action and a range of alternatives. The EA analyzes direct, indirect, and cumulative impacts and analyzes impacts in proportion to their significance.

Because this rule will increase the amount of sound produced by a certain segment of the vehicle fleet, the EA considers the possible impacts of increased ambient noise levels on both urban and rural environments. The EA also describes potential environmental impacts to a variety of resources including biological resources, waste, and environmental justice populations. The findings of the EA are summarized in Section V.D.

The Final EA is available in Docket No. NHTSA–2011–0100 at *http://www.regulations.gov/* as well as on NHTSA's Web site at *http://www.nhtsa.gov/*. Additionally, hard copies may be obtained by contacting Mike Pyne, Safety Standards Engineer, National Highway Traffic Safety Administration, 1200 New Jersey Ave. SE., Washington, DC 20590–0001.

I have reviewed the Final EA, which is hereby incorporated by reference. As described in that Final EA and summarized above, this rulemaking is anticipated to have no or negligible impacts on the human environment. Based on the Final EA, I conclude that implementation of any of the action alternatives (including the final rule) will not have a significant effect on the human environment and that a ''finding of no significant impact'' (*see* 40 CFR 1501.4(e)(1) and 1508.13) is appropriate. This statement constitutes the agency's ''finding of no significant impact,'' and an environmental impact statement will not be prepared.

*Regulatory Flexibility Act*

Pursuant to the Regulatory Flexibility Act (5 U.S.C. 601 *et seq.,* as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA) of 1996), whenever an agency is required to publish a notice of rulemaking for any proposed or final rule, it must prepare and make available for public comment a regulatory flexibility analysis that describes the effect of the rule on small entities (*i.e.,* small businesses, small organizations, and small governmental jurisdictions). The Small Business Administration's regulations at 13 CFR part 121 define a small business, in part, as a business entity ''which operates primarily within the United States.'' [174] No regulatory flexibility analysis is required if the head of an agency certifies the rule will not have a significant economic impact on a substantial number of small entities. SBREFA amended the Regulatory Flexibility Act to require Federal agencies to provide a statement of the factual basis for certifying that a rule will not have a significant economic impact on a substantial number of small entities.

In issuing this rule, I the undersigned hereby certify that this rule will not have a significant economic impact on a substantial number of small entities.

[174] 13 CFR 121.105(a).

We believe that the rulemaking will not have a significant economic impact on the small vehicle manufacturers because the systems are not technically difficult to develop or install and the cost of the systems between $50.49 and $125.34 is small in proportion to the overall vehicle cost for most small vehicle manufacturers.

This rule will directly affect motor vehicle manufacturers and final-stage manufacturers that produce EVs and HVs. The majority of motor vehicle manufacturers will not qualify as a small business. There are less than five manufacturers of light hybrid and electric vehicles that would be subject to the requirements of this proposal that are small businesses. Similarly, there are several manufacturers of low-speed vehicles that are small businesses.

Because the PSEA applies to all motor vehicles (except trailers) in its mandate to reduce quiet vehicle collisions with pedestrians, all of these small manufacturers that produce hybrid or electric vehicles are affected by the requirements in today's final rule. However, the economic impact upon these entities will not be significant for the following reasons.

(1) The cost of the systems is a small proportion of the overall vehicle cost for even the least expensive electric vehicles.

(2) This final rule provides a three year lead-time and allows small volume manufacturers the option of waiting until the end of the phase-in (September 1, 2018) to meet the minimum sound requirements.

*Executive Order 13132 (Federalism)*

NHTSA has examined today's rule pursuant to Executive Order 13132 (64 FR 43255, August 10, 1999) and concluded that no additional consultation with States, local governments or their representatives is mandated beyond the rulemaking process. The agency has concluded that the rulemaking would not have sufficient federalism implications to warrant consultation with State and local officials or the preparation of a federalism summary impact statement. The proposed rule would not have ''substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government.''

NHTSA rules can preempt in two ways. First, the National Traffic and Motor Vehicle Safety Act contains an express preemption provision: When a motor vehicle safety standard is in effect under this chapter, a State or a political subdivision of a State may prescribe or continue in effect a standard applicable to the same aspect of performance of a motor vehicle or motor vehicle equipment only if the standard is identical to the standard prescribed under this chapter. 49 U.S.C. 30103(b)(1). It is this statutory command by Congress that preempts any non-identical State legislative and administrative law addressing the same aspect of performance.

The express preemption provision described above is subject to a savings clause under which ''[c]ompliance with a motor vehicle safety standard prescribed under this chapter does not exempt a person from liability at common law.'' (49 U.S.C. 30103(e)). Pursuant to this provision, State common law tort causes of action against motor vehicle manufacturers that might otherwise be preempted by the express preemption provision are generally preserved. However, the Supreme Court has recognized the possibility, in some instances, of implied preemption of such State common law tort causes of action by virtue of NHTSA's rules, even if not expressly preempted. This second way that NHTSA rules can preempt is dependent upon there being an actual conflict between an FMVSS and the higher standard that would effectively be imposed on motor vehicle manufacturers if someone obtained a State common law tort judgment against the manufacturer, notwithstanding the manufacturer's compliance with the NHTSA standard. Because most NHTSA standards established by an FMVSS are minimum standards, a State common law tort cause of action that seeks to impose a higher standard on motor vehicle manufacturers will generally not be preempted. However, if and when such a conflict does exist—for example, when the standard at issue is both a minimum and a maximum standard—the State common law tort cause of action is impliedly preempted. See Geier v. American Honda Motor Co., 529 U.S. 861 (2000).

Pursuant to Executive Order 13132 and 12988, NHTSA has considered whether this rule could or should preempt State common law causes of action. The agency's ability to announce its conclusion regarding the preemptive effect of one of its rules reduces the likelihood that preemption will be an issue in any subsequent tort litigation.

To this end, the agency has examined the nature (*e.g.,* the language and structure of the regulatory text) and objectives of today's rule and finds that this rule, like many NHTSA rules, prescribes only a minimum safety standard. As such, NHTSA does not intend that this rule preempt state tort law that would effectively impose a higher standard on motor vehicle manufacturers than that established by today's final rule. Establishment of a higher standard by means of State tort law would not conflict with the minimum standard promulgated here. Without any conflict, there could not be any implied preemption of a State common law tort cause of action.

*Executive Order 12988 (Civil Justice Reform)*

With respect to the review of the promulgation of a new regulation, Section 3(b) of Executive Order 12988, ''Civil Justice Reform'' (61 FR 4729; Feb. 7, 1996), requires that Executive agencies make every reasonable effort to ensure that the regulation: (1) Clearly specifies the preemptive effect; (2) clearly specifies the effect on existing Federal law or regulation; (3) provides a clear legal standard for affected conduct, while promoting simplification and burden reduction; (4) clearly specifies the retroactive effect, if any; (5) specifies whether administrative proceedings are to be required before parties file suit in court; (6) adequately defines key terms; and (7) addresses other important issues affecting clarity and general draftsmanship under any guidelines issued by the Attorney General. This document is consistent with that requirement.

Pursuant to this Order, NHTSA notes as follows. The issue of preemption is discussed above. NHTSA notes further that there is no requirement that individuals submit a petition for reconsideration or pursue other administrative proceedings before they may file suit in court.

*Unfunded Mandates Reform Act*

Section 202 of the Unfunded Mandates Reform Act of 1995 (UMRA) requires federal agencies to prepare a written assessment of the costs, benefits, and other effects of proposed or final rules that include a Federal mandate likely to result in the expenditure by State, local, or tribal governments, in the aggregate, or by the private sector, of more than $100 million annually (adjusted for inflation with base year of 1995). Adjusting this amount by the implicit gross domestic product price deflator for 2010 results in $136 million (110.659/81.536 = 1.36).

As noted previously, the agency has prepared a detailed economic assessment in the FRIA. We estimate the annual total fuel and installation costs of this final rule to the light EV, HV and LSV fleet to be $41.8 million at the 3-

percent discount rate and $41.3 million at the 7-percent discount rate. Therefore, this rule is not expected to result in the expenditure by State, local, or tribal governments, in the aggregate, or by the private sector, of more than $136 million annually.

**Paperwork Reduction Act**

Under the Paperwork Reduction Act of 1995, a person is not required to respond to a collection of information by a Federal agency unless the collection displays a valid OMB control number. The final rule contains reporting requirements so that the agency can determine if manufacturers comply with the phase in schedule.

In compliance with the PRA, this notice announces that the Information Collection Request (ICR) abstracted below has been forwarded to OMB for review and comment. The ICR describes the nature of the information collections and their expected burden. This is a request for new collection.

*Agency:* National Highway Traffic Safety Administration (NHTSA).

*Title:* 49 CFR part 575.141, Minimum Sound Requirements for Hybrid and Electric Vehicles.

*Type of Request:* New collection.

*OMB Clearance Number:* Not assigned.

*Form Number:* The collection of this information will not use any standard forms.

*Requested Expiration Date of Approval:* Three years from the date of approval.

*Summary of the Collection of Information:* This collection would require manufacturers of passenger cars, multipurpose passenger vehicles, trucks, buses, and low speed vehicles subject to the phase-in schedule to provide motor vehicle production data for one year: September 1, 2018 to August 31, 2019.

*Description of the Need for the Information and Use of the Information:* The purpose of the reporting requirements will be to aid NHTSA in determining whether a manufacturer has complied with the requirements of Federal Motor Vehicle Safety Standard No. 141, *Minimum Sound for Hybrid and Electric Vehicles,* during the phase-in of those requirements.

*Description of the Likely Respondents (Including Estimated Number, and Proposed Frequency of Response to the Collection of Information):* The respondents are manufacturers of hybrid and electric passenger cars, multipurpose passenger vehicles, trucks, buses, and low-speed vehicles with a GVWR of 4,536 kg (10,000 lbs.) or less. The agency estimates that there are approximately 21 such manufacturers. The proposed collection would occur one per year.

*Estimate of the Total Annual Reporting and Recordkeeping Burden Resulting from the Collection of Information:* NHTSA estimates that the total annual burden is 42 hours (2 hours per manufacturer per year).

Comments are invited on:

• Whether the collection of information is necessary for the proper performance of the functions of the Department, including whether the information will have practical utility.

• Whether the Department's estimate for the burden of the information collection is accurate.

• Ways to minimize the burden of the collection of information on respondents, including the use of automated collection techniques or other forms of information technology.

A comment to OMB is most effective if OMB receives it within 30 days of publication. Send comments to the Office of Information and Regulatory Affairs, Office of Management and Budget, 725 17th Street NW., Washington, DC 20503, Attn: NHTSA Desk Officer. PRA comments are due within 30 days following publication of this document in the **Federal Register**.

The agency recognizes that the collection of information contained in today's final rule may be subject to revision in response to public comments and the OMB review.

**Executive Order 13045**

Executive Order 13045 [175] applies to any rule that: (1) Is determined to be economically significant as defined under E.O. 12866, and (2) concerns an environmental, health or safety risk that NHTSA has reason to believe may have a disproportionate effect on children. If the regulatory action meets both criteria, we must evaluate the environmental health or safety effects of the proposed rule on children, and explain why the proposed regulation is preferable to other potentially effective and reasonably feasible alternatives considered by us.

This rule will not pose such a risk for children. The primary effects of this rule are to ensure that hybrid and electric vehicles produce enough sound so that pedestrians can detect them. We expect this rule to reduce the risk of injuries to children and other pedestrians.

**National Technology Transfer and Advancement Act**

Section 12(d) of the National Technology Transfer and Advancement Act (NTTAA) requires NHTSA to evaluate and use existing voluntary consensus standards in its regulatory activities unless doing so would be inconsistent with applicable law (*e.g.,* the statutory provisions regarding NHTSA's vehicle safety authority) or otherwise impractical.

Voluntary consensus standards are technical standards developed or adopted by voluntary consensus standards bodies. Technical standards are defined by the NTTAA as ''performance-based or design-specific technical specification and related management systems practices.'' They pertain to ''products and processes, such as size, strength, or technical performance of a product, process or material.''

Examples of organizations generally regarded as voluntary consensus standards bodies include the American Society for Testing and Materials (ASTM), the Society of Automotive Engineers (SAE), and the American National Standards Institute (ANSI). If NHTSA does not use available and potentially applicable voluntary consensus standards, we are required by the Act to provide Congress, through OMB, an explanation of the reasons for not using such standards.

The agency uses certain parts of voluntary consensus standard SAE J2889–1, *Measurement of Minimum Noise Emitted by Road Vehicles,* in the test procedure contained in this final rule. SAE J2889–1 only contains measurement procedures and does not contain any minimum performance requirements. The agency did not use any voluntary consensus standards for the minimum acoustic requirements contained in today's final rule because no such voluntary consensus standards exist. The agency added additional test scenarios other than those contained in SAE J2889–1 because those additional test scenarios address aspects of performance not covered in that standard.

The agency also used voluntary consensus standard ISO 10844 ''Acoustics—Test Surface for Road Vehicle Noise Measurements,'' to specify the road surface to be used for compliance testing under this standard. We also used ANSI S1.11 ''Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters,'' to specify the filter roll-offs to be used during the analyses of data collected during compliance testing.

**Incorporation by Reference**

As discussed earlier in the relevant portions of this document, we are incorporating by reference various

[175] 62 FR 19885 (Apr. 23, 1997).

materials into the Code of Federal Regulations in this rulemaking. The standards we are incorporating are ANSI S1.11–2004, ''Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters,'' the 1994, 2011, and 2014 versions of ISO 10844 [176] and SAE Standard J2889–1 Dec. 2014, ''Measurement of Minimum Noise Emitted by Road Vehicles,''

Under 5 U.S.C. 552(a)(1)(E), Congress allows agencies to incorporate by reference materials that are reasonably available to the class of persons affected if the agency has approval from the Director of the Federal Register. As a part of that approval process, the Director of the Federal Register (in 1 CFR 51.5) directs agencies to discuss (in the preamble) the ways that the materials we are incorporating by reference are reasonably available to interested parties.

NHTSA has worked to ensure that standards being considered for incorporation by reference are reasonably available to the class of persons affected. In this case, those directly affected by incorporated provisions are NHTSA and parties contracting with NHTSA to conduct testing of new vehicles. New vehicle manufacturers may also be affected to the extent they wish to conduct NHTSA's compliance test procedures on their own vehicles. These entities have access to copies of aforementioned standards through ANSI, ISO and SAE International for a reasonable fee. These entities have the financial capability to obtain a copy of the material incorporated by reference. Other interested parties in the rulemaking process beyond the class affected by the regulation include members of the public, safety advocacy groups, etc. Such interested parties can access the standard by obtaining a copy from the aforementioned standards development organizations.

Interested parties may also access the standards through NHTSA. All approved material is available for inspection at NHTSA, 1200 New Jersey Avenue SE., Washington, DC 20590, and at the National Archives and Records Administration (NARA). For information on the availability of this material at NHTSA, contact NHTSA's Office of Technical Information Services, phone number (202) 366–2588.

[176] The 1994 version of ISO 10844 is titled ''Acoustics—Test Surface for Road Vehicle Noise Measurements'' the 2011 and 2014 versions of ISO 10844 are titled ''Acoustics—Specification of test tracks for measuring noise emitted by road vehicles and their tyres.''

**Executive Order 13211**

Executive Order 13211 [177] applies to any rule that: (1) Is determined to be economically significant as defined under E.O. 12866, and is likely to have a significant adverse effect on the supply, distribution, or use of energy; or (2) that is designated by the Administrator of the Office of Information and Regulatory Affairs as a significant energy action. If the regulatory action meets either criterion, we must evaluate the adverse energy effects of the proposed rule and explain why the proposed regulation is preferable to other potentially effective and reasonably feasible alternatives considered by NHTSA.

This rule seeks to ensure that hybrid and electric vehicles are detectable by pedestrians. The average weight gain for a light vehicle is estimated to be 1.5 pounds (based upon a similar waterproof speaker used for marine purposes), resulting in 2.3 more gallons of fuel being used over the lifetime of a passenger car and 2.5 more gallons of fuel being used over the lifetime of a light truck. When divided by the life time of the vehicle (26 years for passenger cars and 36 years for light trucks) the yearly increase in fuel consumption attributed to this proposed rule would be negligible. Therefore, this proposed rule would not have a significant adverse effect on the use of energy. Accordingly, this rulemaking action is not designated as a significant energy action.

**Regulation Identifier Number (RIN)**

The Department of Transportation assigns a regulation identifier number (RIN) to each regulatory action listed in the Unified Agenda of Federal Regulations. The Regulatory Information Service Center publishes the Unified Agenda in April and October of each year. You may use the RIN contained in the heading at the beginning of this document to find this action in the Unified Agenda.

**List of Subjects in 49 CFR Part 571**

Imports, Incorporation by reference, Motor vehicle safety, Reporting and recordkeeping requirements, Tires.

**Regulatory Text**

In accordance with the forgoing, NHTSA is amending 49 CFR part 571 as follows:

[177] 66 FR 28355 (May 18, 2001).

## PART 571—FEDERAL MOTOR VEHICLE SAFETY STANDARDS

■ 1. The authority citation for part 571 continues to read as follows:

**Authority:** 49 U.S.C. 322, 30111, 30115, 30117, and 30166; delegation of authority at 49 CFR 1.95.

■ 2. In § 571.5:
■ a. Redesignate paragraphs (c)(1) through (4) as paragraphs (c)(2) through (5);
■ b. Add new paragraph (c)(1);
■ c. Add paragraphs (i)(2) through (4); and
■ d. Redesignate paragraph (l)(49) as paragrapgh (l)(50) and, and add new paragraah (l)(49).

The additions read as follows:

**§ 571.5 Matter incorporated by reference.**

* * * * *

(c) * * *

(1) ANSI S1.11–2004, ''Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters,'' approved February 19, 2004, into § 571.141.

* * * * *

(i) * * *

(2) ISO 10844:1994(E) ''Acoustics—Test Surface for Road Vehicle Noise Measurements,'' First edition, 1994–09–01, into § 571.141.

(3) ISO 10844: 2011(E) ''Acoustics—Specification of test tracks for measuring noise emitted by road vehicles and their tyres,'' Second edition, 2011–02–01 into § 571.141.

(4) ISO 10844: 2014(E) ''Acoustics—Specification of test tracks for measuring noise emitted by road vehicles and their tyres,'' Third edition, 2014–05–15 into § 571.141.

* * * * *

(l) * * *

(49) SAE Standard J2889–1, ''Measurement of Minimum Noise Emitted by Road Vehicles,'' December 2014 into § 571.141.

* * * * *

■ 3. Section 571.141 is added to read as follows:

**§ 571.141 Standard No. 141; Minimum Sound Requirements for Hybrid and Electric Vehicles.**

S1. *Scope.* This standard establishes performance requirements for pedestrian alert sounds for motor vehicles.

S2. *Purpose.* The purpose of this standard is to reduce the number of injuries that result from electric and hybrid vehicle crashes with pedestrians by providing a sound level and sound characteristics necessary for these vehicles to be detected and recognized by pedestrians.

S3. *Application.* This standard applies to—

(a) Electric vehicles with a gross vehicle weight rating (GVWR) of 4,536 Kg or less that are passenger cars, multipurpose passenger vehicles, trucks, or buses;

(b) Hybrid vehicles with a gross vehicle weight rating (GVWR) of 4,536 Kg or less that are passenger cars, multi-purpose passenger vehicles, trucks, or buses; and

(c) Electric vehicles and hybrid vehicles that are low speed vehicles.

*S4. Definitions. Band* or *one-third octave band* means one of thirteen one-third octave bands having nominal center frequencies ranging from 315 to 5000Hz. These are Bands 25 through 37 as defined in Table A1, Mid-band Frequencies for One-Third-Octave-Band and Octave-Band Filters in the Audio Range, of ANSI S1.11–2004: ''Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters'' (incorporated by reference, see § 571.5).

*Band sum* means the combination of Sound Pressure Levels (SPLs) from selected bands that produce an SPL representing the sound in all of these bands. Band sum is calculated with the following equation:

$$Band\ Sum = 10\ log_{10} \sum_{i=1}^{2} 10^{(SPL_i/10)}$$

where $SPL_i$ is the sound pressure level in each selected band.

*Electric vehicle* means a motor vehicle with an electric motor as its sole means of propulsion.

*Front plane* of the vehicle means a vertical plane tangent to the leading edge of the vehicle during forward operation.

*Hybrid vehicle* means a motor vehicle which has more than one means of propulsion for which the vehicle's propulsion system can propel the vehicle in the normal travel mode in at least one forward drive gear or reverse without the internal combustion engine operating.

*Rear plane* means a vertical plane tangent to the leading edge of the rear of the vehicle during operation in reverse.

S5. *Requirements.* Subject to the phase-in set forth in S9 of this standard, each hybrid and electric vehicle must meet the requirements specified in either S5.1 or S5.2. subject to the requirements in S5.3. Each vehicle must also meet the requirements in S5.4 and S5.5.

S5.1 *Performance requirements for four-band alert sounds.*

S5.1.1 *Stationary.* When stationary the vehicle must satisfy S5.1.1.1 and S5.1.1.2 whenever the vehicle's propulsion system is activated and:

(i) In the case of a vehicle with an automatic transmission, the vehicle's gear selector is in Neutral or any gear position other than Park that provides forward vehicle propulsion;

(iii) in the case of a vehicle with a manual transmission, the vehicle's parking brake is released and the gear selector is not in Reverse.

S5.1.1.1 For *detection,* the vehicle must emit a sound having at least the A-weighted sound pressure level according to Table 1 in each of four non-adjacent bands spanning no fewer than 9 of the 13 bands from 315 to 5000 Hz.

S5.1.1.2 For *directivity,* the vehicle must emit a sound measured at the microphone on the line CC' having at least the A-weighted sound pressure level according to Table 1 in each of four non-adjacent bands spanning no fewer than 9 of the 13 bands from 315 to 5000Hz.

TABLE 1—ONE-THIRD OCTAVE BAND MIN. SPL REQUIREMENTS FOR SOUND WHEN STATIONARY AND CONSTANT SPEEDS LESS THAN 10KM/H

| One-third octave band center frequency, Hz | Min SPL, A-weighted dB |
|---|---|
| 315 | 39 |
| 400 | 39 |
| 500 | 40 |
| 630 | 40 |
| 800 | 41 |
| 1000 | 41 |
| 1250 | 42 |
| 1600 | 39 |
| 2000 | 39 |
| 2500 | 37 |
| 3150 | 34 |
| 4000 | 32 |
| 5000 | 31 |

S5.1.2 *Reverse.* For vehicles capable of rearward self-propulsion, whenever the vehicle's gear selector is in the Reverse position, the vehicle must emit a sound having at least the A-weighted sound pressure level according to Table 2 in each of four non-adjacent bands spanning no fewer than 9 of the 13 bands from 315 to 5000Hz.

TABLE 2—ONE-THIRD OCTAVE BAND MIN. SPL REQUIREMENTS FOR SOUND WHILE IN REVERSE

| One-third octave band center frequency, Hz | Min SPL, A-weighted dB |
|---|---|
| 315 | 42 |
| 400 | 41 |
| 500 | 43 |
| 630 | 43 |
| 800 | 44 |
| 1000 | 44 |
| 1250 | 45 |
| 1600 | 41 |
| 2000 | 42 |
| 2500 | 40 |
| 3150 | 37 |
| 4000 | 35 |
| 5000 | 33 |

S5.1.3 *Constant pass-by speeds greater than 0 km/h but less than 20 km/h.* When at a constant speed greater than 0 km/h but less than 20 km/h the vehicle must emit a sound having at least the A-weighted sound pressure level according to Table 1 or Table 3 as applicable based upon vehicle test speed in each of four non-adjacent bands spanning no fewer than 9 of the 13 bands from 315 to 5000 Hz.

TABLE 3—ONE-THIRD OCTAVE BAND MIN. SPL REQUIREMENTS FOR CONSTANT PASS-BY SPEEDS GREATER THAN OR EQUAL TO 10 KM/H BUT LESS THAN 20 KM/H

| One-third octave band center frequency, Hz | Min SPL, A-weighted dB |
|---|---|
| 315 | 45 |
| 400 | 44 |
| 500 | 46 |
| 630 | 46 |
| 800 | 47 |
| 1000 | 47 |
| 1250 | 48 |
| 1600 | 44 |
| 2000 | 45 |
| 2500 | 43 |
| 3150 | 40 |

TABLE 3—ONE-THIRD OCTAVE BAND MIN. SPL REQUIREMENTS FOR CONSTANT PASS-BY SPEEDS GREATER THAN OR EQUAL TO 10 KM/H BUT LESS THAN 20 KM/H—Continued

| One-third octave band center frequency, Hz | Min SPL, A-weighted dB |
|---|---|
| 4000 | 38 |
| 5000 | 36 |

S5.1.4 *Constant pass-by speeds greater than or equal to 20km/h but less than 30 km/h.* When at a constant speed equal to or greater than 20 km/h but less than 30 km/h the vehicle must emit a sound having at least the A-weighted sound pressure level according to Table 4 in each of four non-adjacent bands spanning no fewer than 9 of the 13 bands from 315 to 5000 Hz.

TABLE 4—ONE-THIRD OCTAVE BAND MIN. SPL REQUIREMENTS FOR CONSTANT PASS-BY SPEEDS GREATER THAN OR EQUAL TO 20 KM/H BUT LESS THAN 30 KM/H

| One-third octave band center frequency, Hz | Min SPL, A-weighted dB |
|---|---|
| 315 | 52 |
| 400 | 51 |
| 500 | 52 |
| 630 | 53 |
| 800 | 53 |
| 1000 | 54 |
| 1250 | 54 |
| 1600 | 51 |
| 2000 | 51 |
| 2500 | 50 |
| 3150 | 47 |
| 4000 | 45 |
| 5000 | 43 |

S5.1.5 *Constant 30km/h pass-by.* When at a constant speed of 30–32 km/h the vehicle must emit a sound having at least the A-weighted sound pressure level according to Table 5 in each of four non-adjacent bands spanning no fewer than 9 of the 13 bands from 315 to 5000 Hz.

TABLE 5—ONE-THIRD OCTAVE BAND MIN. SPL REQUIREMENTS FOR 30–32 KM/H PASS-BY

| One-third octave band center frequency, Hz | Min SPL, A-weighted dB |
|---|---|
| 315 | 56 |
| 400 | 55 |
| 500 | 57 |
| 630 | 57 |
| 800 | 58 |
| 1000 | 58 |
| 1250 | 59 |
| 1600 | 55 |
| 2000 | 55 |
| 2500 | 54 |
| 3150 | 51 |
| 4000 | 49 |
| 5000 | 47 |

S5.2 *Performance requirements for two-band alert sounds.* When operating under the vehicle speed conditions specified in Table 6, the vehicle must emit sound having two non-adjacent one-third octave bands from 315 to 3150 Hz each having at least the A-weighted sound pressure level according to the minimum SPL requirements in Table 6 and spanning no fewer than three one-third octave bands from 315 to 3150 Hz. One of the two bands meeting the minimum requirements in Table 6 shall be the band that has the highest SPL of the 315 to 800 Hz bands and the second band shall be the band meeting the minimum requirements in Table 6 that has the highest SPL of the 1000 to 3150 Hz bands. The two bands used to meet the two-band minimum requirements must also meet the band sum requirements as specified in Table 6.

TABLE 6—ONE-THIRD OCTAVE BAND MINIMUM REQUIREMENTS FOR TWO-BAND ALERT

| Vehicle speed | A-weighted SPL, dB(A) | |
|---|---|---|
| | Minimum in each band | Band sum |
| Reverse | 40 | 48 |
| Stationary and up to but not including 10 km/h | 40 | 44 |
| 10 km/h up to but not including 20 km/h | 42 | 51 |
| 20 km/h up to but not including 30 km/h | 47 | 57 |
| 30 km/h | 52 | 62 |

S5.2.1 When tested according to the test procedure in S7.1 the vehicle must emit a sound measured at the microphone on the line CC' having at least two non-adjacent octave bands from 315 to 3150 Hz each having at least the A-weighted sound pressure level, indicated in the ''Minimum in Each Band'' column in Table 6 for the ''Stationary up to but not including 10 km/h'' condition. The two bands used to meet the two-band minimum requirements must also meet the Band Sum as specified in Table 6.

S5.3 If a hybrid vehicle to which this standard applies is evaluated for compliance with requirements in S5.1.1 through S5.1.5 or S5.2 (Stationary, Reverse, Pass-by at 10 km/h, 20 km/h, and 30 km/h, respectively), and during testing to any one of those requirements the vehicle is measured for ten consecutive times without recording a valid measurement, or for a total of 20 times without recording four valid measurements because the vehicle's ICE remains active for the entire duration of a measurement or the vehicle's ICE activates intermittently during every measurement, the vehicle is exempted from meeting the specific requirement that was under evaluation at the time the ICE interfered in the prescribed manner.

S5.4 *Relative volume change to signify acceleration and deceleration.* The sound produced by the vehicle in accordance with paragraph S5 shall change in volume, as calculated in S7.6, from one critical operating condition to the next in accordance with the requirements in Table 7.

TABLE 7—MINIMUM RELATIVE VOLUME CHANGE REQUIREMENTS

| Critical operating speed intervals | Minimum relative volume change, dB |
|---|---|
| Between: | |
| Stationary and 10 km/h | 3 |
| 10 km/h and 20 km/h | 3 |
| 20 km/h and 30 km/h | 3 |

S5.5 *Sameness requirement*

S5.5.1 Any two vehicles of the same make, model, and model year (as those terms are defined at 49 CFR 565.12) to which this safety standard applies shall use the same pedestrian alert system and shall be designed to have the same pedestrian alert sound when operating in any given condition for which an alert sound is required in Section S5 of this safety standard.

S5.5.2 For the purposes of this requirement, a pedestrian alert system includes all hardware and software components that are utilized to generate an alert sound. Aspects of an alert system which shall be the same include, if applicable: Alert system hardware components including speakers, speaker modules, and control modules, as evidenced by specific details such as part numbers and technical illustrations; the location, orientation, and mountings of the hardware components within the vehicle; the digital sound file or other digitally encoded source; the software and/or firmware and algorithms which generate the pedestrian alert sound and/or which process the digital source to generate a pedestrian alert sound; vehicle inputs including vehicle speed and gear selector position utilized by the alert system; any other design features necessary for vehicles of the same make, model, and model year to have the same pedestrian alert sound at each given operating condition specified in this safety standard.

S6. *Test Conditions.*

S6.1 *Weather conditions.* The ambient conditions specified by this section will be met at all times during the tests described in S7. Conditions will be measured with the accuracy required in S6.3.3 at the microphone height specified in S6.4 +/− 0.02 m.

S6.1.1 The ambient temperature will be between 5 °C (41 °F) and 40 °C (104 °F).

S6.1.2 The maximum wind speed at the microphone height is no greater than 5 m/s (11 mph), including gusts.

S6.1.3 No precipitation and the test surface is dry.

S6.1.4 *Background noise level.* The background noise level will be measured and reported as specified in S6.7, *Ambient correction.*

S6.2 *Test surface.* Test surface will meet the requirements of ISO 10844:1994, ISO 10844:2011, or ISO 10844:2014 (incorporated by reference, see § 571.5).

S6.3 *Instrumentation.*

S6.3.1 *Acoustical measurement.* Instruments for acoustical measurement will meet the requirements of S5.1 of SAE J2889–1 (incorporated by reference, see § 571.5).

S6.3.2 *Vehicle speed measurement.* Instruments used to measure vehicle speed during the constant speed pass-by tests in S7 of this standard will be capable of either continuous measurement of speed within ±0.5 km/h over the entire measurement zone specified in S6.4 or independent measurements of speed within ±0.2 km/h at the beginning and end of the measurement zone specified in S6.4.

S6.3.3 *Meteorological instrumentation.* Instruments used to measure ambient conditions at the test site will meet the requirements of S5.3 of SAE J2889–1 (incorporated by reference, see § 571.5).

S6.4 *Test site.* The test site will be established per the requirements of 6.1 of SAE J2889–1 (incorporated by reference, see § 571.5), including Figure 1, ''Test Site Dimensions'' with the definitions of the abbreviations in Figure 1 as given in Table 1of SAE J2889–1 (incorporated by reference, see § 571.5). Microphone positions will meet the requirements of 7.1.1 of SAE J2889–1 (incorporated by reference, see § 571.5).

S6.5 *Test set up for directivity measurement* will be as per S6.4 with the addition of one microphone meeting the requirements of S6.3.1 placed on the line CC', 2m forward of the line PP' at a height of 1.2m above ground level.

S6.6 *Vehicle condition*

(a) The vehicle's doors are shut and locked and windows are shut.

(b) All accessory equipment (air conditioner, wipers, heat, HVAC fan, audio/video systems, etc.) that can be shut down, will be off. Propulsion battery cooling fans and pumps and other components of the vehicle's propulsion battery thermal management system are not considered accessory equipment. During night time testing test vehicle headlights may be activated.

(c) Vehicle's electric propulsion batteries, if any, are charged according to the requirements of S7.1.2.2 of SAE J2889–1 (incorporated by reference, see § 571.5). If propulsion batteries must be recharged during testing to ensure internal combustion engine does not activate, manufacturer instructions will be followed.

(d) Vehicle test weight, including the driver and instrumentation, will be evenly distributed between the left and right side of the vehicle and will not exceed the vehicle's GVWR or GAWR:

(1) For passenger cars, and MPVs, trucks, and buses with a GVWR of 4,536 kg (10,000 pounds) or less, the vehicle test weight is the unloaded vehicle weight plus 180 kg (396 pounds);

(2) For LSVs, the test weight is the unloaded vehicle weight plus 78 kg (170 pounds).

(e) Tires will be free of all debris and each tire's cold tire inflation pressure set to:

(1) For passenger cars, and MPVs, trucks, and buses with a GVWR of 4,536 kg (10,000 pounds) or less, the inflation pressure specified on the vehicle placard in FMVSS No. 110;

(2) For LSVs, the inflation pressure recommended by the manufacturer for GVWR; if none is specified, the maximum inflation pressure listed on the sidewall of the tires.

(f) Tires are conditioned by driving the test vehicle around a circle 30 meters (100 feet) in diameter at a speed that produces a lateral acceleration of 0.5 to 0.6 g for three clockwise laps followed by three counterclockwise laps;

S6.7 *Ambient correction.*

S6.7.1 Measure the ambient noise for at least 30 seconds immediately before and after each series of vehicle tests. A series is a test condition, *i.e.* stationary, reverse, 10 km/h pass-by test, 20 km/h pass-by test, or 30 km/h pass-by test. Ambient noise data files will be collected from each microphone required by the test procedures in S7.

S6.7.2 For each microphone, determine the minimum A-weighted overall ambient SPL during the 60 seconds (or more) of recorded ambient noise consisting of at least 30 seconds recorded immediately before and at least 30 seconds immediately after each test series.

S6.7.3 For each of the 13 one-third octave bands, the minimum A-weighted ambient noise level during the 60 seconds (or more) from the two 30 second periods of ambient noise recorded immediately before and after each test series will be determined for each microphone.

S6.7.4 To correct overall SPL values for ambient noise, calculate the difference, for each microphone, between the measured overall SPL values for a test vehicle obtained in sections S7.1.4(b) and S7.3.4(b) and the minimum overall ambient SPL values determined in S6.7.2, above. Using Table 8, determine a correction factor for each microphone. Subtract the correction factor from the overall SPL value measured under sections S7.1.4(b) and S7.3.4(b) to calculate the corrected overall SPL value. Any test for which the minimum overall SPL of the ambient is within 3 dB of the uncorrected overall SPL of the vehicle is invalid and not analyzed further.

S6.7.5 To correct one-third octave band sound levels for ambient noise, calculate the difference, for each microphone, between the uncorrected level for a one-third octave band (obtained in sections S7.1.5(b), S7.1.6(b) and S7.3.5(b)) and the minimum ambient level in the same one-third octave band as determined in S6.7.3. Use Table 9 to determine if a correction is required for each microphone and one-third octave band. If a correction is required, subtract the appropriate correction factor in Table 9 from the uncorrected one-third octave band sound level to calculate the corrected level for each one-third octave band. If the level of any ambient one-third octave band is within 3 dB of the corresponding uncorrected one-third octave band level, then that one-third octave band is invalid and not analyzed further.

TABLE 8—OVERALL SPL CORRECTIONS FOR AMBIENT NOISE

| Difference between vehicle measurement and ambient noise level | Correction |
|---|---|
| Greater than 10 dB | 0 dB. |
| Greater than 8 dB but less than or equal to 10 dB | 0.5 dB. |
| Greater than 6 dB but less than or equal to 8 dB | 1.0 dB. |
| Greater than 4.5 dB but less than or equal to 6 dB | 1.5 dB. |
| Greater than 3 dB but less than or equal to 4.5 dB | 2.5 dB. |
| Less than or equal to 3 dB | Invalid test run. |

TABLE 9—1/3 OCTAVE BAND CORRECTIONS FOR AMBIENT NOISE

| Difference between vehicle 1/3 octave band sound pressure level and ambient noise level | Correction |
|---|---|
| Greater than 6 dB | 0 dB. |
| Greater than 4.5 dB but less than or equal to 6 dB | 1.5 dB. |
| Greater than 3 dB but less than or equal to 4.5 dB | 2.5 dB. |
| Less than or equal to 3 dB | Specific 1/3 octave band is not useable. |

S7. Test Procedure.

S7.1 Vehicle stationary

S7.1.1 Execute stationary tests and collect acoustic sound files.

(a) Position the vehicle with the front plane at the line PP', the vehicle centerline on the line CC' and the starting system deactivated. For vehicle equipped with a Park position, place the vehicle's gear selector in ''Park'' and engage the parking brake. For vehicles not equipped with a Park position, place the vehicle's gear selector in ''Neutral'' and engage the parking brake. Activate the starting system to energize the vehicle's propulsion system.

(b) For vehicles equipped with a Park position for the gear selector, after activating the starting system to energize the vehicle's propulsion system, apply and maintain a full application of the service brake, disengage the vehicle parking brake and then place the vehicle's gear selector in ''Drive,'' or any forward gear. For vehicles not equipped with a Park position for the gear selector, after activating the starting system to energize the vehicle's propulsion system, apply and maintain a full application of the service brake, disengage the vehicle parking brake, disengage the manual clutch (fully depress and hold the clutch pedal), and place the vehicle's gear selector in any forward gear.

(c) Execute multiple tests to acquire at least four valid tests within 2 dBA overall SPL in accordance with S7.1.2 and S7.1.3. For each test, measure the sound emitted by the stationary test vehicle for a duration of 10 seconds.

(d) During each test a left (driver's side), a right (passenger side), and a front-center acoustic file will be recorded.

S7.1.2. Eliminate invalid tests.

(a) Determine validity of sound files collected during S7.1.1 tests. Measurements that contain any distinct, transient, loud sounds (*e.g.,* chirping birds, overhead planes, trains, car doors being slammed, etc.) are considered invalid. Measurements that contain sounds emitted by any vehicle system that is automatically activated and constantly engaged during the entire 10 second performance test are considered valid. Measurements that contain sound emitted by any vehicle system that is automatically activated and intermittently engaged at any time during the stationary performance test, are considered invalid. Additionally, when testing a hybrid vehicle with an internal combustion engine, measurements that include sound emitted by the ICE either intermittently or continuously are considered invalid. A valid test requires a valid left side, a valid right side, and a valid front-center acoustic sound file.

(b) Sequentially number all tests which are deemed valid based upon the chronological order in which they were conducted. Acoustic files will be identified with a test sequence number and their association with the left side, right side, or front center microphone.

S7.1.3 Identify first four valid tests within 2dBA.

(a) For each valid test sound file identified in S7.1.2, determine a maximum overall SPL value, in decibels. Each SPL value will be reported to the nearest tenth of a decibel.

(b) Compare the first four left-side SPL values from S7.1.3(a) of this paragraph, and determine the range by taking the difference between the largest and smallest of the four values. In the same manner, determine the range of SPL values for the first four right-side and the first four front-center sound files. If the range for the left side, right side, and front-center are all less than or equal to 2.0 dB, then the twelve sound files associated with the first four valid tests will be used for the one-third octave band evaluations in S7.1.5. and S7.1.6. If the range of the SPL values for the left side are not within 2 dBA, or for the right side are not within 2 dBA, or for the front-center of the vehicle are not within 2 dBA, an iterative process will be used to consider sound files from additional sequential tests until the range for all three microphone locations are within 2 dBA for the same sequence number recordings for all three locations.

S7.1.4 Compare the average overall SPL for the left and right side of the test vehicle to determine which is lower.

(a) Document the maximum overall SPL values in each of the eight acoustic data files (four left side files and four right side files) identified in S7.1.3.

(b) Correct each of the eight SPL values from S7.1.4(a) according to S6.7 using the ambient sound level recorded during the test. The results will be reported to the nearest tenth of a decibel.

(c) Calculate a left-side average and a right-side average from the ambient-corrected overall SPL values from S71.4(b), and determine the lower of the two sides. The result will be reported to the nearest tenth of a decibel.

(d) If the left-side value from S7.1.4(c) is the lower one, then the left side acoustic data will be further evaluated for compliance at the one-third octave band levels in accordance with S7.1.5. If the left-side value from S7.1.4(c) is not the lower one, the right-side acoustic data will be further evaluated for compliance at the one-third octave band level in accordance with S7.1.5.

S7.1.5 Select one-third octave bands to be used for evaluating compliance with detection requirements.

(a) For each of the four left-side or right-side acoustic files, which ever was selected in S7.1.4, determine the sound pressure level in each one-third octave band from 315 Hz up to and including 5000 Hz.

(b) Correct the one-third octave band levels in all four sound files to adjust for the ambient sound level recorded during the test according to paragraph S6.7.

(c) For each one-third octave band, average the corrected levels from the four sound files. The results will be reported to the nearest tenth of a decibel.

(d) For alerts designed to meet the four one-third octave band alert sound requirements:

(i) Select any four one-third octave bands that are non-adjacent to each other and that span a range of at least nine one-third octave bands in the range of 315 Hz up to and including 5000 Hz to evaluate according to paragraph S7.1.5(d)(ii). This step will be repeated until compliance is established or it is determined that no combination meeting this selection criterion can satisfy paragraph S7.1.5(d)(ii).

(ii) Compare the average corrected sound pressure level from S7.1.5(c) of this paragraph in each of the four one-third octave bands selected in paragraph S7.1.5(d)(i) to the required minimum level of the corresponding one-third octave band specified in paragraph S5.1.1, Table 1, to determine compliance.

(e) For alerts designed to meet the two-one-third octave band requirements:

(i) Select the two highest one-third octave bands that are non-adjacent to each other and within the range of 315 Hz up to and including 3150 Hz to evaluate according to paragraph (ii), below. This step will be repeated until compliance is established or it is determined that no combination meeting this selection criterion can satisfy paragraph S7.1.5(e)(ii).

(ii) Compare the average corrected sound pressure level from (c) in each of the two one-third octave bands selected in paragraph S7.1.5(e)(i) to the required minimum level of the corresponding one-third octave band specified in paragraph S5.2 Table 6. Also, compare the band sum of the two bands to the required minimum level in Table 6.

S7.1.6 *Procedure for selected one-third octave bands to be used for evaluating compliance with directivity requirements.*

(a) Determine the one-third octave band levels associated with the four front center sound files selected in S7.1.3.

(b) The identified one-third octave band levels in each of the four sound files will be corrected for the measured ambient levels as specified in paragraph S6.7.

(c) The four corrected sound pressure level values calculated from each of the four sound files in each one-third octave band will be averaged together to get the average corrected sound pressure level in each one-third octave band.

(d) For alerts designed to meet the four one-third octave band requirements.

(i) Select any four one-third octave bands that are non-adjacent to each other and that span a range of at least nine one-third octave bands in the range of 315 Hz up to and including 5000 Hz to evaluate according to paragraph S7.1.6(d)(ii). This step will be repeated until compliance is established or it is determined that no combination meeting this selection criterion can satisfy paragraph S7.1.6(d)(ii).

(ii) Compare the average corrected sound pressure level from (c) of this paragraph in each of the four one-third octave bands selected in paragraph S7.1.6(d)(i) to the required minimum level of the corresponding one-third octave band specified in paragraph S5.1.1, Table 1, to determine compliance.

(e) For alerts designed to meet the two one-third octave band requirements.

(i) Select the two highest one-third octave bands that are non-adjacent to each other and within the range of 315 Hz up to and including 3150 Hz to evaluate according to paragraph (ii), below. One band shall be below 1000 Hz and one band shall be at or greater than 1000 Hz. This step will be repeated until compliance is established or it is determined that no combination meeting this selection criterion can satisfy paragraph S7.1.6(e)(ii).

(ii) Compare the average corrected sound pressure level from S7.1.6(c) of this paragraph in each of the two one-third octave bands selected in paragraph S7.1.6(e)(i) to the required minimum level of the corresponding one-third octave band specified in paragraph S5.2 Table 6. Also, compare the band sum of the two bands to the required minimum level in Table 6.

S7.2 *Reverse.* Test the vehicle per S7.1 (S7.1.1–S7.1.5), except that the rear plane of the vehicle is placed on line PP', no third microphone (front center) is used, and the vehicle's gear selector is placed in ''Reverse.''

S7.3 *Constant speed pass-by tests at speeds greater than 0 km/h but less than 20 km/h.*

S7.3.1 Execute pass-by tests at 11km/h (+/−1 km/h) and collect acoustic sound files.

(a) For each test, measure the sound emitted by the test vehicle while at a constant speed of 11km/h (+/− 1km/h) throughout the measurement zone specified in S6.4 between lines AA' and PP'. Execute multiple test runs at 11km/h (+/−1km/h) to acquire at least four valid tests within 2dBA in accordance with S7.3.2 and S7.3.3.

(b) During each test, record a left (driver's side) and a right (passenger side) acoustic sound file.

S7.3.2 Eliminate invalid tests and acoustic sound files

(a) Determine validity of sound files collected during S7.3.1 tests. Measurements that contain any distinct, transient, background sounds (*e.g.,* chirping birds, overhead planes, car doors being slammed, etc.) are considered invalid. Measurements that contain sounds emitted by any vehicle system that is automatically activated and constantly engaged during the entire performance test are considered valid. Measurements that contain sound emitted by any vehicle system that is automatically activated, and intermittently engaged at any time during the performance test, are considered invalid. Additionally, when testing a hybrid vehicle with an internal combustion engine that runs intermittently during a specific test, measurements that contain sound emitted by the ICE are considered invalid. A valid test requires both a valid left side and a valid right side acoustic sound file.

(b) Tests which are deemed valid will be numbered sequentially based upon the chronological order in which they were collected. Sound files will retain their test sequence number and their association with the left side or right side microphone.

S7.3.3 Identify ''first four valid tests within 2 dBA''.

(a) For each valid test sound file identified in S7.3.2, determine a maximum overall SPL value, in decibels. The SPL value will be reported to the nearest tenth of a decibel.

(b) Compare the first four left side maximum overall SPL values. Of the four SPL values calculate the difference between the largest and smallest maximum SPL values. The same process will be used to determine the difference between the largest and smallest maximum SPL values for the first four right side maximum SPL values. If the difference values on the left and right sides of the test vehicle are both less than or equal to 2.0 dB, then the eight sound files associated with the first four valid tests will be used for the final one-third octave band evaluation in accordance with S7.3.4. and S7.3.5. If the first four test sound files on each side of the vehicle are not within 2 dBA, an iterative process will be used to consider sound files from additional sequential tests until the range for both microphone locations are within 2 dBA for the same sequence number recordings for both locations.

S7.3.4 Determine average overall SPL value on each side (left and right) of test vehicle.

(a) Document the maximum overall SPL value in decibels for each of the eight acoustic sound data files (four left-side files and four right-side files) identified in S7.3.3.

(b) Each of the eight acoustic sound data file maximum overall SPL values will be corrected for the recorded ambient conditions as specified in paragraph S6.7. The test results will be reported to the nearest tenth of a decibel.

(c) Calculate the average of the four overall ambient-corrected SPL values on each side of the vehicle to derive one corrected maximum overall SPL value for each side of the vehicle. The result will be reported to the nearest tenth of a decibel.

(d) The side of the vehicle with the lowest average corrected maximum overall SPL value will be the side of the vehicle that is further evaluated for compliance at the one-third octave band levels in accordance with S7.3.5.

S7.3.5 Complete one-third octave band evaluation for compliance verification.

(a) The side of the vehicle selected in S7.3.4 will have four associated individual acoustic sound data files. Each sound file shall be broken down into its one-third octave band levels.

(b) The identified octave band levels in each of the four sound files will be corrected for the measured ambient levels as specified in paragraph S6.7.

(c) The four corrected sound pressure level values calculated from each of the four sound files in each one-third octave band will be averaged together to get the average corrected sound pressure level in each one-third octave band.

(d) For alerts designed to meet the four one-third octave band requirements.

(i) Select any four one-third octave bands that are non-adjacent to each other and that span a range of at least nine one-third octave bands in the range of 315 Hz up to and including 5000 Hz to evaluate according to paragraph S7.3.5(d)(ii). This step will be repeated until compliance is established or it is determined that no combination meeting this selection criterion can satisfy paragraph S7.3.5(d)(ii).

(ii) Compare the average corrected sound pressure level from S7.3.5(c) in each of the four one-third octave bands selected in paragraph S7.3.5(d)(i) to the required minimum level of the corresponding one-third octave band specified in paragraph S5.1.3, Table 3, to determine compliance.

(e) For alerts designed to meet the two one-third octave band requirements.

(i) Select the two highest one-third octave bands that are non-adjacent to each other and within the range of 315 Hz up to and including 3150 Hz to evaluate according to paragraph S7.3.5(e)(ii). This step will be repeated until compliance is established or it is determined that no combination meeting this selection criterion can satisfy paragraph S7.3.5(e)(ii).

(ii) Compare the average corrected sound pressure level from S7.3.5(c) in each of the two one-third octave bands selected in paragraph S7.3.5(e)(i) to the required minimum level of the corresponding one-third octave band specified in paragraph S5.2 and Table 6. Also, compare the band sum of the two bands to the required minimum level in Table 6.

S7.3.6 Repeat S7.3.1–S7.3.5 using any other constant vehicle speed equal to or greater than 10 km/h but less than 20 km/h.

S7.4 *Constant speed pass-by tests at speeds greater than or equal to 20 km/h but less than 30 km/h.* Repeat the test of S7.3 at 21 km/h (+/−1km/h). In S7.3.6, the 21km/h (+/−1km/h) test speed can be replaced using any constant speed greater than or equal to 20 km/h but less than 30 km/h.

S7.5 *Constant speed pass-by tests at 30 km/h.* Repeat the test of S7.3 at 31 km/h (+/−1km/h)

S7.6 *Relative volume change.* The valid test run data selected for each critical operating scenario in S7.1 (S7.1.5(c)), S7.3 (S7.3.5(c)), S7.4 and S7.5 will be used to derive relative volume change as required in S5.4 as follows:

S7.6.1 Calculate the average sound pressure level for each of the 13 one-third octave bands (315 Hz to 5000 Hz) using the four valid test runs identified for each critical operating scenario from S7.1.3 and S7.3.3 (stationary, 10 km/h (11+/−1km/h), 20 km/h (21+/−1km/h), and 30 km/h (31+/−1km/h)).

S7.6.2 For each critical operating scenario, normalize the levels of the 13 one-third octave bands by subtracting the corresponding minimum SPL values specified in Table 1 for the stationary operating condition from each of the one-third octave band averages calculated in S7.6.1.

S7.6.3 Calculate the NORMALIZED BAND SUM for each critical operating scenario (stationary, 10 km/h (11+/−1km/h), 20 km/h (21+/−1km/h), and 30 km/h (31+/−1km/h)) as follows:

$$NORMALIZEDBANDSUM = 10 * \log_{10}\left(\sum_{13}^{i=1} 10^{\frac{Normalized\ Band\ Level_i}{10}}\right)$$

Where:

*i* represents the 13 one-third octave bands and *Normalized Band Level$_i$* is the normalized one-third octave band value derived in S7.6.2.

S7.6.4 Calculate the relative volume change between critical operating scenarios (stationary to 10km/h; 10km/h to 20 km/h; 20km/h to 30 km/h) by subtracting the NORMALIZED BAND SUM of the lower speed operating scenario from the NORMALIZED BAND SUM of the next higher speed operating scenario. *For example, the relative volume change between 10 km/h (11+/−1km/h) and 20 km/h (21+/−1km/h) would be the* NORMALIZED BAND SUM *level at 21+/−1km/h minus the* NORMALIZED BAND SUM *level at 11+/−1km/h.*

S8 *Prohibition on altering the sound of a vehicle subject to this standard.* No entity subject to the authority of the National Highway Traffic Safety Administration may:

(a) Disable, alter, replace or modify any element of a vehicle installed as original equipment for purposes of complying with this Standard, except in connection with a repair of a vehicle malfunction related to its sound emission or to remedy a defect or non-compliance with this standard; or

(b) Provide any person with any mechanism, equipment, process or device intended to disable, alter, replace or modify the sound emitting capability of a vehicle subject to this standard, except in connection with a repair of vehicle malfunction related to its sound emission or to remedy a defect or non-compliance with this standard.

S9 *Phase-in schedule.*

S9.1 *Hybrid and Electric Vehicles manufactured on or after September 1, 2018, and before September 1, 2019.* For hybrid and electric vehicles to which this standard applies manufactured on or after September 1, 2018, and before September 1, 2019, except vehicles produced by small volume manufacturers, the quantity of hybrid and electric vehicles complying with this safety standard shall be not less than 50 percent of one or both of the following:

(a) A manufacturer's average annual production of hybrid and electric vehicles on and after September 1, 2015, and before September 1, 2018;

(b) A manufacturer's total production of hybrid and electric vehicles on and after September 1, 2018, and before September 1, 2019.

S9.2 *Hybrid and Electric Vehicles manufactured on or after September 1, 2019.* All hybrid and electric vehicles to which this standard applies manufactured on or after September 1, 2019, shall comply with this safety standard.

■ 4. Section 571.500 is amended by adding paragraph S5.(b)(12) to read as follows:

### § 571.500 Standard No. 500; Low-speed vehicles.

* * * * *

S5.(b) * * *

(12) An alert sound as required by § 571.141.

* * * * *

## PART 585—PHASE-IN REPORTING REQUIREMENTS

■ 4. The authority citation for part 585 is revised to read as follows:

**Authority:** 49 U.S.C. 322, 30111, 30115, 30117, and 30166; delegation of authority at 49 CFR 1.95

■ 5. Add Subpart N to read as follows:

**Subpart N—Minimum Sound Requirements for Hybrid and Electric Vehicles Reporting Requirements**

Sec.


## Subpart N—Minimum Sound Requirements for Hybrid and Electric Vehicles Reporting Requirements

### § 585.128 Scope.

This subpart establishes requirements for manufacturers of hybrid and electric passenger cars, trucks, buses, multipurpose passenger vehicles, and low-speed vehicles to submit a report, and maintain records related to the report, concerning the number of such vehicles that meet minimum sound requirements of Standard No. 141, Minimum Sound Requirements for Hybrid and Electric Vehicles (49 CFR 571.141).

### § 585.129 Purpose.

The purpose of these reporting requirements is to assist the National Highway Traffic Safety Administration in determining whether a manufacturer has complied with the minimum sound requirements of Standard No. 141, Minimum Sound for Hybrid and Electric Vehicles (49 CFR 571.141).

### § 585.130 Applicability.

This subpart applies to manufacturers of hybrid and electric passenger cars, trucks, buses, multipurpose passenger vehicles, and low-speed vehicles subject to the phase-in requirements of § 571.141, S9.1 *Hybrid and Electric Vehicles manufactured on or after September 1, 2018, and before September 1, 2019.*

### § 585.131 Definitions.

(a) All terms defined in 49 U.S.C. 30102 are used in their statutory meaning.

(b) Bus, gross vehicle weight rating or GVWR, low-speed vehicle, multipurpose passenger vehicle, passenger car, truck, and motorcycle are used as defined in § 571.3 of this chapter.

(c) Production year means the 12-month period between September 1 of one year and August 31 of the following year, inclusive.

(d) Electric Vehicle, and hybrid vehicle are used as defined in § 571.141 of this chapter.

### § 585.132 Response to inquiries.

At any time during the production year ending August 31, 2018, each manufacturer shall, upon request from the Office of Vehicle Safety Compliance, provide information identifying the vehicles (by make, model and vehicle identification number) that have been certified as complying with the requirements of Standard No. 141, Minimum Sound Requirements for Hybrid and Electric Vehicles (49 CFR 571.141). The manufacturer's designation of a vehicle as a certified vehicle is irrevocable.

### § 585.133 Reporting requirements.

(a) Phase-in reporting requirements. Within 60 days after the end of the production year ending August 31, 2018, each manufacturer shall submit a report to the National Highway Traffic Safety Administration concerning its compliance with the requirements of Standard No. 141 Minimum Sound Requirements for Hybrid and Electric Vehicles (49 CFR 571.141) for its vehicles produced in that year. Each report shall provide the information specified in paragraph (b) of this section and in § 585.2 of this part.

(b) Phase-in report content—

(1) Basis for phase-in production goals. Each manufacturer shall provide the number of hybrid vehicles and electric vehicles manufactured in the current production year or, at the manufacturer's option, in each of the three previous production years. A manufacturer that is, for the first time, manufacturing vehicles for sale in the United States must report the number of vehicles manufactured during the current production year.

(2) Production of complying vehicles—

Each manufacturer shall report for the production year being reported on, and each preceding production year, to the extent that vehicles produced during the preceding years are treated under Standard No. 141 as having been produced during the production year being reported on, information on the number of vehicles that meet the requirements of Standard No. 141, Minimum Sound Requirements for Hybrid and Electric Vehicles (49 CFR 571.141).

**§ 585.134 Records.**

Each manufacturer shall maintain records of the Vehicle Identification Number for each vehicle for which information is reported under § 585.133 until December 31, 2023.

Issued on November 10, 2016 in Washington, DC, under authority delegated in 49 CFR 1.95 and 501.5.

**Mark R. Rosekind,**

*Administrator.*

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