DEPARTMENT OF TRANSPORTATION

National Highway Traffic Safety Administration

49 CFR Parts 571 and 585

[Docket No. NHTSA–2011–0148]

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: Notice of proposed rulemaking (NPRM).

SUMMARY: As required by the Pedestrian Safety Enhancement Act (PSEA) of 2010 this rule proposes to establish a Federal motor vehicle safety standard (FMVSS) setting minimum sound requirements for hybrid and electric vehicles. This new standard would require hybrid and electric passenger cars, light trucks and vans (LTVs), medium and heavy duty, trucks, and buses, low speed vehicles (LSVs), and motorcycles to produce sounds meeting the requirements of this standard. This proposed standard 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 would ensure that blind, visually-impaired, and other pedestrians are able to detect and recognize nearby hybrid and electric vehicles, as required by the PSEA, by requiring that hybrid and electric vehicles emit sound that pedestrians would be able to hear in a range of ambient environments and contain acoustic signal content that pedestrians will recognize as being emitted from a vehicle.

The benefit of reducing the pedestrian injury rate per registered vehicle of HVs to ICE vehicles when 4.1% of the fleet is HV and EV would be 2790 fewer pedestrian and pedalcyclist injuries. We also estimate that this proposal will result in 10 fewer pedestrian and pedalcyclist injuries caused by LSVs. Thus, 2800 total injured pedestrians are expected to be avoided due to this proposal representing 35 equivalent lives saved. We do not estimate any quantifiable benefits for EVs because it is our view that EV manufacturers would have installed alert sounds in their cars without passage of the PSEA and this proposed rule. Comparison of costs and benefits expected due to this rule provides a cost of $0.83 to $0.99 million per equivalent life saved across the 3 and 7 percent discount levels for the light EV and HV and LSV fleet. According to our present model, a countermeasure that allows a vehicle to meet the proposed minimum sound requirements would be cost effective compared to our comprehensive cost estimate of the value of a statistical life of $6.3 million.

DATES: Comments must be received on or before March 15, 2013.

ADDRESSES: You may submit comments to the docket number identified in the heading of this document by any of the following methods:

- *Federal eRulemaking Portal:* go to *http://www.regulations.gov*. Follow the online instructions for submitting comments.
- *Mail:* Docket Management Facility, M–30, U.S. Department of Transportation, West Building, Ground Floor, Rm. W12–140, 1200 New Jersey Avenue SE., Washington, DC 20590.
- *Hand Delivery or Courier:* West Building Ground Floor, Room W12–140, 1200 New Jersey Avenue SE., between 9 a.m. and 5 p.m. Eastern Time, Monday through Friday, except Federal holidays.
- *Fax:* (202) 493–2251.

Regardless of how you submit your comments, you should mention the docket number of this document.

You may call the Docket at 202–366–9324.

Instructions: For detailed instructions on submitting comments and additional information on the rulemaking process, see the Public Participation heading of the Supplementary Information section of this document. Note that all comments received will be posted without change to *http://www.regulations.gov*, including any personal information provided.

Privacy Act: Please see the Privacy Act heading under Rulemaking Analyses and Notices.

FOR FURTHER INFORMATION CONTACT:

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I. Executive Summary

As required by the PSEA,[1] this rule proposes to establish FMVSS No.141, *Minimum Sound Requirements for Hybrid and Electric Vehicles,* which would require hybrid and electric passenger cars, LTVs, medium and heavy duty trucks and buses, LSVs, and motorcycles to produce sounds meeting the requirements of this standard. This proposed standard applies to EVs and to those HVs that are capable of propulsion in any forward or reverse gear without the vehicle's ICE operating. The PSEA requires NHTSA to establish performance requirements for an alert sound that is recognizable as motor vehicle in operation that allows blind and other pedestrians to reasonably detect a nearby EV or HV operating below the crossover speed. The crossover speed is the speed at which tire noise, wind noise, and other factors eliminate the need for a separate alert sound. The PSEA defines ''alert sound'' as ''a vehicle-emitted sound to enable pedestrians to discern vehicle presence, direction, location and operation.''[2] The legal authority for this rulemaking comes from the PSEA and 49 U.S.C. 30111.

This standard will ensure that blind, visually-impaired, and other pedestrians are able to detect and recognize nearby hybrid and electric vehicles by requiring that hybrid and electric vehicles emit sound that pedestrians will be able to hear in a range of ambient environments and contain acoustic signal content that pedestrians will recognize as being emitted from a vehicle. The proposed standard establishes minimum sound requirements for hybrid and electric vehicles when operating under 30 kilometers per hour (km/h) (18 mph), when the vehicle's starting system is activated but the vehicle is stationary, and when the vehicle is operating in reverse.

The requirements of this proposal apply only to those HVs that are capable of propulsion in any forward or reverse gear without the vehicle's ICE operating because these were the vehicles that the agency believes fall under the definition of ''hybrid vehicle'' contained in the PSEA. The agency chose a crossover speed of 30 km/h because this was the speed at which the sound levels of the hybrid and electric vehicles measured by the agency approximated the sound levels produced by similar ICE vehicles. This proposal contains minimum sound requirements for the activated but stationary operating condition because the definition of alert sound in the PSEA, as explained in Section III of this NPRM, requires the agency to issue minimum sound requirements to allow pedestrians to detect hybrid and electric vehicles. We have tentatively determined that this requirement can be best met by requiring vehicles to emit sound in this operating condition.

At lower speeds, hybrid and electric vehicles produce less sound than vehicles propelled by an ICE. At higher speeds, tire and wind noise are the main contributors to vehicles noise output so at higher speeds the sounds produced by hybrid and electric vehicles and ICE vehicles are similar. Because hybrid and electric vehicles do not produce as much sound as ICE vehicles when operating at lower speeds, pedestrians and other road users may not be aware of the presence of a nearby hybrid or electric vehicle. If a hybrid vehicle is involved in a low speed maneuver (defined as making a turn, slowing or stopping, backing up, entering or leaving a parking space, or starting in traffic), it is 1.38 times more likely than an ICE vehicle to be involved in a collision with a pedestrian and 1.33 times more likely to be involved in a collision with a pedalcyclist. We believe that this difference in accident rates is mostly attributable to the pedestrians' inability to detect these vehicles by hearing them during these maneuvers. We seek comment on this assumption.

Statistics for pedestrian collision rates of hybrid and electric vehicles with a GVWR over 4,536 kg (10,000 lb), and motorcycles were not available because of the limited penetration of these vehicles into the fleet. NHTSA expects that should the penetration of hybrid and electric heavy vehicles, and motorcycles reach the current rate of penetration of light hybrid and electric vehicles into the fleet, then the difference in pedestrian collision rates between hybrid and electric heavy vehicles, and motorcycles and their traditional ICE counterparts will be similar to the difference in pedestrian collision rates between light HVs and light ICE vehicles.

In addition to analyzing crash data, the agency measured the sound produced by HVs, EVs and ICE vehicles to determine the difference in sound output between the propulsion types at different speeds and 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 used acoustic models to determine the frequency composition of sounds that would give pedestrians the best chance to detect approaching hybrid and electric vehicles without contributing undesirably to surrounding ambient noise levels.

The proposed standard ensures that pedestrians will be able to determine whether a hybrid or electric vehicle is accelerating or decelerating by requiring the frequency content of the sound emitted by the vehicle to increase in a manner that is similar to the sound produced by ICE vehicles when accelerating and decelerating. The agency developed the minimum sound specifications contained in this proposal 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. The standard also requires, as mandated by the PSEA, that all vehicles of the same make, model and model year emit the same sound.

The PSEA requires that the final rule establishing this standard be issued by January 4, 2014 and include a phase-in schedule that concludes with ''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.'' For example the means that if the final rule is issued January 4, 2014, compliance would commence on September 1, 2015, which would mark the start of a three-year phase-in period. We tentatively conclude that the following phase in schedule is reasonable for manufacturers and allows the fastest implementation of the standard for pedestrian safety:

30 percent of the subject vehicles produced on or after September 1of the first year of the phase in;

60 percent of the subject vehicles produced on or after September 1of the second year of the phase in;

90 of the subject vehicles produced on or after September 1of the third year of the phase in; and

100 percent of all vehicles produced on or after, by September 1 of the year that begins three years after the date that the final rule is issued.

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

[2] *Id.* at Section 2(2).

As discussed in detail in Section X of this notice, the benefits of this proposed rule, if made final, will accrue from injuries to pedestrians that will be avoided, assuming that the rule will cause the pedestrian injury rate for HVs and EVs to decrease to that of ICE vehicles. As discussed in Section V, a traditional analysis of pedestrian fatalities is not appropriate for this rulemaking. If HVs and EVs continue to rise in popularity and increase their role in the U.S. fleet to four percent of all vehicle registrations, unchanged by rulemaking or industry action, a total of 2,790 injured pedestrians and pedalcyclists would be expected over the life time of the 2016 model year fleet due to the pedestrians' and pedalcyclists' inability to detect these vehicles by hearing. We estimate that the benefit then of reducing the pedestrian injury rate per registered vehicle of HVs to ICE vehicles when four percent of the fleet is HV and EV would be 2,790 fewer injured pedestrians and pedalcyclists. We do not estimate any quantifiable benefits in pedestrian or pedalcyclist injury reduction for EVs because it is our view that EV manufacturers would have installed alert sounds in their cars without passage of the PSEA and this proposed rule. We also estimate that this proposal will result in 10 fewer injured pedestrians and pedalcyclists caused by LSVs.

DISCOUNTED BENEFITS FOR PASSENGER CARS (PCS) AND LTVS, MY2016, 2010$

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)	0.8034	$58,640,938	9.27	0.8034	$64,106,653	10.14	0.8034	$122,747,591	19.41
(LTV)	0.8022	26,945,946	4.26	0.8022	28,319,549	4.48	0.8022	55,265,495	8.74
Total	....	85,586,884	13.54	....	92,426,203	14.62	....	178,013,086	28.15

7% discount	Pedestrians			Pedalcyclists			Total PED + CYC		
	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)	0.6700	$48,903,944	7.73	0.6700	$53,462,108	8.46	0.6700	$102,366,052	16.19
(LTV)	0.6303	21,171,815	3.35	0.6303	22,251,074	3.52	0.6303	$43,422,889	6.87
Total	....	70,075,758	11.08	....	75,713,183	11.97	....	145,788,941	23.06

TOTAL COSTS FOR PCS AND LTVS, MY2016, 2010$

3% discount	Sales	Sales impacted	Fuel costs/ veh	Fuel costs (total)	Install costs/ veh	Install costs total	Total cost/ veh	Total costs
(PC)	9,032,303	439,586	$4.73	$2,079,240	$30.00	$13,187,566	$34.73	$15,266,805
(LTV)	7,164,729	231,685	5.33	1,234,880	30.00	6,950,542	35.33	8,185,421
Total ..	16,197,032	671,270	4.94	3,314,119	30.00	20,138,107	34.94	23,452,226

7% discount	Sales	Sales impacted	Fuel costs/ veh	Fuel costs (total)	Install costs/ veh	Install costs total	Total cost/ veh	Total costs
(PC)	9,032,303	439,586	$3.83	$1,683,613	$30.00	$13,187,566	$33.83	$14,871,178
(LTV)	7,164,729	231,685	4.23	980,026	30.00	6,950,542	34.23	7,930,568
Total ..	16,197,032	671,270	3.97	2,663,639	30.00	20,138,107	33.97	22,801,746

COSTS AND SCALED BENEFITS FOR LSVS, MY2016 [3]

Discount rate	Sales ratio LSV to light vehicle	Sales	Scaled costs	Scaled injuries (undisc.)	Scaled ELS	Scaled benefits	Scaled benefits minus scaled costs
3%	0.37%	2,500	$87,268	10.39	0.1049	$662,971	$575,703
7%	0.37%	2,500	84,845	10.39	0.0859	542,959	458,114

[3] Scaled benefits and costs for low speed vehicles are estimated directly proportional to light vehicles based on sales. Scaled costs include both installation costs for the system and fuel costs.

NHTSA estimates the fuel and installation cost of adding a speaker system in order to comply with the requirements of this proposal to be around $35 per vehicle for light vehicles. We estimate the total fuel and installation costs of this proposal to the light EV, HV and LSV fleet to be $23.6M at the 3 percent discount rate and $22.9M at the 7 percent discount rate. The estimated total installation cost for hybrid and electric heavy and medium duty trucks and buses and electric motorcycles is $1.48M for MY 2016. We have only calculated the benefits of this proposal for light EVs, HVs and LSVs because we do not have crash rates for hybrid and electric heavy and medium duty trucks and buses and electric motorcycles. To estimate the benefits of this proposal we have converted injured pedestrians and pedalcyclists avoided into equivalent lives saved. We estimate that the impact of this proposal in pedestrian and pedalcyclist injury reduction in light vehicles and LSVs will be 28.15 equivalent lives saved at the 3 percent discount rate and 23.06 equivalent lives saved at the 7 percent discount rate. The benefits of this proposal for the light EV and HV and LSV fleet are $178.7M at the 3 percent discount rate and $146.3M at the 7 percent discount rate. Comparison of costs and benefits expected due to this proposal for the light EV, HV and LSV fleet provides a cost of $0.83 to $0.99 million per equivalent life saved across the 3 and 7 percent discount levels. According to our present model, a countermeasure that allows a vehicle to meet the proposed minimum sound requirements would be cost effective compared to our comprehensive cost estimate of the value of a statistical life of $6.3 million.

TOTAL BENEFITS AND COSTS SUMMARY FOR LIGHT VEHICLES AND LOW SPEED VEHICLES, MY2016, 2010$

	3% discount rate	7% discount rate
Total Monetized Benefits	$178.7M	$146.3M
Total Costs (Install+Fuel)	23.5M	22.9M
Total Net Impact (Benefit—Costs)	155.2M	123.4M

II. Background

Whether or not a vehicle can be easily detected by the sound it makes is a product of vehicle type, vehicle speed, and ambient sound level. Quieter vehicles, such as EVs and HVs, can reduce pedestrians' ability to assess the state of nearby traffic and, as a result, can have an impact on pedestrian safety. EVs and HVs may pose a safety problem for pedestrians, in particular pedestrians who are blind or visually impaired and who therefore rely on auditory cues from vehicles to navigate. For these pedestrians, the primary safety issue arises when an HV or EV operates quietly using its electric motor for propulsion at low speeds. This is also the case when other auditory cues, such as the noise from the vehicle's tires and wind resistance, are less noticeable.

Since August 2007, NHTSA has been monitoring the work of the Society of Automotive Engineers' (SAE) Vehicle Sound for Pedestrians (VSP) Committee. Participants in the VSP committee include vehicle manufacturers, suppliers, consulting firms, government, and other interested parties. The VSP committee's primary goal is to develop a test procedure to measure the minimum sound output of a motor vehicle. In September 2011, the SAE published the test procedure, *Measurement of Minimum Noise Emitted by Road Vehicles,* (SAE–J2889–1).[4] The purpose of J2889–1 is to provide an objective, technology-neutral test to measure the minimum sound emitted by a vehicle in a specified ambient noise condition. This is a test procedure only and does not describe the VSP committee's rationale, provide recommendations about how sounds for HVs and EVs should be developed or produced, nor does it specify the ambient condition at which a vehicle sound should be detectable for the safety of pedestrians.

On May 30, 2008, NHTSA published a notice[5] in the **Federal Register** announcing that the agency would hold a public meeting on June 23, 2008 for government policymakers, stakeholders from organizations representing people who are blind or visually impaired, industry representatives, and public interest groups to discuss the technical, environmental and safety issues associated with EVs, HVs, and quiet ICE vehicles, and the safety of pedestrians. The presentations submitted at the public meeting and a transcript of the meeting can be found in Docket No. NHTSA–2008–0108 on the Web site *http://www.regulations.gov.*[6] Topics discussed at the meeting included a statement of the problem, general pedestrian safety, sound measurement and mobility, automotive industry perspective, SAE work and status, potential solutions, and noise abatement. At the conclusion of the public meeting, NHTSA indicated the agency's intention to put together a research plan and encouraged participants to add comments and ideas to the docket. NHTSA issued a research plan to investigate the topic of quieter vehicles and the safety of pedestrians on May 6, 2009.[7]

In September 2009, NHTSA published a technical report documenting the incidence of crashes involving hybrid-electric passenger vehicles and pedestrians and pedalcyclists.[8] The analysis included a sample of 8,387 hybrid and 559,703 ICE vehicles. The analysis used data from 12 states and a subset of model-year 2000 and later vehicles. The results of the crash data analysis show that HVs are two times more likely than ICE vehicles to be in a pedestrian crash where the vehicle is backing out, slowing/stopping, starting in traffic, and entering or leaving a parking space/driveway. The vehicles involved in such crashes are likely to be moving at low speeds at which the difference between the sounds emitted by ICE vehicles and HVs is substantial. The crash incidence rate for the combined set of maneuvers is 0.6 percent and 1.2 percent for ICE vehicles and HVs respectively and the difference is statistically significant. Some of the factors considered in this analysis are: (1) vehicle maneuver prior to the crash; (2) speed limit as a proxy for vehicle travel speed; and (3) weather and

[4] Society of Automotive Engineers (2011) Measurement of Minimum Noise Emitted by Road Vehicles, SAE–J2889–1. Warrendale, PA. Available at *http://standards.sae.org/wip/j2889/1/.*

[5] 73 FR 31187; May 30, 2008.

[6] The presentations are in document # 0012 and the transcript is in document # 0023 (Docket No. NHTSA–2008–0108–0012 and Docket No. NHTSA–2008–0108–0023, respectively).

[7] Quieter Cars and the Safety of Blind Pedestrians: The NHTSA Research Plan, April 2009, available at *http://www.regulations.gov/#!documentDetail;D=NHTSA-2008-0108-0025.*

[8] 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.*

lighting condition at the time of the crash.

In October 2009, NHTSA issued a report entitled ''Research on Quieter Cars and the Safety of Blind Pedestrians, A Report to Congress.'' [9] The report briefly discusses the quieter vehicle safety issue, how NHTSA's research plan would address the issue, and the status of the agency's research in implementing that plan.

In April 2010, NHTSA issued a report presenting results of Phase 1 of the agency's research.[10] This report 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 countermeasure concepts that are categorized as vehicle-based, infrastructure-based, and systems requiring vehicle-pedestrian communications.

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 twins 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 in EV mode).

NHTSA initiated additional research (Phase 2) in March 2010 to explore potential audible countermeasures to be used in vehicles while operating in electric mode in specific low speed conditions.[11] The potential countermeasures explored included quantitative specifications for sound levels and spectral profiles for detectability. The feasibility of objectively specifying other aspects of sound quality for the purpose of predicting recognizability was also explored.

In our Phase 2 study, researchers assumed that acoustic countermeasures should provide alerting information at least equivalent to the cues provided by ICE vehicles. Groups representing people who are blind or visually impaired have expressed a preference for sound(s) that will be recognized as that of an approaching vehicle so that it will be intuitive for all pedestrians.[12] In the Phase 2 research, acoustic data acquired from a sample of ICE vehicles was used to determine the sound levels at which synthetic vehicle sounds, developed as countermeasures, could be set. ICE equivalent sounds were specified using overall A-weighted sound levels and, one-third octave band spectral content. (See Appendix A, ''Glossary of Sound Engineering Terms'' and Appendix B, ''Acoustic Primer'' for definitions and explanations of all acoustic terms used in this notice.)

Psychoacoustic models and human subject testing were used to explore issues of detectability, masking, and recognition of ICE-like and alternative sound countermeasures. Psychoacoustic models showed that frequency components between 1600 and 5000 Hz were more detectable due to strong signal strength and relatively low ambient levels in this range. Also, frequency components below 315 Hz were often masked by urban ambient noise.[13] Human subject studies were conducted to evaluate countermeasure sounds in a controlled outdoor environment for six miles per hour forward pass-by with the counter measure sound output set at 59.5 A-weighted dB and then at 63.5 A-weighted dB measured 2 meters from the vehicle centerline. The sounds included ICE-like sounds, alternative (non-ICE-like) sounds designed according to psychoacoustic principles to improve detectability, and sounds that combine alternative sounds with some ICE-like components. In addition to the countermeasure sounds, an ICE vehicle sound was included in the study as a baseline for comparison purposes.

The results of this research show that synthetic sounds that resemble those of an ICE produce detection distances similar to actual ICE vehicles. Some of the synthetic sounds examined in the study that were designed according to psychoacoustic principles produced detection distances twice as long as those of ICE sounds. The study participants had difficulty detecting synthetic sounds that contained only the fundamental of the combustion noise of the engine (the lowest frequency associated with the combustion).

This research examined four potential ways in which countermeasure sounds could be specified. The study examined countermeasure sounds based on recordings of ICE vehicles, synthetically generated countermeasure sounds that emulate the sounds of an ICE, non-ICE like countermeasure sounds designed for maximum detectability at a given sound-pressure level, and synthetically generated sounds that have special characteristics to enhance detection and characteristics that ensure that the sounds contain ICE-like components to enhance recognizability. The report noted that an objective specification for non-ICE-like sounds is more difficult to develop than one for synthetic sound generators that emulate the sound of typical ICEs. The report also noted that the former approach could result in a wider variety of sounds, some of which might be not recognized as a vehicle or might be perceived as annoying.

In early 2011, NHTSA initiated additional research and data collection activities to further support this rulemaking (Phase 3). Acoustic measurements and analyses were completed to support the development of specifications for alerting sounds and test procedures for compliance with agency requirements. Acoustic data was gathered from eight vehicles: four ICE vehicles and four EVs/HVs with alerting sounds (one production and three prototype vehicles). The SAE J2889–1 test procedure was used to measure the sound levels for the stopped and pass-by conditions. Acoustic measurements were completed on an ISO 10844:1994 noise pad. All HVs and EVs were measured in electric propulsion mode.

Variations on SAE J2889–1 were used to explore other aspects such as directivity, sound level as a function of vehicle speed, and to capture binaural recordings. Directivity refers to the relative proportions of acoustical energy

[9] 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.*

[10] 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.*

[11] 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.*

[12] Goodes *et al.* (2009) Investigation into the Detection of a Quiet Vehicle by the Blind Community and the Application of an External Noise Emitting System, SAE 2009–01–2189. Society of Automotive Engineers, Warrendale, PA; Maurer (2008) The Danger Posed by Silent Vehicles. National Federation of the Blind. Remarks made for the United Nations Economic Commission for Europe, Working Party on Noise. 47th GRB session February 19, 2008 Geneva. Informal Document No. GRB–47–10. *http://www.unece.org/trans/doc/2008/wp29grb/ECE-TRANS-WP29-GRB-47-inf10e.pdf.*

[13] The level and frequency of sounds masked by the ambient will depend on the sound pressure level and shape of that ambient. For a full description of the typical urban ambient used in this study, see the full report cited in footnote 11.

that is emitted from a source, in this case a vehicle, as a function of direction to the front, back, left, and right. Binaural recordings were captured for potential use in future research activities. Acoustic measurements, modeling, and sound simulation tools were used to identify sound attributes that aid in detection of alert sounds and recognition of these sounds as a motor vehicle.

Two approaches were considered in the development of parameters for alert sounds. In one approach, sound levels for the alert sound were developed using loudness models and a calculation of safe detection distances. In the other approach, sound levels for alert sounds were based on the sound of current ICE vehicles. This research focused on developing specifications that can be applied to all sounds and that are objective and practical.

All of the research activities summarized above are described in more detail in Section VI. NHTSA Research and Industry Practices.

III. Pedestrian Safety Enhancement Act of 2010

On January 4, 2011, the Pedestrian Safety Enhancement Act of 2010 (Public Law 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) [14] requiring an ''alert sound'' [15] for pedestrians to be emitted by all types of motor vehicles [16] that are electric vehicles [17] (EVs) or hybrid vehicles [18] (HVs). The covered types of vehicles include light vehicles (passenger cars, vans, sport utility vehicles and pickup trucks), as well as LSVs, motorcycles, medium and heavy trucks and buses. 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 a vehicle-emitted sound that enables pedestrians to discern the presence, direction,[19] location, and operation of the vehicle.[20] 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 the operating scenarios previously mentioned the definition of alert sound in the PSEA requires the agency to establish requirements for a sound while the vehicle is activated but stationary and when the vehicle is operating in reverse.

The agency has concluded that the requirement in the PSEA that the alert sound must allow pedestrians to ''discern vehicle presence, direction, location, and operation,'' [21] requires the agency to establish minimum sound requirements for the stationary but activated operating condition. The requirement that pedestrians be able to discern vehicle presence must be read 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 an engaged ignition is in a state of being functional even though it may not be moving. It is the agency's position that the provision that pedestrians be able to detect the presence of a vehicle that is turned on requires that the vehicle emit a minimum sound level when the vehicle is stationary, but the starting system is activated.

The agency believes that the PSEA requires the agency to establish requirements for a sound while the vehicle is moving reverse for the same reason that a sound while the vehicle is stationary is required. The PSEA requires minimum sound level requirements promulgated by NHTSA to allow pedestrians to discern vehicle presence and operation. A vehicle moving in reverse is unquestionably operating, thus a minimum sound level is required for this condition.

The PSEA also requires that the minimum sound level requirements promulgated by NHTSA allow pedestrians to discern the direction of the vehicle. This language also indicates that the PSEA requires any standard to establish minimum sound requirements for when the vehicle is operating in reverse.

Because the PSEA directs NHTSA to issue these requirements as a FMVSS under the National Traffic and Motor Vehicle Safety Act (Vehicle Safety Act),[22] 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,[23] and objective [24] 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 a FMVSS, the pedestrian alert sound system standard we are proposing today would be enforced in the same fashion as other safety standards issued under the Vehicle Safety Act. Thus, violators of the standard would be subject to civil penalties.[25] A vehicle manufacturer would be required to conduct a recall and provide remedy without charge if its vehicles were determined to fail to comply with the standard or if the vehicle's alert sound were determined to contain a safety related defect.[26]

Under the PSEA, the standard must specify performance requirements for an alert sound that enables blind and other pedestrians to reasonably detect EVs

[14] 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. 49 U.S.C. 30111.

[15] The definition of that term is discussed below.

[16] Section 2(4) 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.

[17] Section2(10) of the PSEA defines ''electric vehicle'' as a motor vehicle with an electric motor as its sole means of propulsion.

[18] 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.''

[19] 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.

[20] Section 2(2).

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

[22] 49 U.S.C. Chapter 301.

[23] 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).

[24] 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).

[25] 49 U.S.C. 30112 and 30165.

[26] 49 U.S.C. 30118–30120.

and HVs operating below their cross-over speed.[27] 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 and operating in any other scenarios that the Secretary deems appropriate.[28] 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 below the cross-over speed.[29] NHTSA plans to 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 in the ambient noise environment 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 is nothing in 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.[30] 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.'' [31] 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.[32] 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.[33] 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. For example, pitch shifting and increases in sound pressure level denote changes in speed and are common to all vehicles driven by mechanical power. Further, sounds that the public currently recognizes as generated by a vehicle driven by mechanical power have tonal components.

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 reverse or start up. 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. 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. 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.

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. The agency recognizes that, in the near term, most manufacturers would install speaker systems that emit synthetically developed sounds in order to meet the requirements of the proposed standard.

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 proposed 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 agency will test to ensure sounds produced by two vehicles of the same model are the same (within 3 A-weighted dB) at the stationary condition so that a determination of the sameness of the sounds is not dependent on tire or wind noise or other factors that could influence a vehicle's sound output. The agency will not consider any modifications made to a vehicle that affect the mechanical, tire or wind noise produced by that vehicle to make an alert sound added to the vehicle inoperative.

The PSEA requires NHTSA to consider the overall community noise impact of any alert sound required by the new safety standard. In addition, NHTSA will consider the environmental analysis required by the National Environmental Policy Act (NEPA) when setting the standard.

As part of the rulemaking process, NHTSA is required to consult with various other organizations. This is further described in Section IV below.

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[27] Section 2(3) of the PSEA defines ''cross-over 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.

[28] 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.

[29] Section 3(b).

[30] Section 3(b)(2).

[31] Section 2(5).

[32] *Keene Corp.* v. *United States,* 508 U.S. 200, 208 (1993).

[33] 49 U.S.C. § 30102(a)(6).

In addition to requiring NHTSA to publish a final rule establishing the standard requiring an alert sound for EVs and HVs by January 4, 2014, the PSEA requires that the agency provide a phase-in period, as determined by NHTSA. However, 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. Thus, if the final rule were promulgated sometime in 2014, the three-year period after the date of publication of the final rule would end sometime in 2017. The first calendar year that would begin after that date in 2017 would be calendar year 2018. Thus, under that time scenario, full compliance would be required not later than September 1, 2018.

Finally, the PSEA requires NHTSA to conduct a study and report to Congress whether the agency believes that there is a safety need to require the alert sounds required by the FMVSS promulgated to meet the mandate of the Act for some motor vehicles with internal combustion engines. The report must be submitted to Congress by January 4, 2015. If NHTSA determines that there is a safety need to require alert sounds for those motor vehicles the agency must initiate a rulemaking to require alert sounds for them.

IV. Consultation With External Organizations

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, and the United Nations Economic Commission for Europe (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) [34] 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 later in this document.) The second docket (No. NHTSA–2011–0100) [35] was created to collect comments on the NOI; it also includes a copy of that notice. The third docket (No. NHTSA–2011–0148) [36] 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.), outside comments and items to be released in the future up to and including this Notice of Proposed Rulemaking.

NHTSA has since 2009 also been hosting a series of roundtable meetings with industry, technical organizations and groups representing people who are visually-impaired. Below are the dates and topics of discussion:

- April 14th, 2009: Status of Phase 1 research and industry updates.
- August 4th, 2009: Phase 1 research plan.
- January 25th, 2010: Final results of Phase 1 research and industry updates.
- June 24th, 2010: Phase 2 research plan and status of Phase 2 work.
- February 22nd, 2011: Final results of Phase 2 research. Attendees were asked to submit comments.

The following organizations have been participating in these meetings: 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 Automotive Manufacturers and Global Automakers (formerly the Association of International Automobile Manufacturers (AIAM)) 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 standard SAE J2889–1, *Measurement of Minimum Noise Emitted by Road Vehicles.*[37] The agency has been sending liaisons to the VSP meetings since 2008. SAE is the U.S. technical advisory group to the International Organization for Standardizations (ISO) and they both have cooperated in the development of the standard. The ISO document (ISO/NP 16254 Measurement of minimum noise emitted by road vehicles) [38] and SAE document are reported to be technically identical but this has not been confirmed by NHTSA at this time. The agency is currently using standard

[34] *http://www.regulations.gov/#!searchResults;rpp=10;po=0;s=NHTSA–2008–0108.*

[35] *http://www.regulations.gov/#!searchResults;rpp=10;po=0;s=%252BNHTSA–2011–0100.*

[36] *http://www.regulations.gov/#!searchResults;rpp=10;po=0;s=NHTSA–2011–0148.*

[37] *http://standards.sae.org/j2889/1_201109.*

[38] *http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=56019.*

SAE J2889–1 and ISO10844 [39] as references in the test procedure development.

The UNECE World Forum WP.29 determined that road transportation vehicles propelled in whole or in part by electric means present a danger to pedestrians and directed the Working Party on Noise (GRB) to assess what necessary steps WP.29 should take to help mitigate the problem. In response, GRB established an informal group on Quiet Road Transport Vehicles (QRTV) [40] to carry out the necessary activities to address the quieter vehicles issue and the potential need for global harmonization. NHTSA has been participating in the QRTV's meetings since its foundation in 2010 and has kept the group informed about ongoing agency research activities as well as the results from completed research studies.

At its March 2011 meeting, WP.29 adopted guidelines covering alert sounds for electric and hybrid vehicles that are closely based on the Japanese guidelines discussed more fully later in this document. 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. has proposed working on a new GTR, with Japan as co-sponsor, to develop harmonized pedestrian alert sound requirements for electric and hybrid-electric vehicles under the 1998 Global Agreement. WP.29 is now working to develop a GTR that will consider international safety concerns and leverage expertise and research from around the world. Meetings of the working group are planned to take place regularly with periodic reports to WP.29 until the expected establishment date for the new GTR in November 2014. NHTSA is currently leading the GTR development process.

Other international organizations, such as the International Organization of Motor Vehicles Manufacturers (OICA) and Japan Automobile Manufacturers Association (JAMA) have been providing NHTSA with their own research findings and have also been attending our quiet vehicle meetings.

V. Safety Problem

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

Crash Risk

Passenger hybrid electric vehicles first became available to consumers in 2000, and their numbers as well as their proportion of the passenger vehicle fleet have risen every year since their introduction. According to the R.L. Polk and Company National Vehicle Population Profile, there were 18,628 registered passenger HVs in 2001. By 2004, there were 145,194 registered HVs comprising 0.1 percent of the passenger vehicle fleet. By 2009, the number had grown to 1,382,605 registered HVs comprising 0.6 percent of the fleet.

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.[41] The report used data collected from 12 individual states. The years for which data was available varied across different states. Generally, the data used ranged from the years 2000 to 2006. HV crashes had an overall 40 percent higher chance to involve pedestrians. 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. 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. Therefore, we were unable to determine whether any of the pedestrians involved in these crashes were blind or visually impaired.

A recent analysis updated and verified these previous findings [42] 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, with a total of 24,297 HVs (approximately three times the HVs of the 2009 study) and 1,001,000 ICE vehicles by Honda and Toyota, with five different models, in 16 States during 2000–2008. This updated analysis indicates that a total of 186 HVs and 5,699 ICE vehicles were involved in pedestrian crashes. A total of 116 HVs and 3,052 ICE vehicles were involved in crashes with bicycles. Overall, a statistical analysis referred to as odds ratios indicates 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.[43] 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. This finding also indicates 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, typically low-speed, maneuvers 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 after completing a low speed maneuver. The results in this updated analysis show trends similar to those first reported in our 2009 report. The sample sizes of pedestrian or bicycle crashes were verified to validate the sufficient statistical powers in this updated analysis.

The rate of crashes between HVs and pedalcyclists was different than the rate of crashes between HVs and pedestrians. While a larger percentage of pedalcyclist crashes for both HVs and ICE vehicles occurred at posted speed limits of 35 mph and below, the difference in rates of pedalcyclist crashes between HVs and ICE vehicles was higher at speed limits above 35 mph that at speed limits of 35 mph and below. For posted speed limits of 35 mph and below HVs showed an

[39] *http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=45358.*

[40] Papers relating to the informal group periodic meetings may be found at *http://live.unece.org/trans/main/wp29/wp29wgs/wp29grb/qrtv_1.html, http://live.unece.org/trans/main/wp29/wp29wgs/wp29grb/qrtv_2.html, http://live.unece.org/trans/main/wp29/wp29wgs/wp29grb/qrtv_3.html, http://live.unece.org/trans/main/wp29/wp29wgs/wp29grb/qrtv_4.html, http://live.unece.org/trans/main/wp29/wp29wgs/wp29grb/qrtv_5.html,* and *http://live.unece.org/trans/main/wp29/wp29wgs/wp29grb/qrtv_6.html.*

[41] See footnote 6.

[42] 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.*

[43] 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 on while moving, the agency removed the HV 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.

increased rate of pedalcyclist crashes when compared to ICE vehicles, however, the results were not statically significant. The difference in pedealcyclist crash rates between HVs and ICE vehicles was also greater when driving straight as compared to low-speed maneuvers.

This updated analysis further included all vehicle models from all manufacturers during the period covered by the study, beyond the five models from Toyota and Honda, and a similar pedestrian crash trend was also found from the expanded data. Comparisons restricted to HV and similar ICE pairs (Prius and Corolla; Civic HV and ICE model) only were also made. These comparisons also resulted in similar conclusions about HV pedestrian crashes relative to ICE vehicle pedestrian crashes, including that the odds of an HV being in a pedestrian crash is greater than the odds of an ICE vehicle being in a similar crash.

Despite the similarities in the overall sound level produced by the two vehicles, the differential crash rate for the Civic HV and the ICE version of the Civic was even larger than for other pairs of HVs and ICEs. We note that the HV Civic is much different than the other hybrid vehicles in the analysis because when the agency tested this vehicle, we could not get the ICE engine to shutoff even at idle. Thus, unlike the other HVs tested, the ICE was always on in this vehicle, but we acknowledge that in the real-world, the ICE may shut-off at some point. We do know that, although sound levels are similar, there are differences between the frequency profile of the HV and ICE Civics, but we do not know how pedestrians would perceive this difference either in general or in the low-speed maneuvers used in our crash analysis. The agency seeks comments on whether the differences in pedestrian crash rates between HVs and ICEs are solely due to a pedestrians' inability to detect the vehicle based on the vehicle's sound while operating below the crossover speed or whether there may be other factors that we have not identified that affect the difference in crash rates between the two types of vehicles.

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; there is still not enough data to draw conclusions in all scenarios of interest such as for individual low-speed maneuvers like making a turn, starting up, or in parking lots.

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 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. This proposal would establish minimum sound requirements for hybrid and electric vehicles operating at speeds of 30 km/hr (18 miles per hour (mph)) and below. A majority of pedestrian fatalities occur when the vehicle involved in the collision is travelling at a speed greater than 18 mph. Overall, 67 percent of the pedestrian fatalities involving HVs or EVs and with known speed limits occurred at a speed limit above 35 mph. For all pedestrian fatalities with known speed limits, 62 percent occurred at a speed limit above 35 mph and 61 percent of those involving passenger vehicles occurred at a speed limit above 35 mph. The goal of this proposal is to prevent injuries to pedestrians that result from pedestrians being unable to hear nearby hybrid and electric vehicles. At speeds of 35 mph and above, at which a majority fatal crashes involving pedestrians occur, the sound levels produced by hybrid and electric vehicles are the same as the sound levels produced by ICE vehicles. Therefore, establishing minimum sound requirements for hybrid and electric vehicles operating at low speeds is not expected to have an impact on pedestrian fatalities.

The second reason is that the rate of pedestrian fatalities per registered vehicle for HVs and EVs is not larger (and is in fact lower) 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.

B. 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 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 contributes to that person's ability to negotiate through his/her environment in a variety of situations.[44]

Two long-established navigation aids that visually-impaired people use are the white cane and a guide dog. 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.

Of the thirteen guide dog schools currently operating in the United States, most require applicants for guide dogs to have at least some skill in traveling with a long white cane, since the basic techniques for using a white cane and a guide dog are similar in many

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

respects. A guide dog does not lead a person but simply guides him or her around obstacles; the handler is still responsible for navigation.

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 travel safely and independently 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 alerts 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. The sound of a vehicle starting is important for the same reason. If a blind person is approaching a driveway and notes a vehicle that is stationary but running, or hears a vehicle start, 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.

Because traffic sound is a navigation aid for blind and visually-impaired pedestrians, as well as an indispensable part of traveling safely, blind people listen to the sound of traffic actively and constantly when they are walking, even when they are not at an intersection. The sound of traffic helps blind individuals follow the roadway; this is critical, even when there is a sidewalk, to keep the blind individual on course. Traffic sounds also allow the detection of roadway changes like curves, forks, or merges. The sound of traffic is particularly important in negotiating intersections. By listening to the traffic, a blind or visually-impaired traveler can determine how the intersection is controlled (traffic signal, stop sign, etc.); how many lanes of traffic are involved; and any unusual characteristics of the intersection (*e.g.,* three-way intersections or roundabouts). These determinations can be made by listening to the sounds of vehicle engines—often through one or two entire signal cycles—to determine driver behavior, which is usually a reliable indicator of the characteristics of the intersection. This includes the sound of stationary vehicles—particularly in multi-lane or oddly shaped intersections—because it is important to identify which lanes of traffic are active, when, and for how long; and to then follow the line of traffic that most nearly parallels the direction in which the traveler wishes to proceed. At the same time that the blind traveler is listening to the overall traffic pattern, he or she also listens for cues from individual vehicles, particularly when determining the precise moment to enter the crosswalk. At signaled intersections, an idling vehicle in the street parallel to the path of the traveler that accelerates and moves through the intersection is an indication that a traffic signal has just changed and that it is safe to proceed into the cross street, with maximum time to complete the crossing. In general, by crossing when the traffic flow is parallel to him or her, a blind individual can safely cross most intersections without difficulty. The individual will use the sound of the parallel traffic while crossing to maintain a roughly straight line through the intersection. Figure 1 shows several examples of how a blind pedestrian would use the sound of traffic to cross a complex intersection.

Example 1: A blind pedestrian standing at corner A (facing corner B) ready to cross, will wait for the stationary vehicles behind him/her to start moving as an indication that the traffic light has changed. Then, the pedestrian will proceed to cross the street and follow the parallel line of traffic on his left (from A to B) confident there is enough time to safely cross the street.

Example 2: A blind pedestrian standing at corner A (facing corner C) ready to cross, will use the sound of the stationary vehicles on his/her left and the parallel traffic on his/her right as guides to follow a straight path while crossing.

Example 3: A blind pedestrian at corner C (facing corner D) ready to cross, will wait for the traffic from C to A to stop and the parallel traffic across the intersection to start, to safely walk from corner C to Corner D. The sounds from the stationary vehicles on his/her left and the parallel traffic across the intersection serve as guides to keep a straight path while crossing.

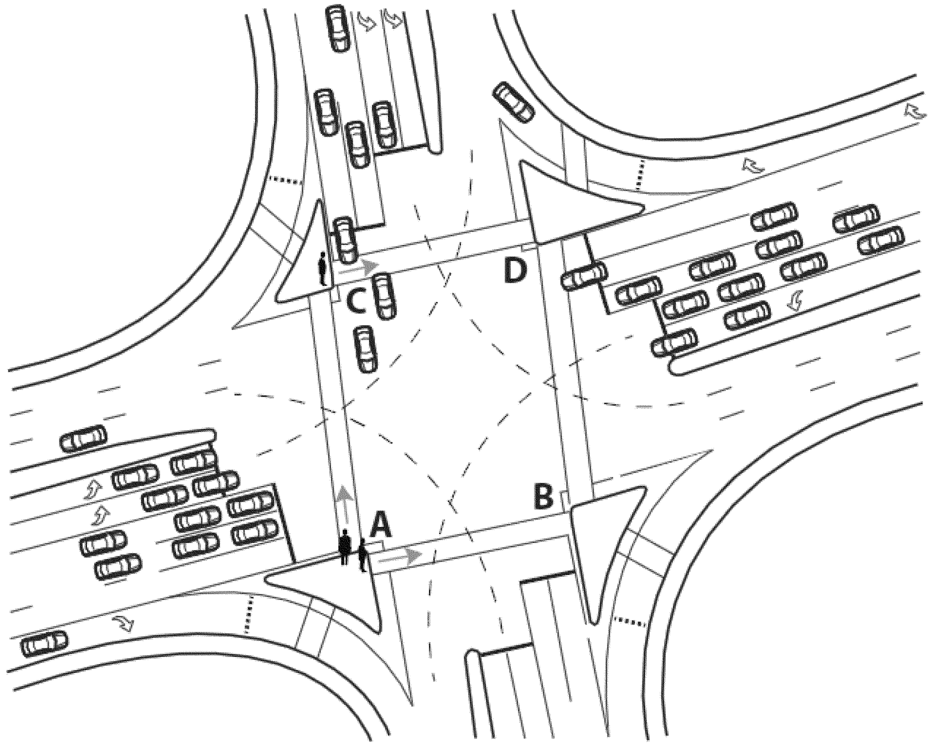

Figure 1: Complex Intersection

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 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.

VI. NHTSA Research and Industry Practices

On May 6, 2009 NHTSA issued a research plan describing the research relating to quieter vehicles it planned to conduct. This section reports on the research completed to date.

A. NHTSA Phase 1 Research [45]

In April 2010 NHTSA released a report titled ''Quieter Cars and the Safety of Blind Pedestrians: Phase 1'' referred to as Phase 1. This report documented a study conducted by the John A. Volpe National Transportation Systems Center (Volpe) under an interagency agreement. This study documents the overall sound levels and general spectral content for a selection of HVs and ICE vehicles in different operating conditions, evaluates vehicle detectability for two ambient sound levels, and considers countermeasure concepts. The study investigated operating scenarios of concern for pedestrians who are blind or visually impaired, documented acoustic measurements of hybrid, electric and ICE vehicles and ambient environments in which blind or visually impaired pedestrians might reasonably be expected to make travel decisions based on sound alone, examined the auditory detectability of vehicles in safety scenarios of concern to individuals who are blind or visually impaired and examined potential countermeasures.

Safety Scenarios for Pedestrians Who Are Blind or Visually-Impaired

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 are:

- *Vehicle approaching at low speed:* One of the strategies used by pedestrians who are blind is to cross when the road is quiet. This technique assumes that it is safe to proceed when a vehicle is loud enough to be heard far enough away, there are no other masking sounds present, and no other vehicles are detected.
- *Vehicle backing out (as if coming out of a driveway*): There is a concern

[45] see footnote 8.

quieter vehicles may not be detectable when backing out. This scenario is complex for pedestrians since it is difficult to anticipate where there may be a driveway and the driver's visibility may be limited. The pedestrian may have limited time to *react and respond to* avoid a conflict.

• *Vehicle travelling in parallel and slowing:* Pedestrians who are blind often need to distinguish between a vehicle moving through an intersection and a vehicle turning into their path. The pedestrian needs to perceive this information when the vehicle is in the parallel street, before it turns into his or her path. The sound of slowing vehicles in the parallel street helps pedestrians identify turning vehicles.

• *Vehicle accelerating from stop:* Pedestrians who are blind use the sound of traffic in the parallel street to establish alignment and to identify a time to cross. 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. Pedestrians may initiate their crossing as soon as they detect the surge of parallel traffic or may delay the decision to make sure traffic is moving straight through the intersection and not turning into their path. A delay in detecting the surge of parallel traffic may impact the opportunity to complete a crossing within the designated walking interval.

• *Vehicle stationary:* The sound of vehicles idling provides important cues. For example, the sound of a vehicle in the far lane gives cues about the width of the road (number of lanes), and conveys information about the distance to walk and the time needed to navigate across the street. A quieter vehicle may not be detected when it is stationary at intersections or parking lots and it may start moving suddenly at the same time a pedestrian enters the conflicting path.

NHTSA was able to gather crash data for collisions involving pedestrians and HVs when the HV was operating in one of the scenario described above (the crash report did not separately analyze vehicle starting from a stop and the vehicle stationary conditions) immediately prior to the crash in both the crash report released by NHTSA in September of 2009 [46] and the updated crash report released in October 2011.[47] The 2011 report analyzed the crash rates for vehicles making a turn, slowing/stopping, backing, entering and leaving a parking space/driveway and starting in traffic separately and then analyzed all those operating conditions together. Because of the sample size an independent odds ratio was not available for any of the scenarios. When taken together, however, these low speed operating conditions show a statistically significant 1.38 odds ratio showing an increased risk of pedestrian collisions.

For this study, the sounds emitted by HVs and ICE vehicles were measured and recorded under operating conditions representative of the previously identified safety scenarios.[48] The operating conditions were as follows: (1) a vehicle backing up at 5 mph (mimicking a vehicle backing out of a driveway); (2) a vehicle slowing from 20 to 10 mph (mimicking a vehicle preparing to turn right from the parallel street); (3) a vehicle approaching at a low constant speed (6 mph and 10 mph); (4) a vehicle accelerating from a stop; and (5) a vehicle idling. Average A-weighted sound levels for each of the six vehicles tested are reported in Table 1.

TABLE 1—OVERALL A-WEIGHTED SOUND LEVEL AT THE MICROPHONE LOCATION (12 FT)

[Average A-weighted level, LAeq0.5s, dB]

Scenario/vehicle operation	2010 Toyota Prius	2009 Toyota Matrix	Honda Civic Hybrid	Honda Civic ICE	2009 Toyota Highlande Hybrid	2008 Toyota Highlander
Approaching at 6 mph	44.7	53.5	49.3	52.0	53.2	55.5
Backing out (5 mph)	44.2	51.3	48.5	58.2	45.9	52.7
Slowing from 20 to 10 mph	53.0	54.2	56.6	55.0	53.0	55.4
Acceleration	62.9	63.1	65.4	63.5	64.8	64.9
Idling or Stationary but activated	[1]	47.8	44.8	46.0	[1]	48.1

[1] Background.

Additionally, measurements were collected for vehicles approaching at moderate constant speeds (20 mph, 30 mph, and 40 mph) in order to document the convergence, if any, of HVs and ICE vehicles at higher speeds. In general, HVs were quieter below approximately 20 mph, above which either the vehicle's ICE engine turned on, tire and road noise became dominant, or both. HVs also tended to have less high frequency content than ICEs at low speeds. Further details and results from this study can be found in NHTSA's final report DOT HS 811 304.[49]

Auditory Detectability of Vehicles in Critical Safety Scenarios [50]

In Phase 1, NHTSA 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 [51] 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

[46] See footnote 7,

[47] See footnote 39.

[48] The SAE J2889–1 draft test method covers only two operating conditions: stationary vehicle and 10 km/h (6 mph) constant speed pass by. This study follows recommendations of the SAE draft method with regard to instrument settings, calibration, meteorological monitoring, etcetera; however, it deviates from the SAE method with respect to operating condition, data measured, as well as height, distance, and orientation of the microphones. For each measurement, one-half second contiguous average SPLs were measured. The maximum of these for each event were analyzed for the development of Table 1. These levels are representative of the sound level when the vehicle is at or near the microphone line (line PP' in SAE J2889–1, Figure 1).

[49] See Docket for this notice, Item # NHTSA–2011–0148–0004.

[50] See footnote 8; Garay-Vega *et al.,* Auditory Detectability of Hybrid Electric Vehicles by Pedestrians Who Are Blind. 90th Annual Meeting Transportation Research Board January 23–27, (2011), Washington, DC Available at *http://amonline.trb.org/12ktc8/1.*

[51] 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.

(operated in electric mode), except for the slowing maneuver. Vehicle type, ambient level, and operating condition had a significant effect on response time.

Data collection included missed detection frequency and response time (and corresponding time-to-vehicle arrival and detection distance). Missed detection frequency is defined as instances when the target vehicle is present and the participant fails to respond. Response time is computed as the time from the start of a trial to the instant the participant presses a space bar as an indication he/she detects the target vehicle. Time-to-vehicle-arrival is the time from first detection of a target vehicle to the instant the vehicle passes the microphone line/pedestrian location. Detection distance is the longitudinal space between the vehicle and the pedestrian (microphone) location at the instant the participant indicated detection of a target vehicle.

A repeated measure of analysis of variance (ANOVA) was used to analyze the main and interaction effects of the independent variables: vehicle type, vehicle maneuver and ambient sound level. A separate analysis was completed for each scenario, and a pair-wise t-test compared each vehicle with the other (ICE vehicle and HV twins) for each ambient sound level. The time-to-vehicle arrival for each vehicle-ambient condition is shown in Table 2, Table 3 and Table 4 for each of three scenarios.

Vehicle Approaching at 6 mph (9.6 km/h) Pass by: The first traveling situation examined was a pedestrian standing on the curb waiting to cross a one-way street when there may be vehicles approaching from the left. Some trials included a target vehicle and some trials only included background noise. The target vehicle in this scenario was traveling from the left at a constant speed of 6 mph. There were vehicles in the background in all trials. The pedestrian had to be able to detect a vehicle that would affect the decision about when to start to cross the street. This scenario tested the distance and time at which a pedestrian can detect a vehicle approaching at low speed. On average, participants took 1.1 seconds longer to detect vehicles in the high ambient sound condition than in the low ambient sound condition. The main effect of ambient was statistically significant. The mean time-to-vehicle-arrival was 5.5 and 4.3 seconds for the low and high ambient condition respectively. Participants detected both ICE vehicles sooner than the HV twins. The main effect of vehicle type was statistically significant. The interaction effect of vehicle type and ambient was also statistically significant, meaning that the difference between when a passenger was able to detect an ICE vehicle versus its HV twin was greater when ambient was high than when it was low. Table 2 presents the individual differences between ICE vehicles and their HV peers (*i.e.,* Prius vs. Matrix and Highlander hybrid vs. Highlander ICE); pair-wise comparisons are statistically significant within a given ambient condition. Participants were more likely to miss the Toyota HVs than the Toyota ICE vehicles approaching at a constant low speed. The missed detection rates in the low ambient condition were: 0.02 for the Prius; 0.01 for the Matrix; 0.03 for the Highlander Hybrid; and 0.0 for the Highlander ICE vehicle. The corresponding values in the high ambient condition were: 0.21 for the Prius; 0.02 for the Matrix; 0.04 for the Highlander; and 0.01 for the Highlander ICE vehicle.

TABLE 2—TIME-TO-VEHICLE ARRIVAL AND DETECTION DISTANCE FOR 6 MPH VEHICLE PASS-BY BY VEHICLE TYPE AND AMBIENT CONDITION

Vehicle	Ambient sound level	Time-to-vehicle arrival (s)	Detection distance (ft)
2010 Toyota Prius	Low	4.3	37.9
	High	2.4	20.9
2009 Toyota Matrix	Low	5.5	48.4
	High	4.6	40.5
2009 Highlander Hybrid	Low	5.3	46.6
	High	4.1	36.6
2008 Highlander ICE	Low	6.8	59.4
	High	6.3	55.1

Vehicle Backing Out (5 mph (8 km/h) Reverse): The second traveling situation was a pedestrian walking along a sidewalk with driveways on the left side; the pedestrian heard distant vehicles in the background in all trials. This is similar to walking in an area that is a few blocks away from a main road. The target vehicle was a nearby vehicle backing towards the pedestrian at a constant speed of 5 mph. This task is complex for pedestrians since it is difficult to anticipate where there may be a driveway and when a vehicle will move out of a driveway. In addition, a driver's visibility may be limited and the pedestrian may have very limited time to respond to avoid a conflict. The main effect of ambient was statistically significant. The average time-to-vehicle-arrival was 4.4 and 2.7 seconds for the low and high ambient condition, respectively. Participants took longer to detect both HVs than their ICE twins. The main effect of vehicle type was statistically significant. Table 3 shows the individual differences between ICE vehicles and their HV twins; pair-wise comparisons were statistically significant within a given ambient condition. Participants were more likely to miss the Toyota HVs than the Toyota ICE vehicles in the backing out session. The missed detection rates in the low ambient condition were: 0.05 for the Prius; 0.02 for the Matrix; 0.10 for the Highlander Hybrid; and 0.02 for the Highlander ICE. The corresponding values in the high ambient condition were: 0.11 for the Prius; 0.0 for the Matrix; 0.26 for the Highlander; and 0.02 for the Highlander ICE. On average, participants took longer to detect vehicles in the high ambient sound condition than in the low ambient sound condition.

TABLE 3—TIME-TO-VEHICLE ARRIVAL AND DETECTION DISTANCE FOR VEHICLE BACKING OUT BY VEHICLE AND AMBIENT CONDITION

Vehicle	Ambient sound level	Time-to-vehicle arrival(s)
2010 Toyota Prius	Low	4.0
	High	2.5
2009 Toyota Matrix	Low	5.2
	High	3.6
2009 Highlander Hybrid	Low	3.3
	High	1.4
2008 Highlander ICE	Low	5.2
	High	3.3

Vehicle Traveling in Parallel Lane and Slowing (Slowing from 20 to 10 mph (32 to 16 km/h): The third and last traveling situation examined in the study was a pedestrian trying to decide when to start crossing a street with the signal in his/her favor and a surge of parallel traffic on the immediate left. The sound of slowing vehicles in the parallel street helps blind pedestrians identify turning vehicles. In some trials (no-signal condition), a vehicle continued straight through the intersection at 20 mph, so pedestrians can cross whenever they choose. However, in other trials there was a vehicle slowing from 20 mph to 10 mph as if to turn right into the pedestrian path (target vehicle). The pedestrian had to be able to detect when the vehicle was slowing. This scenario tests whether the pedestrian perceived this information when the vehicle was in the parallel street. Participants were more likely to miss the ICE vehicles approaching in the parallel lane and slowing than the HVs in the same situation. Table 4 shows the time-to-vehicle arrival and detection distance for the 'vehicle slowing' scenario. Pair-wise comparisons (HV vs. ICE twin) were statistically significant within a given ambient condition. On average, participants detected HVs sooner than their ICE vehicle twins. The main effect of vehicle type was statistically significant. The trend observed in the vehicle-slowing scenario (*i.e.,* HVs are detected sooner than their ICE vehicle twins) may be explained by a noticeable peak in the 5000 Hz one-third octave band for the HVs tested during this operation. The tone emitted was associated with the electronic components of the vehicles when braking (*e.g.,* regenerative braking). The missed detection rates in the low ambient condition were: 0.05 for the Prius; 0.31 for the Matrix; 0.03 for the Highlander Hybrid; and 0.17 for the Highlander ICE vehicle. The missed detection rates in the high ambient condition were: 0.05 for the Prius; 0.35 for the Matrix; 0.03 for the Highlander Hybrid; and 0.17 for the Highlander ICE vehicle.

TABLE 4—TIME-TO-VEHICLE ARRIVAL AND DETECTION DISTANCE FOR VEHICLE DECELERATING FROM 20 TO 10 MPH BY VEHICLE TYPE AND AMBIENT CONDITION

Vehicle	Ambient sound level	Time-to-vehicle arrival(s)	Detection distance (ft)
2010 Toyota Prius	Low	2.0	35.9
	High	1.9	33.8
2009 Toyota Matrix	Low	1.1	18.0
	High	0.8	12.8
2009 Highlander Hybrid	Low	3.0	58.8
	High	2.7	51.6
2008 Highlander ICE	Low	1.5	25.7
	High	1.3	21.8

Table 5 shows the time-to-vehicle arrival 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 (5 mph)	3.7	5.2	2.0	3.5
Slowing from 20 to 10 mph	2.5	1.3	2.3	1.1

B. NHTSA 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.'' The research conducted by Volpe first sought to define acoustic specifications to be used as alert sounds for quiet vehicles based on the sounds produced by ICE vehicles. Volpe then analyzed the loudness of the ICE sounds in a suburban ambient using psychoacoustic modeling. Volpe used human subject testing to evaluate the performance of several different varieties of countermeasure sounds including ICE sounds. Based on the results from the Phase I research, the psychoacoustic modeling and the human subjects testing Volpe developed potential specifications for vehicle countermeasure sounds.

The Phase 2 research developed various options and approaches to specify vehicle sounds that could be used to provide information at least equivalent to the cues provided by ICE vehicles, including speed change. In this research, acoustic data acquired from a sample of 10 ICE vehicles was used to determine the sound levels at which synthetic vehicle sounds, developed as countermeasures, could be set. ICE-equivalent sounds were specified as overall A-weighted sound levels and spectral content at the one-third octave band level. Psychoacoustic models and human-subject testing were used to explore issues of detectability, masking, and recognition of ICE-like and alternative sound countermeasures.

The researchers determined that the elements of a specification for vehicle sounds should consider sound output levels; pitch changes that convey changes in vehicle speed; and acoustic qualities that determine whether the sound is perceived as a vehicle. The options discussed in the Phase 2 final report [52] assume 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.

Note: Human-subject tests for Phase 2 were conducted in an ambient level of approximately 58–61 dB (A).

Phase 2 work focused initially on the following two ideas: (1) the lack of detectability of quieter vehicles can be remediated if they are fitted with synthetic sound generators that emulate the sound of typical ICEs; and (2) the specifications for the vehicle sounds can be defined in terms of objective parameters—namely, overall sound output as measured by the SAE J2889–1 procedure and spectral distribution specifications for the minimum amount of sound level in one-third-octave bands.

Recognizability is more complex than detectability. Most sounds, and sounds as complex as those emitted by an ICE, have numerous properties in addition to loudness and spectral distribution that affect human perception. Among these properties are rise time, decay time, repetition rates, variations in pitch and loudness, and phase relations among various components of the sound. These challenges can be demonstrated, for example, by playing a recording of a sound backwards, for example, that changes in these properties can render a sound unrecognizable even though loudness and spectral distribution are unchanged. There are no established quantitative metrics for many qualities of a sound that a person might use for recognition.

In the Phase 2 report Volpe first considered whether HVs and EVs should be equipped with sounds that are based on the acoustic profile of ICE vehicles. This concept is based on the assumption that the ICE vehicles measured in this study are typical of the current fleet, emit an acceptable amount of noise during low-speed operations, and that some (*e.g.,* ICE-like) countermeasure sounds can be based on the statistical average of real-vehicle spectral characteristics. Researchers developed the potential specifications for alert sounds shown in Table 6 and Table 7 based on acoustic analysis of sounds produced by ICE vehicles to demonstrate what acoustic specifications for a vehicle alert sound might look like. The derivations of these data are given in Section 5 of the Phase 2 final report.

TABLE 6—MINIMUM OVERALL A-WEIGHTED LEVEL (LAEQ, 1/2; SEC) BY VEHICLE OPERATION

Vehicle operation	$L_{Aeq,\ 1/2\ sec,}$ dB(A)
6 mph	61.1
10 mph	63.6
15 mph	68.1
20 mph	70.2
Acceleration	66.7
Start-up	70.7
Stationary but activated	55.2

Table 7 shows the corresponding minimum A-weighted one-third-octave-band spectra for each operating mode. ICE vehicles have energy components in all frequencies (*e.g.,* 100 to 20k Hz), however, the psychoacoustic models implemented in this study show that energy components in the one-third octave bands ranging from 1600 Hz to 5000 Hz contributed the most to detection, and those ranging from 315 Hz to 1600 Hz contributed additional detection and pitch information. These spectral distribution limits are derived from the procedures described in Section 6 of the Phase 2 final report.

TABLE 7—A-WEIGHTED ONE-THIRD-OCTAVE-BAND SPECTRA AT MICROPHONE LINE LAEQ, 1/2 SEC

1/3 Octave band center frequency, Hz	6 mph	10 mph	15 mph	20 mph	Acceleration	Startup	Stationary but activated
100 to 20000	61.1	63.6	68.1	70.2	66.7	70.7	55.2
315	43.9	46.9	50.2	52.5	49.8	44.2	37.3
400	46.5	48.7	53.0	54.1	51.4	46.6	39.0
500	47.9	51.2	55.6	57.1	53.4	51.8	42.1
630	49.0	52.5	56.9	59.1	54.6	52.4	42.3
800	51.1	54.6	59.5	62.3	55.1	55.2	43.2
1000	51.4	55.2	60.2	63.2	55.6	57.8	44.9
1250	52.2	54.6	59.6	62.2	57.2	60.5	46.3
1600	52.0	54.3	58.8	61.3	57.0	61.1	45.4

[52] See footnote 11.

TABLE 7—A-WEIGHTED ONE-THIRD-OCTAVE-BAND SPECTRA AT MICROPHONE LINE LAEQ, 1/2 SEC—Continued

1/3 Octave band center frequency, Hz	6 mph	10 mph	15 mph	20 mph	Acceleration	Startup	Stationary but activated
2000	50.3	52.0	56.1	57.9	55.7	60.5	44.6
2500	49.1	50.3	53.9	54.9	55.1	61.1	43.8
3150	48.6	49.2	52.4	52.1	54.9	61.6	44.1
4000	46.9	47.5	50.5	49.5	53.2	60.9	42.4
5000	44.1	45.0	47.8	46.4	50.8	59.2	40.3

The Volpe Center examined two options[53] under this first concept (ICE-like sounds):

Recordings of Actual ICE Sounds

The first option under the ICE-like sound concept explored using recordings of actual ICE vehicles as alert sounds. Recordings would be made when the vehicle is operating at constant speeds, forward from 0 to 20 mph and in reverse at 6 mph. Other components of the vehicles noise output (*e.g.,* tire noise, aerodynamic noise, AC fan noise) would be emitted regardless of whether an ICE is in use and would not be included in these recordings. Sound generation systems with signal processing capabilities would be used to continuously and monotonically vary the sounds from one operating condition to the next according to vehicle input (*e.g.* vehicle speed sensors, throttle sensors, etc.). In this option, emitted sounds would be based on standardized recordings with processing limited to pitch shifting in proportion to vehicle speed and interpolation between sounds.

Synthesized ICE-Equivalent Sounds

The second option under the ICE-like sound concept explored using simulated ICE sounds directly synthesized by a digital-signal processor (DSP) programmed to create ICE-like sounds (based on actual target sounds) that would vary pitch and loudness depending on vehicle inputs. This is in contrast to the first option, described above, in which the sounds come directly from recordings of actual vehicles, and the processor must store and interpolate among files representing every mode of operation and for every speed within the 0 to 20-mph range. Here, the resulting synthesized sounds would resemble those of the first option, but have fewer spectral components. A synthesizer could be simpler and cheaper than a sound generator based on real ICE sounds. For this option, target sounds, recorded from actual vehicles for the operations specified above would be used. The synthesized sounds would then be developed to match the spectral shape of these target sounds. (**Note:** by definition, power-spectra spectral lines have a resolution of 1 Hz).

Sound generation systems with signal processing capabilities would be used to continuously and monotonically vary the sounds from one operating condition to the next according to vehicle input (*e.g.* vehicle speed sensors, throttle sensors, etc.) and the synthesis algorithms developed for their sounds. The two options listed above assume that band-limited (315 Hz to 5000 Hz) ICE-like sounds will be recognizable as motor vehicles.

Alternative, Non-ICE-Like Sounds Designed for Detectability

The second concept, described in the Phase 2 final report, consists of alternative countermeasure sounds with acoustic characteristics different from ICE vehicles. Some of the countermeasures evaluated in the human-subject studies have sound characteristics that could improve detectability when compared to ICE-equivalent sounds. The following sound characteristics can improve detectability of a sound source[54]:

- Pulsating quality with pulse widths of 100 to 200 msec.
- Inter-pulse intervals of about 150 msec.
- Fundamental tonal component in 150 to 1000 Hz range.
- At least three prominent harmonics in the 1 to 4 kHz range.
- Pitch shifting denoting vehicle speed change.

The design of a non-ICE sound involves a complex tradeoff among several factors including annoyance, cost, detectability, and overall sound pressure level values. While the required sound pressure level values for non-ICE-like sounds will generally be lower than for ICE-like sounds for the same detection distance, there is no objective basis upon which to calculate the difference in sound pressure level values for the class of non-ICE sounds as a whole. Rather, the equivalent detectability sound pressure level value for a particular non-ICE sound must initially be determined experimentally by a jury process that rates detectability. As psychoacoustic models improve, it may be possible to use them in place of jury testing to determine minimum sound pressure level specifications for these sounds, but that approach is not yet sufficiently accurate.

In this concept sound generation systems with signal processing capabilities would be used to continuously and monotonically vary the pitch and amplitude of sounds as appropriate to operating conditions according to vehicle inputs (*e.g.* vehicle speed sensors, throttle sensors, etc.). The appropriate relationship between sound amplitude and throttle position would need to be determined. The detectability of a specific non-ICE sound can be best determined only through human subjects testing, at the present state of the art.

Hybrid of Options Discussed Above

A third concept to designing countermeasure sounds, explored in the Phase II report, would be a combination of the concepts (*i.e.* using ICE-like or non-ICE-like sounds) discussed above, with the goal of gaining the benefits of each, while minimizing the disadvantages. Simulated ICE sound could be generated which would vary pitch and loudness depending on vehicle inputs. This system could simultaneously generate both ICE-like sounds at a lower sound pressure level than the concepts based on ICE sounds discussed above, and synthetic sounds designed for optimal alerting potential with minimal annoyance. The ICE-like sound components may not be heard in higher urban ambient-noise conditions, but their association with the alerting sound would be learned over time from when the pedestrian is exposed to the sound in lower ambients. This method would most likely depend on jury testing of human subjects to set the sound level for detection.

[53] In this section of the notice the word ''option'' refers to countermeasure concepts developed in Phase 2 research and not rulemaking options considered by the agency when developing this proposal (see Sections VII and VIII for NHTSA's proposal and alternatives considered, respectively).

[54] Stanton & Edworthy (Eds.) (1999) Human Factors in Auditory Warnings

Human Subject Evaluation of Detectability

A human subject study was conducted to compare the auditory detectability of potential sounds for hybrid and electric vehicles operating at a low speed. The sounds evaluated included: (1) Sounds produced by vehicles with integrated sound systems rented from manufacturers, and (2) sounds produced by prototype systems rented from manufacturers, and played back by loudspeakers temporarily mounted on HVs rented separately. Five vendors, motor vehicle manufacturers or suppliers of automotive electronics, provided prototypes of synthetic sound generators for EVs or HVs. The five systems were labeled ''A'' to ''E''. A total of nine sounds were evaluated: A1, A2, A5, B, C, D, E1, E3, and E4. Sounds were evaluated at two sound pressure levels typical of ICE vehicles at low speeds (*i.e.,* A-weighted SPL of 59.5 dB and 63.5 dB).[55] An ICE vehicle that produced A-weighted SPL of 60 dB in the 6 mph pass-by test was used as a reference in this evaluation. The ICE vehicle was labeled 'R'.

Sound A1 was an engine like sound with a turbine-like whine that had a prominent peek that varied from 150 Hz to 300 Hz based on vehicle speed. Sound A2 was an engine sound with enhanced valve noise with prominent signal content between 100 Hz and 200 Hz. Sound A5 was a whirring sound with a diesel engine sound. The fundamental signal content of the whirring part of the sound for sound A5 was between 400 Hz and 600 Hz based on vehicle speed. Sound B emulated the exhaust note (the fundamental of the combustion noise) of an engine. The sound did not contain appreciable components above 250 Hz. Sound C was a Wavy, turbo-like sound with most of its energy as broadband noise in the 200 Hz to 5000 Hz range. Sound D was a broadband sound designed to suggest an electric motor coupled to other rotating machinery. Sound E1 was a pure engine noise with most of its energy below 300 Hz. Sound E3 was an engine-like sound with a 'whirring' character and a flatter spectral distribution than Sound E1 and had none of the prominent harmonics of the combustion note. Sound E4 contained short bursts of predominantly high-frequency sound with the peak amplitude of the fundamental varying in frequency from about 450 Hz to 700 Hz based on speed.

Data was collected outdoors during three independent sessions conducted on three days in July and August 2010. The first session included four operating modes: idle (stationary), acceleration from stop, start-up and 6 mph forward pass-by. The following two sessions included the 6 mph forward pass-by. The HVs used in the study were operated in electric mode during the pass-by trials. The sample included 79 participants 34 of which were sighted and 45 of which were legally blind. The legally blind participants were independent travelers and all participates had self-reported normal hearing.

The study took place in a parking lot located on the USDOT/Volpe Center campus in Cambridge, Massachusetts. The test site has the acoustic characteristic of an urban area with a typical ambient noise of approximately A-weighted sound pressure level of 58–61 dB. The dependent variables examined in the study included raw detection distance, proportion of detection, time-to-vehicle arrival, and detection distance. Raw detection distance is the number of feet the vehicle was from the participant when the participant indicated she or he heard the sound. A failure to detect the sound before the vehicle passed was treated as missing data. Proportion of detection is the proportion of trials of a given condition in which the participant detected the sound anytime before the vehicle passed the participant. Time-to-vehicle-arrival is the time, in seconds, from detection of a target vehicle sound to the instant the vehicle passes the pedestrian location. Detection distance is the calculated distance, feet, to the target vehicle at the moment each subject responded.

Each subject had a push button device which they used to indicate when they detected a nearby vehicle. Participants were asked to press a response button when they detected and recognized a vehicle that would affect their decision about when to start crossing the street.

Table 8 shows the mean detection distances for the sounds evaluated in the human-subject studies for the 6 mph pass-by; sounds at the top of the list can be described as sounds designed according to psychoacoustic principles and sounds at the end of the list can be described as ICE-like sounds with only the fundamental combustion noise or otherwise lacking in the qualities that support detectability. The results show that high amplitude sounds (A-weighted SPL of 63.5 dB) were detected more often and at greater distances than low amplitude sounds (A-weighted SPL of 59.5 dB).

TABLE 8—MEAN DETECTION DISTANCE (FT) FOR ALL SOUNDS AT TWO AMPLITUDES AND FOR THE REFERENCE ICE VEHICLE

Sound number	Average detection distance (feet) for amplitude equal 59.5 dB(A)	Average detection distance (feet) for amplitude equal 63.5 dB(A)
E4	72	85
A2	57	77
E3	52	70
A5	50	47
ICE vehicle, 60 dB(A)	41	NA
A1	35	44
C	32	41
E1	30	32
B	20	25
D	19	NA

[55] As measured by the SAE J–2889 draft test procedure (SAE J–2889, draft, 2009).

Results show that A2, A5, E3, and E4 have significantly better detectability than the ICE reference sound at 6 mph. These sounds never have significantly worse detectability in any condition. Thus, these sounds overall have better detectability than the ICE reference sound. In contrast, sounds A1, B, C, D, and E1 all have significantly worse detectability than the reference sound for the 6 mph forward pass-by. These sounds never have significantly better detectability in any of the conditions presented to subjects. Thus, these sounds overall have worse detectability than the reference sound.

The analysis also indicated significant main effects of sound and a significant three-way interaction of session, sound, and direction. This implies that the relative performance of each sound, including the reference sound, is jointly contingent on the direction it comes from and the session it was presented in. The directional effect results primarily from the fact that the roof-top fans on buildings to the west were the predominant source of ambient noise, which can mask vehicles approaching from the west compared with vehicles approaching from the east. The detectability of each sound relative to the reference was evaluated by comparing each sound to the reference vehicle for the corresponding session and direction condition of each.

To compare the detectability of the sounds to each other, a mixed design ANOVA was performed on detectability with session and vision as between-subjects independent variables, and sound, direction, and amplitude as within-subject independent variables.[56] Sounds were ranked by comparing each to the other (t-tests) for each session by-direction-by-amplitude condition. To assist in the control for family-wise error rate, the analyses only included the four sounds shown to be superior to the reference sound. Results show that E4 has overall significantly better detectability than the other sounds, and within each condition it is never worse than any other sound, except for one condition when compared to A2. Sounds A2 and E3 are overall not significantly different than each other, showing only a difference in a single condition. Sound A5 has overall significantly worse detectability than the other sounds, and within each condition is it never better, except for one condition when compared to E3. The overall ranking of the sounds from most to least detectable is therefore: E4, A2 and E3, and A5.[57]

In summary, the human subject testing in Phase 2 suggest that synthetic sounds that resemble those of an ICE produce similar detection distances as actual ICE vehicles. In some instances, synthetic sounds designed according to psychoacoustic principles can produce double the detection distances relative to the reference vehicle. The results also suggest that synthetic sounds that contain only the fundamental combustion noise are relatively ineffective. None of the analyses found a significant effect of vision ability.[58] Participants who are legally blind, on average, were no better or worse than sighted participants in detecting the approach sounds.

C. NHTSA Phase 3 Research

The third phase of NHTSA's research involving quiet vehicles consisted of developing an objective, repeatable test procedure and objective specifications for minimum sound requirements for hybrid and electric vehicles. NHTSA's Vehicle Research and Test Center (VRTC) conducted acoustic measurements and recordings of several HVs and EVs and those vehicle's ICE pair vehicles. 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 evaluate the new SAE J2889–1 test method and several variations used to test operating conditions that were not included in SAE J2889–1 and provide data to establish performance criteria. The research was conducted using 3 HVs, 1 EV, and 4 ICE vehicles.

SAE J2889–1 was still in draft form at the start of the project, but the final version published in September of 2011 was not significantly different from the draft. The vehicles were used to gather sample data on the difference in sound pressure levels between ICE sounds and EV or HV sounds as well as directivity and sound quality levels using eleven test scenarios developed for this program (4 static and 7 pass-by). Some of the hybrid and electric vehicles were tested with multiple alert sounds. Some the hybrid and electric vehicles were also tested with no alert sound at all to determine crossover levels.

A significant modification to the SAE procedure was the addition of a laser at the microphone line-labeled as PP' in SAE J2889–1. This addition enabled recording the time at which the leading edge of the vehicle reached the microphone location.

Test Scenarios[59]

VRTC measured the vehicle sound output for the operating scenarios listed below for ICE vehicles, hybrid and electric vehicles with an alert sound active, and hybrid and electric vehicles with no alert sound active. The overall goal of the research was to capture as much acoustic data as possible for both ICE sounds and artificial sounds added to hybrid and electric vehicles as alert sounds so that the sounds could be analyzed when the agency was the establishing acoustic specifications contained in this proposal.

- *Scenario 1: SAE J2889–1 modified Startup (8 microphones).* This set up was used to generate a 360 degree sound or directivity profile for the vehicle.
- *Scenario 2: SAE J2889–1 modified Stationary but active (8 microphones).* This scenario was the same as Scenario 1 except that the sound of the vehicle while stationary was recorded.
- *Scenario 3: SAE J2889–1 modified Startup (5 microphones).* Data from this recording can be used can be used to generate a 180 degree sound or directivity profile for the vehicle.
- *Scenario 4: SAE J2889–1 modified Stationary but active (5 microphones).* This scenario was the same as Scenario 3 except that the sound of the vehicle while stationary was recorded.
- *Scenario 5: SAE J2889–1 10 km/h Forward Constant Speed (2 microphones).* This test produced result from 2 microphones on either side of the vehicle centerline.
- *Scenario 6: SAE J2889–1 20 km/h Forward Constant Speed (2 microphones*). This test produced result from 2 microphones on either side of the vehicle centerline.
- *Scenario 7: SAE J2889–1 30 km/h Forward Constant Speed (2 microphones*). This test produced result from 2 microphones on either side of the vehicle centerline.
- *Scenario 8: SAE J2889–1 10 km/h Reverse Constant Speed (2 microphones).* This test was pass-by noise test with data being recorded as the vehicle is driven backwards though the noise test pad with two

[56] The reference sound 'R' and sound 'D' were excluded from this analysis since they did not differ in amplitude.

[57] The acoustic characteristics of these sounds are discussed in Section 5.2 of NHTSA Report No. DOT HS 811 496.

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

[59] Diagrams showing the microphone setup for all the scenarios are contained in the Phase 3 report from VRTC.

microphones on either side of the vehicle centerline.

- *Scenario 9: 0 to 10 km/h Forward Acceleration to Constant Speed (2 microphones)* The vehicle was positioned 2 meters before the PP' line and accelerated at 0.1 g from 0 to 10 km/h pass-by noise test with data being recorded by two microphones on either side of the vehicle centerline as the vehicle is accelerated though the remainder of the noise test pad.
- *Scenario 10: 30 to 10 km/h Forward Deceleration to Constant Speed (2 microphones).* The vehicle was driven at 30 km/h into the test zone and began deceleration at 0.1 g to 10 km/h at the PP' line.
- *Scenario 11: 0 to 10 km/h Reverse Acceleration to Constant Speed (2 microphones).* The vehicle was positioned 2 meters before the PP' line and accelerated from 0 to 10 km/h with data being recorded by microphones on both sides of the vehicle centerline as the vehicle was accelerated though the remainder of the noise test pad.

When testing the vehicle in the scenarios described above VRTC identified some challenges. The test drivers found that it was difficult to reliably maintain a low travel speed for some vehicles during the 10 km/hr forward pass-by test as these vehicles tried to shift gears or the electric controls energized or de-energized. During the pass-by tests conducted in reverse at 10 km/hr the test drivers experienced some of the same difficulties experienced during the forward pass-by testing. Also, it was very difficult to maintain the vehicle in the center of the lane. Testing in reverse could only be done during daylight hours due to difficulty in driving backwards, drifting in the lane and possible equipment damage. During the testing of the vehicle accelerating from 0 to 10 km/hr the test drivers encountered difficulty in maintaining a consistent acceleration rate. Positioning the vehicle for this test and starting the data acquisition was very labor intensive

When testing the vehicle decelerating from 30 to 10 km/hr the test drivers encountered difficulty in maintaining a consistent deceleration rate. Determining the starting point of deceleration was difficult. Some vehicle braking rates were difficult to maintain the 0.1 g rate. During braking the vehicles' regenerative braking systems transitioned back and forth from mechanical to regenerative braking. When testing the vehicles while accelerating in reverse the test drivers encountered difficulty in maintaining a consistent acceleration rate and maintaining the center of the lane for the remainder of the test pad. Positioning the vehicle and starting the data acquisition was very labor intensive for this test.

Interpretation of Results

One of the purposes of the Phase 3 acoustic measurements was to gather additional data on the difference in sound levels between EVs and HVs operating in electric mode and ICE vehicles. For the pass-by tests in Phase 3 the ICE vehicles were 6.2 to 8.5 A-weighted dB louder than the EV/HVs without added sound at 10 km/h. At 20 km/h the difference between the HV/HVs and ICE vehicles varied, but the average level was 3.5 A-weighted dB louder for the ICE vehicles. At 30 km/h the sound levels of the HV/HVs approached the levels of the ICE vehicles and the individual measurements for the two types of vehicles have considerable overlap. Table 9 shows the results of HEV/EV vehicles with no sound alert system as compared to their ICE counterpart.

TABLE 9—PASS-BY SOUND LEVEL FOR HEV/EV VEHICLES WITHOUT ALERT SOUND ACTIVE VERSUS COUNTERPART ICE VEHICLES

Manufacturer	Speed, km/h	HEV/EV Sound level, dB	ICE Sound level, dB	ICE minus HEV/EV, dB
Nissan	10	50.5	56.6	6.2
	20	60.0	62.3	2.2
	30	66.5	68.1	1.5
Prototype Vehicle G	10	51.4	59.9	8.5
	20	60.5	63.1	0.6
	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	3.5
	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 from 6 to 10 dB less than that directly in front of the vehicle. For the vehicles with an speaker system the sound level behind the vehicle was 12 to 15 dB lower behind the vehicle, and in some cases the sound level at the microphone behind the vehicle was not distinguishable from a quiet background sound level of 40 dB. There was a systematic difference from left to right for some vehicles, particularly with an artificial sound.

Acoustic Analysis Performed by Volpe

As part of the Phase 3 research Volpe examined the frequency range, minimum sound level for selected one-third octave bands, and requirements for broadband noise and tones as possible criteria for vehicle sound using a loudness model to determine when the sounds might be detectable in a given ambient. Also considered were the relative proportions of acoustical energy emitted from a vehicle as a function of direction (directivity) and ways to denote changes in vehicle speed. Two approaches were used to identify potential detectability specifications for alert sounds to be included in the NPRM: (a) sound parameters based on a loudness model and detection distances and (b) sound parameters based on the sound of ICE vehicles.

Volpe's work in developing the acoustic 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. 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.

Because the response of the study participants in the human subject experimentation in Phase 2 varied significantly due to variations in the ambient, 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 this proposal. Volpe also observed during the human factors research that sounds with strong tonal components were more detectable.

Volpe developed the specifications based on the sound of ICE vehicles using measurements of ICE vehicles captured in Phase 2 and acoustic data provided by representatives of auto manufacturers.

Before presenting these two approaches, it is important to explain how background noise, critical frequency range, and loudness models relate to the detectability of a sound.

Background Noise

When talking about the detectability of a sound, it is important to understand masking and background noise (ambient noise). Masking occurs when the perception of one sound is affected by the presence of an unrelated sound. Background noise can affect the extent to which masking occurs. Two characteristics of background sounds are of primary importance: overall sound pressure level and the frequency content or shape of the frequency spectrum. Masking depends on the signal-to-noise ratio in the different frequency bands and therefore cannot be estimated from the overall A-weighted sound level alone. Acoustic data for background noise can be obtained from recordings of background noise made at various locations. Recordings of actual traffic may include peaks (*e.g.,* passage of nearby loud vehicles) that can introduce variability when using human subjects for testing or when applying detectability models. An alternative to recordings of the actual traffic is to use standardized synthetic background noise. Synthetic background noise consists of, for example, 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 (*e.g.,* those caused by the passage of a particular loud vehicle or aircraft). This broadband noise creates masking while reducing the issues associated with fluctuations or peaks. The standardized noise is an advantage for repeatability. For more information about this, see Pedersen *et al.* 2011.[60]

A standardized background noise was used in Phase 3 in the implementation of Moore's Loudness model to compute minimum sound levels for detection in a given one-third octave band and to identify frequency ranges relevant for alert sounds.[61] The ambient selected for these analyses is representative of many common urban ambients.[62] Being detectable in this ambient would mean that the alert sound would be detectable in other ambients with lower overall levels and similar spectral shapes. The spectral shape is given in Figure 2. The overall A-weighted level for detection computations was 55 dB). Results for 60 A-weighted dB can be accurately estimated by adding 5 dB to the results from the 55 A-weighted dB analysis. Similarly, results for 50 A-weighted dB can be accurately estimated by subtracting 5 dB from the results from the 55 A-weighted dB analysis.

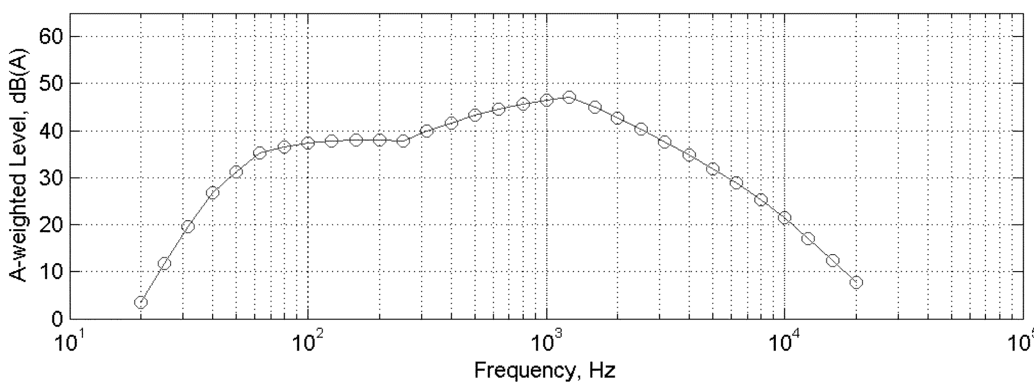

Figure 2. A-weighted Spectrum and Ambient at 55 A-weighted dB

Critical Frequency Range

Critical frequency regions, defined by a set of one-third octave bands, are determined by applying psychoacoustic principles for a given ambient condition. The purpose of identifying a critical frequency region(s) is to ensure that a sound signal is emitted from the vehicle such that it would be expected to be detectable at a reasonable distance away from a pedestrian. Due to masking effects of the ambient and potential hearing loss of the pedestrian, opportunities for detection will be maximized if the alert signal contains detectable components over a wide frequency range.

Frequencies in the audible range for children and most young adults are from about 20 to 20,000 Hz. Human

[60] Pedersen *et al.* (2011). White paper on external sounds for electric cars—Recommendations and guidelines. Delta-Senselab. Copenhagen.

[61] For a discussion of loudness models see page 67.

[62] See footnote 59.

hearing is more sensitive in the 500–5,000 Hz range than it is at low frequencies or very high frequencies.[63] Exposure to loud noise and age-related factors often diminish a person's sensitivity to sound at higher frequencies. Mid-range frequencies (approximately 320—5120 Hz) are perceived with greater loudness than lower (20 to 320 Hz) or higher frequencies (5000 to 20,000 Hz). Frequencies below 300 Hz are commonly masked by urban background noise.[64]

Localization of sounds is accomplished through multiple neurophysiological processes, each of which is most effective in a different range of frequencies. Above 1600 Hz, inter-aural level differences (caused by the shadowing effect of the head) become the primary directional cues. For some combinations of frequency and angular orientation between sound source and listener, cancellation of the direction cues can occur. Hence, an accurate localization of a sound source is most likely to occur when it contains multiple high-frequency components that are audible above the background noise.[65 66]

A person's relative sensitivity to different frequencies varies with loudness. Loudness is a numerical designation of the strength, expressed in units called ''sones,'' of a sound that is proportional to the subjective magnitude as estimated by listeners having normal hearing (ANSI S3.4 2007).[67] Loudness models predict this strength by accounting for how the human auditory system processes both the amplitude and frequency characteristics of a sound.

Loudness Models

Sound-pressure-level-based metrics, such as, the A-weighted level, provide a first estimate of the perceived loudness of a sound. These metrics fail to account for several factors that affect the perceived loudness including: the level dependence of the frequency sensitivity, level dependence on frequency selectivity, and frequency based masking effects. The level dependence of the frequency sensitivity refers to the fact that for the same change in sound pressure level for a low frequency sound and a high frequency sound, the low frequency sound will be perceived as increasing in loudness more than the high frequency sound. The level dependence of the frequency selectivity refers to how the human auditory system separates frequency components of a complex sound's signal. Frequency-based masking is used to describe how a high-energy component can prevent or reduce the perception of a lower-energy component at a different frequency. That is, for example, an ambient with a high level of low-frequency sound can mask a signal with components in a higher frequency range.

Several psychoacoustic models exist that relate sound pressure level data to the perceived loudness of the signal or its detectability/audibility. Moore's Loudness model[68 69] was used in Phase 3 to estimate the minimum sound level needed for a sound to be detectable in the presence of an ambient. This model is useful for the prediction of thresholds in quiet ambients and for thresholds in the presence of a masker,[70] as well as for computing equal loudness contours.[71] This model was developed for use with ISO 226, *Normal Equal-Loudness Contours,* (1987) and the absolute thresholds found in ISO 389–7, *Acoustics—Reference zero for the calibration of audiometric equipment—Part 7: Reference threshold of hearing under free-field and diffuse-field listening conditions,* (1996). Since the model's original development, both of these standards have been updated to ISO 226 (2003) and ISO 389–7 (2005). There are newer implementations of Moore's model that reflect these new data. However, we are not aware of any implementations that include these updates as well as provide for computing thresholds in the presence of a masker. Since computing thresholds in the presence of a masker is of fundamental importance for the work in Phase 3, and since the updates represent ''fine tuning'' of the model, the 1997 model was identified as the most suitable choice.

Moore's Loudness model, as described in Moore and Glasberg (1997),[72] accounts for the following factors: how the sound is presented to the subject (free field, diffuse field, via headphones); transmission through the pinna (outer ear) and the middle ear; frequency sensitivity and selectivity; excitation compression/amplification; the transformation of pressure entering the cochlea to an excitation pattern (determined from the magnitude of auditory filter output); transformation from an excitation pattern to specific loudness for sounds in quiet ambient environments and in the presence of a masker (specific loudness is analog to power spectral density); and integration of specific loudness (integrating the area under the curve of a power spectral density function gives the total power of that function).

The general procedure for running the model is to provide un-weighted one-third octave band levels for both the signal and the masker and to provide information on how the signal is presented. For the purposes of the Phase 3 work, free-field, frontal presentation was used, which is both accurately and conservatively compared to diffuse field or headphones. The model provides several levels of detail in the results, including the specific loudness as a function of the number of equivalent rectangular bandwidths. It is the integral of this function, or simply Loudness in sones that was utilized in Phase 3.

This model was adequate for the needs of Phase 3. However, since this is a time-invariant model, it does not take into account differences in duration (sounds with very short durations are perceived differently than long duration sounds due to the temporal windows associated with the auditory system). Nor does it account for periodic modulations including the effect of co-modulation masking release.

As part of the Phase 3 research, in addition to exploring the detectability of sounds, the agency examined acoustic characteristics that make sounds recognizable. Recognition includes two aspects: 1) recognition that the sound is emanating from a motor vehicle, and, 2) recognition of the type of operation that the vehicle is conducting so that the pedestrian can take appropriate measures. Our research has shown that sounds that contain both broadband components and tones are more likely to be recognized as vehicles. Sounds that contain only high frequencies have a synthetic (and unpleasant) character.

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[63] Fletcher, H. and Munson, W. A. (1933). Loudness, its definition, measurement, and calculation. *Journal of the Acoustic Society of America.* 5 (1), 82–108.

[64] See footnote 11 Chapter 6.

[65] Feddersen *et al.* (1957). Localization of high frequency tones. Journal of the Acoustical Society of America. 5, 82–108.

[66] Yost, W.A. (1994) Fundamentals of Hearing: An Introduction. San Diego: Academic Press.

[67] American National Standard (1995). Procedure for the computation of loudness of steady sound (ANSI S1.13). New York, New York: Secretariat, Acoustical Society of America.

[68] Moore *et al.* (1997). A model for the prediction of thresholds, loudness, and partial loudness, *J. Audio Eng. Soc.* 45(5).

[69] Moore and Glasberg (1997). A model of loudness perception applied to cochlear hearing loss. Auditory Neuroscience, 3, 289–311.

[70] A value of 0 sones is approximately the threshold of perception. Moore models threshold to be at 0.003 sones to match ISO 389–7:2005 to within 0.2 dB over the frequency range from 50 to 12,500 Hz (ANSI S3.4–2007).

[71] Loudness contours is a graphical representation of frequency (x-axis) versus levels (y-axis) such that tones of different frequency and different level are judged to be equally loud.

[72] See footnote 67, 289–311.

Sounds with lower frequency tones and broadband components have a more closely resemble the sound produced by an ICE vehicle. In the Phase 2 human factors research Volpe observed that sounds with strong tonal components were more detectable.

While developing the acoustic parameters contained in this proposal during Phase 3, parameters that were critical to recognition were determined by simulating sounds. Sound simulations were developed for the following vehicle operating scenarios: stationary but activated, constant speed pass-bys, and accelerating pass-bys. Pass-bys included Doppler shifts and accelerations also included a pitch shifting tied to vehicle speed. The sound pressure levels changed as a function of speed and as a function of position relative to the receiver during the vehicle pass-by sound simulations. Roughly two hundred sounds were generated and evaluated. Based on initial assessment of these sounds and engineering judgment, at least one tone (and preferably more) should be included in the acoustic specifications for HVs and EVs for the purpose of recognition. The lowest tone should have a frequency no greater than 400 Hz. 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. (Note: the methodology in ANSI S1.13–1995 appears to be overly conservative for the Phase 3 work. It may be better to: a) either reduce the bandwidth, or b) include all tones within the band for this calculation for the current application. Comments are specifically sought on this issue).

Broadband components, which may be modulated, should be in each one-third octave band from 160 Hz to 5000 Hz. Tones at frequencies above 2000 Hz do not contribute to recognition. To aid in recognition of vehicle acceleration and deceleration, the pitch (as measured by the fundamental frequency) should increase and decrease by at least one percent per km/hr of speed over the range from 0 km/hr to 30 km/hr. Additional cues for recognition will be obtained by the movement of the vehicle relative to the pedestrian, and were not considered for potential acoustic specifications.

The following are recommendations to increase recognition based on the Phase 3 research:

- No greater than 50 percent amplitude modulation at stationary but activated, at a frequency equal to the modeled combustion frequency.
- Ratios of the total tonal power to the total broadband power should not exceed 15 dB. (Note: this is not the same as the Tone-to-Noise Ratio).
- Multiple harmonics with a fundamental equal to a hypothetical combustion frequency.
- The lowest harmonic included should be as low in frequency as the countermeasure system can reliably produce.
- The first or second harmonic present should have the highest amplitude with higher harmonics generally decreasing in amplitude.
- Amplitude should increase as a function of speed beyond the required change for minimum detection (but not beyond the maximum level).

The agency solicits comments regarding the specific values, *e.g.* 50 percent, 15 dB, etc., as well as why characteristics should be included/excluded from this list.

In addition to the recommendations for the recognition of HV and EV sounds contained above, the Phase 3 research found the acoustic requirements for HVs and EVs should include pitch shifting as an element to enhance recognition. A pitch shifting requirement would keep out melodies or sounds that change over time. The low-frequency requirement would convey the sound of rotating machinery. Limiting amplitude modulation would reduce annoyance and help with recognition, as will excluding frequency modulation and the noise component of the sound filter shapes with high roll-off rates.

D. International Approach to Pedestrian Alert Sounds

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.

The MLIT included the following guidelines for the type and volume for the sound generator system:

- ''The sound shall be continuous sound associating motor vehicles running condition.''
- ''Siren, chime, bells, melody, horns sounds, animals, insects, and sound of natural phenomenon such as wave, wind, river current, etc., are not allowed.''
- ''The sounds generated shall be automatically altered in volume or tone depending on the vehicle speed for easier recognition of the movement of the vehicle.''
- ''Sound volume shall not exceed a level of the sound generated when vehicles driven by internal combustion only run at speed of 20 km/h.''

The use of 'add-on' devices, generating sound continuously for five seconds or longer, have been approved in order to increase AVAS penetration. MLIT will look into social acceptability and verification of technology implementation issues before moving from a voluntary process to a mandate.[74]

In addition to the actions taken in Japan the United Nations Economic Commission for Europe (UNECE) World Forum for Harmonization of Vehicle Regulation has an informal group on Quiet Road Transport Vehicles (QRTV). The objective of the QRTV is to ''[d]etermine the viability of 'quiet vehicle' audible acoustic signaling techniques and the potential need for their global harmonization.'' The QRTV's program plan includes: review the available research; determine human factors needed for pedestrians; develop technical performance parameters for vehicles based on human factors needs; determine audible sound characteristics and ways to convey desired vehicle performance information to pedestrians; and determine technical and

[73] Secretariat, Acoustical Society of America (1995). Procedure for the computation of loudness of steady sound, American National Standard ANSI S1.13. New York, NY.

[74] MLIT and JASIC (2010). Guidelines for Measure Against Quietness Problem of HV. GRB Informal group on Quiet Road Transport Vehicles (QRTV) Working papers of the 3rd informal meeting. Tokyo, 13–15 July 2010. Available at: *http://www.unece.org/trans/main/wp29/wp29wgs/wp29grb/QRTV_3.html.*

economical feasibility of potential audible warning techniques.[75]

UNECE has adopted guidelines substantially similar to the MLIT guidelines discussed above with the same requirements and recommendations.[76] The guidelines are intended to provide manufacturers with recommendations to follow in developing alert sound systems for adding sound to quiet vehicles.

E. SAE Sound Measurement Procedure

SAE J2889–1 SEP2011, *Measurement of Minimum Noise Emitted by Road Vehicles,*[77] is a performance-based and technology neutral test standard. The standard specifies an objective method for measuring the minimum noise emitted by road vehicles. The standard reflects the development of engine and propulsion technologies that cannot be correctly tested under other SAE standards. SAE J2889–1 SEP2011 specifies test site and meteorological conditions, as well as the ambient noise level under which the sound should be recorded. The standard includes provisions for outdoor and indoor (hemi-anechoic) testing. The test procedure includes specifications for microphone position, condition of vehicles (*e.g.,* battery state, tires, warning signals), operating condition (*i.e.,* 10 km/hr (6 mph) and stopped), measurement readings, and reporting requirements. SAE J2889–1 is derived from SAE 2805, *Measurement of Noise Emitted by Accelerating Road Vehicles,* and therefore some of the requirements related to ambient, equipment, and facilities are the same.

The standard also includes procedures to evaluate external vehicle sound generator systems for alerting pedestrians about a vehicle's operating conditions. The outcome includes various acoustic metrics for the external vehicle sound generators such as sound pressure level, frequency content, and changes in sound pressure level and frequency as a function of vehicle speed. SAE J2889–1 SEP2011 does not account for psychoacoustic factors such as annoyance, recognizability, or detectability.

SAE published a second version of SAE J2899–1 in May of 2012. This version, SAE J2889–1 MAY2012, in addition to the provisions described above, contains a bench test to allow the alert sound's shift in pitch to be measured on a component level and a procedure to measure the alert sound's shift in pitch on a vehicle level indoors. SAE J2889–1 MAY2012 also contains a procedure for measuring a ''commencing motion'' sound.

The International Organization for Standardization (ISO) is cooperating with SAE in its efforts to develop a vehicle minimum noise measurement standard. The ISO document ISO/NP 16254 *Measurement of Minimum Noise Emitted by Road Vehicles*[78] and SAE J2889–1 are reportedly technically identical but this has not yet been confirmed by NHTSA because the ISO document is still in draft form.

F. Alert Sounds Currently Provided by Manufacturers

Automotive manufacturers that produce EVs for the U.S. market have recently developed various pedestrian alert sounds. At the time that PSEA was enacted, most manufacturers of HVs had not typically been equipping those vehicles with alert sounds for the U.S. market. As of the date of this writing, we have detailed knowledge of only one system developed by Nissan. We know that others are under development and that several manufacturers plan to equip their vehicles with these systems in the near future. Nissan has developed a system called Approaching Vehicle Sound for Pedestrians (VSP) for the 2011 Nissan Leaf.[79] The system consists of a digital sound synthesizer connected to a speaker mounted under the hood of the vehicle and a sound control system. The sound controller gets three inputs: Vehicle speed, gear position, and brake signal. The VSP has an on/off switch located in the instrument panel for temporary deactivation by the driver. A forward sound activates at low speeds, fades off as the vehicle reaches 30 km/hr (18 mph) and fades back on as the vehicle speed reduces to 25 km/hr. The pitch increases proportionally with vehicle speed. A unique sound is activated when the gear is in ''reverse'' and when the vehicle starts from a stopped position. No sound is emitted when the vehicle is in ''drive'' gear but stationary, but the vehicle does emit a sound when stationary in ''reverse'' gear. The sounds emitted from the vehicle are digitally generated as opposed to being a recording of an ICE vehicle, and plays through speakers.

Nissan indicates that the sound was designed to achieve the same detectability as ICE sound while maintaining a quiet cabin for the driver and without being intrusive to communities. The VSP was developed based on three design guidelines. First, increase peak frequency content between 600 and 800 Hz to improve detectability for aging pedestrians with high frequency hearing loss. Second, increase peak frequency content between 2000 and 5000 Hz to improve detectability of pedestrians with normal hearing. Lastly, reduce frequency content at around 1000 Hz to avoid noise intrusion. The VSP was set to have a similar sound pressure level as a Nissan Versa 1.8L at 10 km/hr (6 mph) while having two peaks at 630 Hz and 2500 Hz, and a valley at 1000 Hz.

G. The Notice of Intent To Prepare an Environmental Assessment

On July 12, 2011, the agency published a Notice of Intent to Prepare an Environmental Assessment (NOI) seeking comment on the alternatives that the agency should consider when analyzing the environmental consequences of a proposed quiet vehicle rule. The NOI stated that the purpose and need of the rulemaking was to ''require EVs and HVs, which tend to be quieter than the ICE vehicles, to be equipped with a pedestrian alert sound system that would activate in certain vehicle operating conditions to aid blind and other pedestrians in detecting the presence, direction, location, and operation of those vehicles.''[80]

The NOI discussed the following five alternatives that the agency planned on considering in its analysis of the environmental consequences of the rule and requested that the commenters propose other alternatives for the agency to consider: (1) Taking no action; (2) requiring alert sounds based on recordings of ICE vehicles; (3) specifying acoustic requirements for synthetic sounds that would closely resemble sounds produced by ICE vehicles; (4) setting requirements for alert sounds that possess aspects of both

[75] QRTV (2010). Terms of Reference and Rules of Procedure for the GRB Informal Group on Quiet Road Transport Vehicles (QRTV). Available at: *http://www.unece.org/trans/main/wp29/wp29wgs/wp29grb/QRTV_1.html.*

[76] *http://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29wgs/wp29gen/wp29fdoc/ECE-TRANS-WP29-78-r2e.pdf.*

[77] See footnote 2.

[78] ISO/NP 16254 Measurement of Minimum Noise Emitted by Road Vehicles. *http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=56019.*

[79] Konet *et al.* (2011) Development of Approaching Vehicle Sound for Pedestrians (VSP) for Quiet Electric Vehicles. SAE International. Paper No. 2011–01–0928. Abstract available at: *http://saeeng.saejournals.org/content/4/1/1217.abstract.*

[80] 76 FR 40860 (July 12, 2011). The agency intends this proposal to be technology neutral. The statement of purpose and need in the NOI acknowledges, for the purposes of the agency's NEPA analysis of the environmental impacts of this rulemaking action, that many manufacturers will choose to install speaker systems on their vehicles in order to meet the minimum sound requirements in this proposal. This proposal establishes minimum sound requirements that HVs and EVs must meet. It does not specify that vehicles must be equipped with a speaker system.

sounds produced by ICE vehicles and acoustic elements that contribute to detectability; and (5) using psychoacoustic principals to develop requirements for alert sounds that would have enhanced detectability but would not necessarily have a reference to sounds produced by ICE vehicles. The NOI stated that it was likely that a rule that allowed alternatives 4 and 5 would need to include a jury testing procedure to ensure that the sounds were recognizable to pedestrians as a motor vehicle in operation.

Comments Received in Response to NOI

In response to the NOI, NHTSA received 33 comments from state governments and Indian tribes, advocacy organizations for individuals who are blind, national and international standards organizations, auto manufacturers, heavy vehicle manufacturers, trade organizations that represent motor vehicle manufacturers, component manufacturers, environmental groups and private individuals. The agency received comments on both the technical and environmental aspects of the NOI.

Most of the commenters expressed support for all of the alternatives, except the no action alternative. All the commenters that commented on possible methods for determining compliance with the various alternatives stated that the performance criteria for alert sounds should be based on objective factors and that jury testing was not an appropriate method for determining compliance with an FMVSS.

Several of the commenters requested that the agency set the minimum sound level requirements for EVs and HVs to the sound levels produced by quiet ICE vehicles rather than the average sound pressure level produced by ICEs. These commenters expressed concerns that if NHTSA set the minimum sound pressure level requirements for EVs and HVs to the average sound level produced by ICE vehicles, this would stop noise reduction trends in vehicle design. Commenters that stated that the minimum sound level requirements for EVs and HVs should be tied to quiet ICE vehicles were also concerned about minimizing the environmental effects of adding sound to EVs and HVs and driver acceptance of the added sounds. One commenter stated that the acoustic specifications developed by the agency should include a dB level dip in the mid-range frequencies around 1000 Hz to limit the community noise impact of adding sound to hybrid and electric vehicles.

Several commenters also questioned whether there was a safety need for the agency to set minimum sound level requirements for the stationary but activated operating condition. Most motor vehicle manufacturers stated that the agency should only require that EVs and HVs produce sound until the vehicle reaches a speed of 20 km/hr (12 mph) while advocacy groups for individuals who are blind stated that EVs and HVs should produce sound until 32 km/hr (20 mph).

Light vehicle manufacturers stated that the agency should not be overly concerned with writing the acoustic specifications for the alert sound to prevent the use of annoying noises. These manufacturers stated that they did not believe it was necessary to try to prevent annoying sounds because manufacturers would not use annoying sounds as alert sounds because they do not want to annoy their customers.

Several commenters stated that the agency should adopt the ECE guidelines for alert sound systems (the ECE guidelines are based on the Japanese guidelines discussed in Section VIII.E), as the agency's requirements for alert sounds for HVs and EVs. These commenters believed that the ECE guidelines provide manufacturers with flexibility in developing sounds while appropriately balancing the needs of pedestrians and concerns about environmental noise impact. In discussions with the agency manufacturers have stated that they believe that the ECE guidelines would address the agency's concerns about annoying alert sounds.[81]

Several commenters pointed out potential drawbacks in requiring an alert sound that was a recording of an ICE vehicle.

The commenters requested that the agency maintain a significant degree of flexibility in developing acoustic specifications for alert sounds. Several commenters stated they did not believe that all of the characteristics that the agency used to describe sounds comprising alternative 5 were necessary to provide effective pedestrian alert sounds. Advocacy groups for individuals who are blind also stated that the agency should not allow alert sounds with none of the acoustic characteristics of current ICE vehicles and that the agency should not consider alternative 5 in specifying acoustic requirements for an alert sound.

Some of the manufacturers of heavy vehicles stated that heavy-duty hybrid vehicles that are not capable of electric propulsion should be exempt from the requirements of the standard because these vehicles produce sufficient sound for pedestrians to detect them in all operating conditions, including stationary but activated. Several commenters also stated that motorcycles should be exempt from the requirements of the proposal.

A few of the commenters questioned whether adding sound to HVs and EVs was an appropriate means of addressing the increased rate of collisions between HVs and EVs and pedestrians. Three of these commenters believed that avoiding pedestrian collisions was the responsibility of the driver. One commenter believed that NHTSA should address crashes between HVs and EVs and pedestrians by adding advanced pedestrian crash avoidance technology to these vehicles.

VII. NHTSA's Proposal

NHTSA has considered three different viable alternatives for ensuring that HVs and EVs provide detectable, recognizable sound cues for pedestrians on which the agency seeks comments. These alternatives include setting the minimum sound levels for EVs and HVs based on the sound level required for a safe detection distance which is the agency's preferred alternative, setting the minimum sound levels for EVs and HVs based on the sound levels produced by light ICE vehicles and using a jury testing procedure instead of acoustic specifications to ensure that sounds produced by HVs and EVs are recognizable. The alternatives differ in the manner in which they balance recognizability, regulatory feasibility, and manufacturer flexibility. In this section, we propose the alternative that we believe is the best approach. The other two alternatives that are not being proposed, jury testing for recognizability and acoustic profiles designed around sounds produced by ICE vehicles, are discussed in detail in Section VIII of this notice.

Under our proposal EVs and HVs would be required to produce sounds that conform to the specifications listed in S5 of the Proposed Regulatory Text (see Section XIII of this notice). Our proposal is similar to Alternative 4 described in the previously referenced NOI as it contains acoustic elements designed to enhance detection and to aid with recognition of motor vehicle operation. Through a compliance test, the agency would be able to easily measure the sound produced by an EV or HV and determine whether that sound conforms to the requirements in S5 of the proposed regulatory text. The

[81] See Section VIII. E. for a discussion of why we are not proposing to adopt the Japanese or ECE guidelines.

agency developed the acoustic specifications contained in this proposal using a loudness model and a representative urban ambient sound level to ensure that sounds fitting the specifications would be detectable in a wide range of ambient noise conditions.

The agency has included specifications for low frequency because the agency believes that the low frequency one-third octave band requirements contained in S5 will assist pedestrians in recognizing sounds that conform to the requirements as being produced by a motor vehicle. The low frequency content of the sounds produced by current ICE engines is the spectral component that pedestrians hear and associate with these sounds. While the agency believes that the specifications in S5 provide manufacturers a significant degree of flexibility to develop vehicle sounds, the specifications do place some constraints on the sounds that manufacturers are able to use as countermeasure sounds. These constraints will ensure that countermeasure sounds will be recognizable and provide the needed auditory cues to be useful to pedestrians, while avoiding unnecessary environmental impact.

The agency also developed and is seeking comment on a set of minimum sound requirements for HVs and EVs using an analysis of sounds produced by ICE vehicles. The proposed requirements include minimum sound pressure level specifications in different one-third octave bands so the frequency content of sounds produced by HVs and EVs would resemble the spectral content of ICE vehicles. Sounds that meet these proposed requirements would resemble sounds described in Alternative 3 of the NOI. Relative to the other two viable alternatives, this approach would place primary emphasis on feasibility and recognizability.

A. Acoustic Specifications Developed To Enhance Detection and Recognition

This NPRM proposes performance requirements for sounds produced by HVs and EVs so that pedestrians can detect, recognize, and locate these vehicles. While NHTSA acknowledges that many manufacturers will choose to install a speaker system to comply with the requirements of this proposal, this is a technology neutral proposal, so manufacturers would be able to choose any means of compliance they wish so long as the vehicle produces a sound that complies with the acoustic specifications in Section XIII of this notice.

The agency has sought to balance community noise impact with the safety of pedestrians in developing the acoustic specifications contained in this proposal. For people living in communities near highways and along busy streets, elevated noise levels can be annoying and diminish quality of life. The agency recognizes the contributions motor vehicles make to ambient sound levels in urban areas and near highways. The DOT's Federal Highway Administration has previously conducted studies (not part of this rulemaking) that examine noise-reducing pavements in an attempt to reduce tire noise produced by vehicles. We note the research on noise reduction that is being conducted by other operating administrations within DOT in order to emphasize that this proposal is not contrary to, and will not interfere with, noise reduction efforts. In setting a minimum requirement for sound produced by HVs and EVs, the agency has sought to ensure these sound level requirements would not contribute to transportation noise pollution. A majority of transportation noise is caused by vehicles traveling at high speed. In this proposal, the agency would set minimum sound requirements for vehicles traveling at lower speeds. The proposal would not affect vehicle noise output during the high speed scenarios that contribute to noise pollution. Furthermore, as required by the PSEA, the agency considered the maximum noise emission requirements for heavy vehicles and motorcycles issued by the Environmental Protection Agency (EPA) in setting the minimum sound requirements contained in this proposal.[82]

In developing this proposal, NHTSA sought to maintain the current situation involving ICE vehicles in which the pedestrian and the driver share responsibility for avoiding pedestrian vehicle collisions. Thus, a pedestrian must be able to hear a vehicle from the point at which the vehicle would no longer be able to safely stop if the pedestrian decided to walk into an intersection. A pedestrian must be able to initiate a street crossing with the knowledge that there are no vehicles present that would be unable to stop before colliding with the pedestrian. At distances farther than the vehicle's stopping distance, the driver would be able to respond to the presence of a pedestrian and avoid a collision. At distances within which the driver would not be able to respond to the presence of a pedestrian and stop the vehicle, the pedestrian must be able to hear the vehicle so the pedestrian can share responsibility for avoiding a crash by not stepping into the street.

[82] 40 CFR parts 201–211.

B. Critical Operating Scenarios

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] 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. In addition to the critical operating conditions mentioned above, the agency believes that the definition of ''alert sound'' in the PSEA requires the agency to establish minimum sound requirements for when a vehicle is in a stationary but activated condition and while operating in reverse.

1. Stationary But Activated

It is NHTSA's position that the scenario in which the vehicle is stationary, but its starting system is activated [85] is a critical operating scenario because the definition of ''alert sound'' contained in the PSEA requires that a pedestrian be able to locate a nearby vehicle that is running; it is the agency's position that including this scenario satisfies that provision of the PSEA. Furthermore, sound provided by idling ICE vehicles is essential to assisting visually-impaired pedestrians in making safe travel decisions. Sounds made by vehicles that are stationary but activated address collisions between pedestrians and HVs and EVs starting from a stopped position.

The agency has concluded that the requirement in the PSEA that the alert sound required by the agency should allow pedestrians to ''discern vehicle presence, direction, location, and operation,'' [86] requires the agency to establish minimum sound requirements for the stationary but activated operating

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

[84] *Id.*

[85] This condition is commonly referred to as an ''idling'' vehicle for vehicles with internal combustion engines. However, the term ''idle'' technically refers to an engine state, not a vehicle state, and has no relevance to electric motors. The description used here ''stationary but activated'' means the vehicle is not moving, but its starting system is activated.

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

condition. As discussed in Section III of this notice, when read together the terms ''presence'' and ''operation'' in the definition of alert sound in PSEA require the agency to establish minimum sound requirements when the vehicle is stationary, but the starting system is activated.

As discussed in Section V of this notice, sound cues produced by idling ICE vehicles are critical for the safety of 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 reference provided by idling vehicles is especially important to provide auditory cues for visually-impaired pedestrians crossing streets at complex intersections where the streets intersect at non-perpendicular angles. 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 of how wide a street is so they can accurately gauge the amount of time needed to safely cross.

A sound emitted by an HV or EV when stationary but activated is analogous to the ICE vehicle idling and ensures that the responsibility to avoid a crash 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 stop should be able to see a pedestrian in front of the vehicle and thus avoid a crash, the driver may not always be able to be relied upon, especially in situations where the driver may have an obstructed view. A driver pulling out of a parking space in a 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 with the vehicle by not stepping in front of the vehicle.

In deciding to include a sound requirement for HVs and EVs at the stationary but activated condition, we also relied on the experiences of agency staff when attempting to navigate street crossings while blindfolded. NHTSA staff traveled to the national 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. The meeting included a class room session and a session in which the participants from NHTSA were blindfolded and trained on navigation using a white cane outside on city streets with blind and visually impaired individuals as guides. The participants from NHTSA attempted to navigate city streets and cross at non-signaled intersections while blindfolded. 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.

Our October 2011 statistical report on the incidence rates of crashes between HVs and pedestrians [87] also supports stationary but activated as a critical operating scenario for pedestrians. The report shows six incidents of collisions when the vehicle was starting from a stopped position. While the difference in HV and ICE vehicle crashes with pedestrians for vehicles starting from a stopped position is not statistically significant, this can be partially attributed to the limited penetration of HVs in the fleet. There were no EV collisions with pedestrians documented in NHTSA's report because electric vehicles were not widely available in 2008, the last year for which data is available. Overall, EVs and HVs represent a small percentage of the total vehicle fleet and fully electric vehicles have yet to be introduced to the U.S. fleet in significant numbers. Therefore, the sample size of HVs represented in the State Data System, and the number of HV pedestrian collisions, remains extremely small. The limited available crash data does show that HVs have collided with pedestrians when starting from a stopped position even though the sample size is not large enough to prove a statistically significant incidence rate. The growing penetration of HVs and EVs into the vehicle fleet means that vehicle collisions with pedestrians when an HV or EV is starting from a stopped position represents a safety concern that is rising to a level of significance, for which the agency believes it is appropriate to require that vehicles provide adequate sound cues while stationary but activated. In passing the PSEA, Congress directed NHTSA to be proactive in addressing the risk to pedestrians posed by HVs and EVs. Congress did not intend for NHTSA to wait until crashes between pedestrians and HVs and EVs starting from a stop rise to the level where NHTSA has a data set that shows that a sound for the stationary but activated condition is needed.

The agency does not believe that establishing minimum sound requirements for EVs and HVs operating in the stationary but active condition will have any noticeable impact on ambient noise levels. As discussed in Section X.D, NHTSA has conducted an Environmental Assessment (EA) to analysis the environmental effects of this rulemaking. The EA shows that the difference in ambient sound levels if the agency issues minimum sound requirements for the stationary but active condition compared to if the agency did not require sound at that condition would be negligible.

The agency does not believe that there would be any incremental cost to requiring a sound at the stationary but active operating condition to a vehicle that is already equipped with an alert sound system. Rather, as with all other required operating scenarios, a vehicle with an alert sound system could be reconfigured to play a sound at the stationary but active condition through a simple software modification, which would not require any additional equipment to be installed on the vehicle.

In comments on the NOI and in meetings between representatives from various auto manufacturers and NHTSA staff, several manufacturers stated that the agency should not establish minimum sound requirements for the stationary but activated condition. These manufacturers do not believe there is a safety need for an alert sound when vehicles are stationary but activated. 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 impact.

Advocacy organizations for individuals who are blind or visually impaired believe that the agency should establish minimum sound requirements for the stationary but active condition. In meetings with agency rulemaking staff, representatives from NFB have stated that a sound at the stationary but active operating scenario is necessary for the safety of blind or visually impaired pedestrians in avoiding collisions with EVs and HVs operating at low speeds. Representatives from NFB stated that blind individuals exercise greater caution when they hear a nearby idling ICE vehicle because they know that the vehicle could begin moving at any moment. Representatives from NFB stated that a nearby vehicle that made no sound that could start

[87] See footnote 36.

moving at any moment presents a safety hazard to blind or visually impaired pedestrians because the vehicle could collide with a blind or visually impaired pedestrians without the pedestrian even knowing that the vehicle posed a danger to them. The agency believes that minimum sound levels for EVs and HVs operating when stationary but activated are necessary from a safety perspective for the reasons previously discussed. The agency believes that it is important to establish minimum sound requirements for the stationary but activated condition so that the sound will alert nearby pedestrians of the presence of a vehicle without unduly contributing to overall ambient noise levels. The agency believes that the safety interest in assisting pedestrians with detecting nearby vehicles and providing the visually-impaired with acoustic cues necessary to make safe travel decisions justifies establishing minimum sound level requirements for EVs and HVs operating when stationary but activated.

The agency acknowledges that with the technology under consideration today for adding sound to HVs and EVs, most vehicles that would be subject to this proposed rule (should it become final) will establish compliance by means of adding a sound generating system that includes at least one speaker. Requiring a sound at this condition may result in manufacturers adding speakers to some vehicles (for example motorcycles or some heavy vehicles) that may not otherwise need a speaker to meet the requirements of the other operating conditions in today's proposal (because the vehicle operation in those conditions makes enough sound without adding an artificial sound). However, we believe that the definition of alert sound in the PSEA requires the agency to establish minimum sound requirements for this condition. We seek comment on the number of vehicles to which this proposal would apply that would only require speakers to meet the acoustic requirements in this proposal at the stationary but active condition.

Also, the agency solicits comment on possible configurations of the alert sound that would lower or deactivate the alert sound in situations in which pedestrians would not be present. One of the methods proposed for mitigating the noise caused by stationary EVs and HVs would be to allow the vehicle to reduce or turn off its sound after the vehicle had been stationary for a period of five to ten minutes. The agency does not believe that a switch that would allow the driver to turn off the vehicle's sound is a viable option for controlling the noise impact of EVs and HVs when stationary but activated because the PSEA specifically forbids the agency from allowing the driver to deactivate the sound; in addition, the agency believes that allowing drivers to deactivate the sound would compromise pedestrian safety.

As an alternative to requiring a sound when the vehicle is activated but not moving, Mercedes-Benz USA, LLC (Mercedes) stated that the agency should instead include acoustic specifications for a ''commencing motion sound'' that would be activated as soon as the vehicle starts moving.[88] Mercedes stated that the specifications for such a sound should be the same as the specifications for the sound at 10 km/hr (6 mph). Mercedes stated that the sound pressure level of the ''commencing motion sound'' should be noticeably higher than the sound pressure level required for low speeds. Volkswagen Group of America, Inc. also stated that the agency should require a ''commencing motion sound'' instead of a sound when the vehicle is activated but stationary. We seek comment on whether requiring a ''commencing motion sound'' is as an effective approach to implementing the requirements in the PSEA that an alert sound allow pedestrians to discern the ''presence, direction, location and operation'' of the vehicle as establishing minimum sound requirements for when the vehicle is activated but stationary.

2. Reverse

The agency believes that reverse is a critical operating scenario for which the agency should issue minimum sound level requirements for HVs and EVs to provide acoustic cues to pedestrians to prevent pedestrian collisions and to satisfy the requirements of the PSEA. Requirements for the reverse operation of EVs and HVs will ensure that these vehicles provide sound cues to pedestrians so pedestrians will be able to avoid these vehicles when the vehicles are backing out of parking spaces or driveways.

Several manufacturers in meetings with NHTSA staff stated that minimum sound requirements for EVs and HVs operating in reverse were not necessary because the agency's proposed amendments to FMVSS No. 111, *Rear Visibility,* as required by the Cameron Gulbransen Kids Transportation Safety Act, would allow drivers to see pedestrians while backing and thus avoid collisions. NHTSA's proposed amendments to FMVSS No. 111, while intended to address vehicle collisions with pedestrians while backing, do not fully ensure that EVs and HVs will not experience higher rates of pedestrian collisions than ICE vehicles while backing. 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. If EVs and HVs do not produce audible sound levels during reverse operations, pedestrians, especially those who are blind and visually impaired, would not have the opportunity to avoid collisions with backing vehicles because they would not be able to tell that they are being threatened by a backing vehicle.

NHTSA's report on the incidence rates of crashes between HVs and pedestrians found 13 collisions with pedestrians when a HV is backing. The difference between the incidence rates of HVs involved in pedestrian crashes while backing and the incidence rate of ICE vehicles involved in pedestrian crashes while backing was not statistically significant. We do not believe that the lack of a statistically significant difference in incidence rates between ICE vehicles and HVs involved in pedestrian crashes while backing can be attributed to the absence of a safety problem related to a vehicle's noise level during this operating condition. As discussed above, the absence of a difference in the incidence rates in backup pedestrian crashes between ICE vehicles and HVs is, the agency believes, due to the low penetration of these vehicles into the fleet and the sample size of HVs and EVs in the State Data System. Also, backing incidents with pedestrians may tend to be underreported because they occur in parking lots, garages, and drive ways, as well as other ''off roadways'' that traditionally have not been captured by existing data collection systems.

NHTSA believes that the PSEA requires the agency to set minimum sound requirements for the backing scenario for the same reason that the agency believes that minimum sound requirements are necessary for the stationary but activated condition. The PSEA requires minimum sound level requirements promulgated by NHTSA to allow pedestrians to discern vehicle presence and operation. A vehicle moving in reverse is unquestionably operating, thus a minimum sound level is required for this condition.

The PSEA also requires that the minimum sound level requirements promulgated by NHTSA allow pedestrians to discern the direction of the vehicle. This language also indicates that the PSEA requires any standard to establish minimum sound requirements

[88] Docket No. NHTSA–2011–0148–0029.

for when the vehicle is operating in reverse.

3. Acceleration and Deceleration

Section 5 of the proposed regulatory text would ensure that sounds produced by EVs and HVs that meet the requirements of this proposal will allow pedestrians to determine when a vehicle is accelerating or decelerating. Pitch shifting is the sound characteristic that pedestrians currently associate with an accelerating vehicle based on the sounds produced by an ICE vehicle. The agency included requirements for pitch shifting in S5 to ensure that components of the sounds produced by EVs and HVs moved along the frequency spectrum in a manner similar to those of ICE vehicles as vehicle speed increases. Pitch shifting will also denote that the vehicle is decelerating. The sound pressure level in each one-third octave band required in S5 changes as speed increases, leading to an increasing overall sound pressure level that corresponds to the behavior of an ICE vehicle. Thus, in addition to the acoustic cues provided by pitch shifting, pedestrians will be able to tell if an EV or HV is accelerating or decelerating based on the increase or decrease in sound emitted from the vehicle, just as they would be able to in the case of an ICE vehicle.

The agency did not include a separate acoustic measurement procedure for acceleration and deceleration because we believe that the requirements for pitch shifting and the increase in overall sound level as the vehicle increases speed (or the decrease in sound level as the vehicle decelerates) will provide enough information so that pedestrians will be able to determine when EVs and HVs are accelerating and decelerating. The agency also decided not to include acoustic measurement procedures for acceleration and deceleration because of concerns about the feasibility of testing in these conditions. It is difficult for even an experienced test driver to repeatedly achieve and maintain a specific rate of acceleration or deceleration over the distance used in the proposed test procedure. Given the difficulty of ensuring repeatable results of an acoustic test measuring acceleration and the fact that information about changes in vehicle speed is provided by pitch shifting and increases and decreases in sound pressure level corresponding to changes in vehicle speed, NHTSA decided that the test procedure did not need to include a dynamic test for acceleration or deceleration.

4. Constant Speed

The agency is proposing 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/hr (6 mph), 20 km/hr (12 mph) and 30 km/hr (18 mph). The agency's proposal would ensure EVs and HVs produce sound that is sufficient to allow pedestrians to detect these vehicles at all speeds between 0 and 10 km/hr (6 mph), 10 km/hr (6 mph), 20 km/hr (12 mph), and 30 km/hr (18 mph) by requiring that the minimum sound levels be attained for all speeds between these test speeds. The proposal contains minimum acoustic requirements up to the speed of 30 km/hr (18 mph) because, for the reasons discussed in Section VII.E.3 of this notice, the agency believes that this is the appropriate cross over speed. Manufacturers have suggested in meetings with the agency that the test procedure for sound measurement should only specify a pass by test at 10 km/hr (6 mph) because, according to manufacturers, this is the speed at which the sound levels produced by ICE vehicles and EVs and HVs differ the most. The agency believes that it is 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 for which requirements are specified.

C. Application

1. The Definition of Hybrid Vehicle

The PSEA defines hybrid vehicle as a vehicle with more than one means of propulsion. The agency has concluded that the definition in the PSEA requires the agency to apply the standard only to hybrid vehicles that are capable of propulsion in any forward or reverse gear without the vehicle's ICE operating. Under the agency's interpretation of the definition of hybrid vehicle in the PSEA, more than one means of propulsion means more than one independent means of propulsion. This proposed definition of hybrid vehicle would exclude from the application of the proposed standard those vehicles that are equipped with an electric motor that runs in tandem with the vehicle's ICE to provide additional motive power when the vehicle is accelerating.[89]

Because the ICE is always running when these vehicles are in motion on hybrids that employ the electric engine to provide additional power when accelerating, the fact that these vehicles may not provide sufficient sound for pedestrians to detect them cannot be attributed to the vehicle's propulsion source. If a pedestrian cannot hear this type of vehicle it is because of the quietness of the vehicle's ICE. Therefore, we believe that it is most appropriate to address vehicles that are equipped with an electric motor that provides assistance to the ICE when the vehicle is accelerating in the report to Congress regarding the safety need to establish minimum sound requirements for quiet ICE vehicles required by the PSEA.

The agency would also like to note that the definition of ''hybrid vehicle'' in the PSEA is not limited to hybrid-electric vehicles. Thus, the standard would apply to hybrid vehicles that operate using hydraulic propulsion independently of the vehicle's ICE.

2. Vehicles With a GVWR Over 10,000 Pounds

NHTSA is proposing that the acoustic specifications in Section XIII apply to all hybrid and electric motor vehicles covered by the PSEA, including all hybrid and electric passenger cars, multipurpose vehicles, trucks, buses, low-speed vehicles and motorcycles.[90]

Across the entire fleet (ICE, hybrid, and electric vehicles included), heavy vehicles have a lower pedestrian crash rate than light vehicles (10,000 pounds and less). Only 0.3 percent of all heavy vehicle crashes involved pedestrians while 0.59 percent of all light vehicle crashes involve pedestrians. The pedestrian crash rate of heavy vehicles involved in low-speed maneuvers is also lower than that of light vehicles. Only 0.42 percent of all heavy vehicle crashes at low speeds involved pedestrians while 0.80 percent of all low speed light vehicle crashes involve pedestrians.

NHTSA was not able to determine a separate pedestrian crash rate for hybrid and electric heavy duty vehicles based on the data available in the State Data System. The sample of all crashes of hybrid and electric heavy vehicles in the State Data System is extremely limited and the State Data System did not, when it was examined, contain any incidents of hybrid or electric heavy vehicle pedestrian crashes. The agency

[89] The agency is aware that a vast majority of vehicles that are equipped with an electric motor to provide additional motive power when the vehicle is accelerating are equipped with idle-stop. For a discussion of why the agency has chosen not to require vehicles equipped with idle-stop that are not capable of propulsion by a means other than the vehicle's ICE to meet the minimum sound level requirements in this proposed standard see Section VII.C.5.

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

believes that the lack of crash data on hybrid and electric heavy vehicles is due to the very low market penetration of these vehicles at the present time. Therefore, the agency attributes the lack of any hybrid or electric heavy vehicle pedestrian crashes not to the fact that these vehicles provide sufficient sounds levels to allow safe pedestrian detection but instead to the fact that these vehicles are not present in the fleet in any significant numbers. The agency believes that it is reasonable to assume that as hybrid and electric heavy vehicles achieve a higher penetration into the vehicle fleet that the difference between the crash rates for hybrid and electric heavy vehicles and ICE heavy vehicles will be similar to the difference in crash rates between light hybrid and electric vehicles and light ICE vehicles.

We note that the PSEA did not exclude vehicles with a GVWR over 10,000 pounds from the scope of the required rulemaking. We believe Congress intended the agency to be proactive in addressing the safety problem posed by quiet hybrid and electric heavy vehicles before hybrid and electric heavy vehicle pedestrian crashes begin to show up in crash data bases in significant numbers. In other words, through the passage of the PSEA, Congress has determined that there is a safety need for HVs and EVs of various sizes to produce a minimum sound level.

The agency recognizes that there are some challenges in including vehicles with GVWR over 10,000 lbs in the current rulemaking. The agency has not determined the extent to which hybrid heavy vehicles produce less sound than their traditional ICE peer vehicles. The agency also is not aware of the extent to which hybrid electric vehicles with a GVWR of over 10,000 lbs are capable of propulsion using only electric power without the ICE running.[91] Heavy vehicle manufacturers, in their comments on our NOI, stated that to the extent that heavy vehicles are not capable of propulsion solely by some means other than the vehicle's ICE, they should be exempt from the requirements of this proposal.

While the agency is today proposing to include heavy vehicles as part of this rulemaking, we note that the agency intends to conduct further research before issuing a final rule to determine the sound levels produced by heavy-duty hybrid and electric vehicles and to establish whether the sound requirements for light vehicles are also appropriate for heavy vehicles.

The agency is also aware of practical concerns about acoustic testing of heavy vehicles. The agency is aware that there are a limited number of noise pads necessary for vehicle acoustics testing that can accommodate heavy vehicles. We seek comment on whether it is necessary to test heavy vehicles on a noise pad meeting the requirements of ISO 10844, *Acoustics—Specification of test tracks for measuring noise emitted by road vehicles and their tires.* In the alternative the agency is considering specifying an acoustic testing surface for heavy vehicle testing that is based on a typical vehicle test track pavement.

The agency also has not validated whether the sound specifications that it has developed based on research conducted on light vehicles would provide appropriate countermeasure sounds for heavy-duty vehicles. We seek comment on this issue.

The agency is aware that many heavy and medium duty trucks are equipped with backup alarms to provide warning when the vehicle is backing. Because we do not want to require that these vehicles produce additional sound if they are already producing sound when backing, we would not require vehicles with a GVWR over 10,000 pounds to meet the acoustic specifications in S5.1.2 when backing. Instead, these vehicles would only be required to produce a sound with an overall sound pressure level of 52 A-weighted dB when backing. We seek comment on this issue. In addition, the agency also has yet to determine whether it is necessary from a safety perspective for pedestrians to differentiate light vehicles from heavy vehicles. The agency is aware, based on conversations with advocacy groups representing people that are visually-impaired, that a visually-impaired person may wait a longer amount of time than normal to cross a street after hearing a heavy truck pass in order to avoid colliding with a trailer that might be attached to the truck.

The agency also seeks comment regarding the appropriateness of limiting the application of this proposal to vehicles with a gross vehicle weight rating of 10,000 pounds and less.

Another regulatory option that the agency considered for heavy-duty HVs and EVs would require that these vehicles produce only a minimum sound pressure level rather than the full set of acoustic specifications in S5. Pending planned research on the sounds emitted by heavy vehicles, ICE, HV, and EV, the agency has tentatively concluded that applying the full acoustic specifications that the agency intends to apply to light vehicles to heavy vehicles would better fulfill the requirements of the PSEA.

3. Electric Motorcycles

The agency has tentatively concluded that the minimum sound level requirements in S5 proposed in this notice should apply to electric motorcycles (we are not aware of the existence of any hybrid motorcycles). Motorcycles are not specifically excluded by the PSEA. Also, the agency has yet to determine that these vehicles provide sound levels that are sufficient to allow pedestrians to detect these vehicles in time to avoid collisions.

Table 10 shows the number of collisions between motorcycles and pedestrians from 2000 until 2008. This data was obtained from the State Data System. Because the State Data System does not include any data regarding the power source used by motorcycles, the agency was not able to determine if the incidence rate of collisions between pedestrians and electric motorcycles is different between the incidence rate of collisions between pedestrians and motorcycles with ICEs.

[91] In its comments to the Notice of Intent to Prepare an Environmental Assessment (NOI) that the agency issued to solicit comments on the environmental consequence of this rulemaking, Hino Motors, Ltd. stated that it is planning on introducing a heavy-duty hybrid truck that is capable of propulsion using only the electric motor. Hino, however, stated that even when the truck is being propelled by the electric motor the ICE will remain on in order to power auxiliary systems. Comment of Hino Motors Ltd. *available at* *www.regulations.gov*, Docket No. NHTSA–2011–0100–0015.

TABLE 10—PRELIMINARY RESULTS OF MOTORCYCLE CRASHES
[16 States during 2000–08]

	Backing entering/exit parking spots, turning, starting, and slowing	Straight moving and other normal speeds	Total
Pedestrian crashes	55	438	493
Other crashes and missing data	20,669	90,371	111,040
Total	20,724	90,809	111,533

As with heavy-duty vehicles, there are challenges in establishing minimum sound levels for electric motorcycles in this rulemaking. The agency has not determined the extent to which electric motorcycles have a greater risk of collisions with pedestrians than motorcycles with ICEs or the extent to which electric motorcycles are quieter than ICE motorcycles of the same type. The agency has not measured any motorcycles according to the procedures contained in this proposal so the agency has yet to determine whether the measurement procedure used to measure sound emitted by 4-wheeled vehicles would be appropriate for motorcycles.

BMW of North America, LLC (BMW), in its comments on the NOI (discussed in Section VI.G. above), submitted crash data on incidents of motorcycle collisions with pedestrians. BMW stated that based on the number of crashes between motorcycles and pedestrians and the percentage of pedestrian crashes involving motorcycles, there is no safety need for minimum sound requirements for electric motorcycles. BMW cited several different sources of data to illustrate the low rates of crashes between motorcycles and pedestrians. 2009 statistics from the New York Department of Motor Vehicles show that approximately 0.4 percent of pedestrian/motor vehicle collisions involved motorcycles.[92] Data from the FARS for the period between 2005 and 2009 shows that only 0.7 percent of the pedestrian fatalities during that period involved motorcycles colliding with pedestrians. Data from the NHTSA's General Estimates System (GES) for the same time period shows that 1.07 percent of the pedestrians injured in motor vehicle crashes were injured in crashes involving motorcycles.

Both BMW and the Motorcycle Industry Council (MIC) stated that because of unique attributes of motorcycles, there is no safety need for NHTSA to establish minimum sound levels for electric motorcycles. According to 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.

Both BMW and MIC stated that adding a speaker system to a motorcycle could involve technical challenges not present for other vehicles. MIC and BMW claimed that it would be more difficult to add a speaker to a motorcycle than a passenger car because there is less space available on a motorcycle for a speaker system, the weight of the system would be a larger percentage of the vehicle's weight, which could affect low-speed stability, energy consumption by the speaker system would have a greater impact on a vehicle's range, and the price of installing the system would be higher than that for other vehicles. MIC and BMW also claimed that electric motorcycles should not be subject to the minimum sound level requirements in this proposal because electric motorcycles are not quiet.[93]

The agency acknowledges that establishing minimum sound requirements for electric motorcycles raises unique issues that are not present for other light vehicles. The agency, however, notes that because this proposal is technology neutral, it would be possible for electric motorcycles to meet the requirements of this proposal without the use of a speaker system. The agency seeks comment on whether the minimum sound level requirements in this proposal should apply to electric motorcycles. The agency seeks comment on the crash risk to pedestrians and pedalcyclists posed by electric motorcycles and the cost of the proposal as applied to these vehicles.

4. Low-Speed Vehicles

The agency has tentatively concluded that low-speed vehicles (LSVs) must meet the requirements in this proposal. While the agency expects that LSVs that run via an electric motor are extremely quiet, the agency has not conducted any acoustic measurements of these vehicles to determine the amount of sound they produce. The agency has very limited real-world data on crashes involving LSVs so the rate at which these vehicles are involved in pedestrian collisions is unknown. The agency has not yet determined the extent to which minimum sound levels developed for light vehicles would be appropriate for LSVs. The agency seeks comment on whether the requirements in this proposal should apply to LSVs.

5. Quiet ICE Vehicles

The agency does not intend to require a minimum sound level for quiet ICE vehicles in this rulemaking. The agency is aware that, similar to HVs and EVs, some ICE vehicles may pose a risk to pedestrians because of the low level of sound that they produce when operating at low speeds. The PSEA requires the agency to study and report to Congress whether there is a need for the agency to apply the minimum sound requirement established for HVs and EVs to ICE vehicles so that these vehicles can be readily detected by pedestrians. If, after the study, the agency determines that there is a safety need to apply these minimum sound requirements to quiet ICE vehicles, NHTSA is required to initiate a rulemaking to do so. The agency is also aware that many manufacturers intend

[92] BMW's comments on the NOI. *Available at, www.regulations.gov*, Docket No. NHTSA–2011–0100–0020.

[93] MIC submitted measurements of overall sound pressure level of two electric vehicle models recorded at 8 km/hr (5 mph) and 16 km/hr (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.

to make idle stop technology available on ICE vehicles in the near future.[94] The agency realizes that the introduction of ICE vehicles equipped with idle stop means that there will be ICE vehicles that will be effectively silent when the vehicle is not moving. While the agency does not propose, in this rulemaking, to require that ICE vehicles equipped with idle stop produce a minimum sound level while at idle, the agency plans to consider whether vehicles equipped with idle stop have a greater risk of collision with pedestrians than vehicles that produce a sound at idle with an eye toward a rulemaking in the future to address this issue.

D. Requirements

The agency's preferred method for establishing minimum sound requirements for EVs and HVs uses a detectability model to determine the sound that the vehicle needs to produce to allow pedestrians to detect the vehicle at a given distance. The sounds that meet the minimum requirements using the detection model would be similar to those described in Alternative 4 in the NOI.

1. Acoustic Parameters Designed According to a Detectability Model

The two critical aspects of the minimum sound level requirements in this proposed approach are that the sound be detectable and recognizable. This approach addresses the detectability aspect of the minimum sound level requirements by determining the sound specifications needed for a pedestrian to detect a vehicle at a safe distance and by examining the typical ambient sound profile to determine which one-third octave bands contribute the most to a pedestrian's ability to detect vehicles.[95] This proposal addresses the pedestrian recognition aspect of the minimum sound requirements by insuring that the sound has aspects that allow pedestrians to recognize the sound as being produced by a motor vehicle and by allowing the pedestrian to recognize the mode of operation of the vehicle.

The agency developed the minimum detectability requirements for HVs and EVs by first determining the distance at which a pedestrian would need to hear a vehicle in order to make a decision about whether it was safe to cross the street. Thus, the distance at which a pedestrian would need to hear a vehicle is at least as long as the vehicle's stopping distance. At distances shorter than a vehicle's stopping distance the pedestrian must be able to hear the vehicle, otherwise a situation might develop in which the pedestrian steps off the curb (because s/he cannot hear the vehicle) and the driver of the vehicle would be unable to stop the vehicle in time to avoid a collision with the pedestrian.

The agency set the distance at which it believes that the pedestrian should be able to hear an approaching HV or EV, also referred to as the detection distance, using stopping sight distances computed from the guide on highway design[96] of the American Association of State Highway Transportation Officials (AASHTO). Stopping sight distance is the distance that enables a vehicle traveling at or near the design speed to stop before reaching an object in its path. The stopping sight distance is the sum of the *driver reaction distance* and the *braking distance.* The driver reaction distance is the distance traveled by a vehicle from the instant the object becomes visible to the driver to the instant the driver applies the brakes. The braking distance is the distance needed to stop the vehicle once the driver applies the brakes. The sight distance for a vehicle traveling at the design speed and on a level road can be computed with the following formula:

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

Where:

t = brake reaction time, s

V = design speed, km/hr

a = deceleration rate, m/s^2

Drivers typically brake at an average emergency deceleration of about 5.4 m/s^2 on dry roads. A comfortable deceleration for most drivers braking on wet surfaces is 3.4 m/s^2. Drivers' expectation plays a role in driver reaction time. Mean reaction time to unexpected, but common, events is about 1.25 seconds. Mean reaction time for surprise events, such as an object suddenly moving into the drivers' path is about 1.5 seconds. A longer reaction time, of 2.5 seconds would consider the capabilities of almost all drivers, including older drivers and distracted drivers.

The values used as the basis for this proposal are 5.4 m/s^2 for deceleration and 1.5 seconds for brake reaction time. 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[97] and the slower deceleration rate for wet pavement, we believe, would result in a sound profile that is unnecessarily loud for most conditions. The agency believes that 1.5 seconds is an appropriate value to use for driver reaction time (to stopped objects) because this represents the reaction time of most drivers for surprise events.[98]

Based on calculations using these values, the agency determined that the desired detection distances were 2 meters in front of the vehicle for stationary but activated, 5 m in front of the vehicle for the 10 km/hr (6 mph) pass by, 11 m for the 20 km/h (12 mph) pass-by operation, and 19 m for 30 km/h (18 mph) pass-by operation. The results of this computation were rounded up to the nearest meter. Levels were increased by 0.5 dB to provide a small safety factor and rounded to the nearest integer for simplicity. This small increase was deemed sufficient due to other conservative aspects of the estimation, *e.g.* multiple detection opportunities due to the multiple components. The agency solicits comment on the appropriateness of a 1.5 second reaction time and 5.4 m/s^2 declaration rate in determining the desired detection distances.

Due to a variety of factors that affect the manner in which sound moves through an environment, it is not practical to measure sound with the specificity that the agency desires from the distances at which pedestrians need to be able to detect the sound. Atmospheric absorption, ground conditions and divergence of sound all affect sound measurements conducted at distances greater than the two meters specified in SAE J2889–1. Acoustic measurements conducted at distances greater than two meters are not able to accurately record a sound's frequency profile at the one-third octave band level. Furthermore, because of attenuation, a sound's decibel level decreases the further a measurement is taken from the sound source. At the detection distances that the agency

[94] Vehicles equipped with an idle stop function shut down or slow the vehicle's engine when the vehicle comes to a stop. Because the vehicle's engine shuts off, the vehicle is no longer providing any acoustic cues to pedestrians to indicate its presence.

[95] The agency's research to develop the minimum specifications for alert sounds for hybrid and electric vehicles is discussed in greater detail in the agency's report ''Research on Minimum Sound Specifications for Hybrid and Electric Vehicles.''. Available at Docket No. NHTSA–2011–0148–0048.

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

[97] See footnote 5.

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

believes are necessary for pedestrians to be able to hear vehicles, the sound pressure level sounds produced by vehicles begin to approach the ambient. As the sound pressure level begins to approach that of the ambient sound level, it is more difficult to measure the frequency composition of the sound. Based on the factors discussed above, the agency determined that the best approach for determining the minimum sound level HVs and EVs need to produce to ensure safe detectability would be to determine what the sound level would need to be at two meters from the vehicle in order to allow the pedestrian to hear the sound at the desired detection distance.

Using the method below, it is possible to determine what the sound levels of the vehicle will need to be at a distance of two meters from the vehicle so that pedestrians will be able to detect the sound at the desired detection distance. The table below depicts how the sound produced by the vehicle attenuates when measured using the procedure in SAE J2889–1.

TABLE 11—COMPUTATION OF ADJUSTMENT OF SPL (A-WEIGHTED dB) FROM SOURCE TO SAE MICROPHONE LOCATION

Speed, km/hr	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	−6.0	−12.2	−16.8

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

X represents the distance from the source while Y is the distance from the source to the microphones in SAE J2889–1. Z represents the height of the microphone in meters specified in SAE J2889–1. The values in the Table 11, above, were calculated using the formula below assuming a 1.2 meters value for Z.

$$r_0 = \sqrt{y^2 + z^2}$$
$$r_1 = \sqrt{x^2 + y^2 + z^2}$$
$$r_{doubling} = \log_{10}\frac{\frac{r_1}{r_0}}{\log_{10}(2)}$$
$$Attenuation = -6 \times r_{doubling}\ dB$$

A critical factor for establishing a minimum sound for pedestrians based on a desired detection distance is the ambient noise environment in which the pedestrian is attempting to detect the vehicle. The agency selected an ambient of 55 A-weighted dB to develop the minimum sound level specifications. The agency choose an ambient sound pressure level of 55 A-weighted dB because that is a level representative of a moderate suburban ambient where pedestrians would be expected to be able to detect vehicles based on hearing alone. In conversations with the agency during Phase 1 research, visually-impaired individuals indicated that in noisier suburban ambient conditions, they would not try to cross streets unassisted. The ambient levels that the agency measured during Phase 1 research for which visually-impaired pedestrians would be expected to cross using hearing alone were 49.5 A-weighted dB and 49.8 A-weighted dB.

In selecting an ambient at which the agency expects that pedestrians should be able to detect an approaching vehicle using their hearing, the agency relied on recommendations for quiet vehicle alert sound specifications developed by Danish acoustics experts.[99] In developing the recommendations the Danish researchers measured different ambient levels around Copenhagen. The ambient levels in residential areas where pedestrians would be expected to detect an approaching vehicle using their hearing was 55 A-weighted dB.

In a presentation to NHTSA staff, Honda Motor Company (Honda) stated that the ambient at which pedestrians would reasonably be able to detect vehicles using hearing alone is around 52.5 A-weighted dB.[100] Honda based this conclusion on a human factors approach in which recordings of three different ambient sound levels (quiet residential, moderate suburban, and urban) were played and participants were asked whether they would rely on hearing alone to detect an approaching vehicle. While the study did not include any visually-impaired participants, the agency agrees that pedestrians—those that are visually impaired and others that are not—could not be reasonably expected to detect approaching vehicles in ambient conditions near 60 A-weighted dB.

The agency believes that a 55 A-weighted dB ambient represents a reasonable level below the 60 A-weighted dB ambient (in which pedestrians would no longer be able to reasonably rely on hearing to detect approaching vehicles).

The spectral distribution of the ambient is another factor that affects the detectability of an alerting sound. Tonal components of an alerting sound in portions of the ambient spectrum that are not strong contribute to detectability. Using a loudness model and synthetic ambient that represent a typical urban ambient profile in which a pedestrian would be attempting to detect a vehicle, the agency developed minimum sound level requirements for selected one-third octave bands.

In order to aid pedestrian detection and recognition of sounds produced by EVs and HVs, the agency has tentatively concluded that the sound level produced by a vehicle will increase with an increase in vehicle speed. The agency has two goals in increasing the vehicle's sound level as the vehicle increases speed. First, increasing the vehicle's sound level as the vehicle increases speed will allow pedestrians to detect the vehicle from a greater distance to correspond to the vehicle's increased sight stopping distance at higher speeds and the greater distance necessary to stop the vehicle. Second, ICE vehicles produce increasing sound levels as they accelerate so the sound produced by HVs and EVs will mimic the behavior of ICE sounds to enhance recognition.

In developing the acoustic specifications in this proposal, the agency considered one-third octave bands from 160 Hz to 5000 Hz. When all one-third octave bands from 160 Hz to 5000 Hz are set to a minimum audible level, it can be demonstrated that, relative to the overall sound level, some

[99] Pedersen *et al.* White Paper on External Sounds of Electric Cars-Guidelines and Recommendations. *Available at http://media.wix.com/ugd/64a49a_43313ad70e7c40f43150cf747b2e5c44.pdf?dn=A520040+-+DSTN+-+White+paper+electric+cars+-+av122410+-+ECT+LR.pdf.*

[100] The Presentation that Honda gave at the meeting is available on regulations.gov. Docket No. NHTSA–2011–0100–0038.

bands are less efficient at providing a detectable signal. That is, bands below 315 Hz and bands from 630 to 1600 Hz increase the overall levels more for the same contribution to detection. The levels of these bands are indicated by arrows in Figure 3. The arrows in the figure point to the regions of the spectrum that are most effective for warning sounds, *i.e.,* those where the threshold is not too high and the ambient is not too high to mask sounds at the threshold.

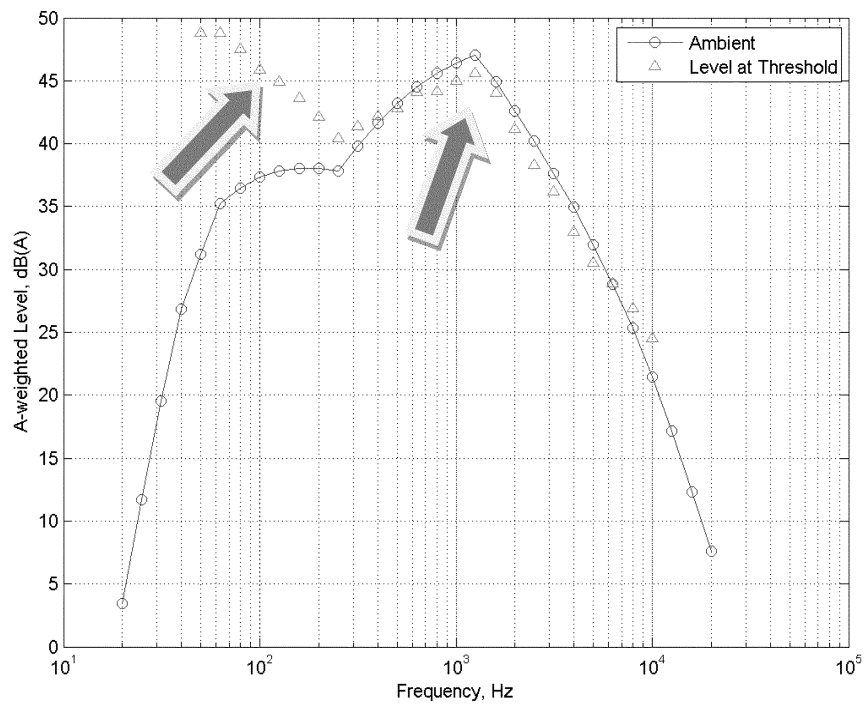

Figure 3. A-weighted Levels at Threshold

Due to masking effects of the ambient and potential hearing loss of the pedestrian, opportunities for detection will be maximized if the countermeasure signal contains detectable components over a wide frequency range; therefore, a minimum level is proposed for a set of one-third octave bands that includes mid-frequency one-third octave bands (315, 400, and 500 Hz) as well as high frequency one-third octave bands (2000, 2500, 3150, 4000, and 5000 Hz). Low frequency bands (below 315 Hz) were not considered due to the expected strong masking effects of the ambient at low frequencies. The agency chose these one-third octave bands because these bands contributed the most to detection without increasing the overall levels of the sound. Specifying minimum sound pressure level requirements 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 different acoustic profiles. Specifications for the mid-range frequency bands between 315 and 500 Hz will assist pedestrians in detecting HVs and EVs in ambient noise environments such as areas near construction activity with a significant degree of high frequency signal content. Low-frequency bands (below 315 Hz) are omitted because they do not contribute to detection and the likelihood that many practical countermeasure devices may not be able to produce high level, low-frequency sounds.

In consideration of community noise impact, the agency omitted mid-frequency bands from 630 to 1600 Hz from the acoustic specifications because, for the ambient considered, these bands contributed more to the overall sound level than other bands for the same increase in detectability. By omitting minimum sound level requirements for the one-third octave bands in the 630 to 1600 Hz frequency range, the agency is able to ensure that the alert sounds allow pedestrians to safely detect nearby EVs and HVs without contributing unnecessarily to an increase in overall ambient noise levels.

Table 12 shows the one-third octave band frequency requirements for vehicle emitted sounds for all of the test conditions in S7 of the proposed regulatory text.

TABLE 12—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

TABLE 12—MINIMUM SOUND LEVELS FOR DETECTION—Continued

One-third octave band center frequency, Hz	Stationary but activated	Backing	10 km/h	20 km/h	30 km/h
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

The agency is not including requirements for overall sound pressure level in the proposed standard. Because each one-third octave band contributes to the overall sound pressure level of a sound it is possible to determine what the sound pressure level of sounds meeting the requirements of Table 12 would be. The overall sound pressure level of sounds meeting the requirements for each one-third octave band listed in Table 12 would be 49 A-weighted dB when is in the stationary condition, 52 A-weighted dB when backing, 55 A-weighted dB at 10 km/hr (6 mph), 62 A-weighted dB at 20 km/hr (12 mph), and 66 A-weighted dB at 30 km/hr (18 mph).

The agency has tentatively concluded that the sound emitted by EVs and HVs must meet the minimum sound pressure level requirements for every one-third octave band listed in Table 12. The agency chose to require sounds emitted by EVs and HVs to meet minimum sound pressure level requirements for all of the one-third octave bands listed in Table 12 because these one-third octave bands all contribute to pedestrians' ability to detect these sounds. The agency realizes that requiring HVs and EVs to emit sounds meeting the minimum sound level requirements for every one-third octave band listed in Table 12 would make these vehicles more detectable than current ICE vehicles for some ambient noise environments. A majority of the ICE vehicles tested during the agency's Phase 2 and Phase 3 research would not meet the requirements in Table 12 for the one-third octave bands below 2000 Hz.[101] While these vehicles did not meet all of the one-third octave band specifications in Table 12, these vehicles were still considered to be detectable under the agency's detection model. The agency's detection model considers a vehicle to be detectable if it exceeds the minimum sound pressure levels listed in Table 12 for any single one-third octave band. A majority of the ICE vehicles tested by the agency were detectable in at least two one-third octave bands for the 10 km/hr (6 mph) pass by test. Even though the agency's detection model would consider a vehicle to be detectable if it meets one of the one-third octave bands levels in Table 12, requiring a sound to meet the minimum levels in more than one one-third octave band increases the likelihood that sound will be detectable in a wider range of ambient noise conditions. The agency's detection model was created using a specific ambient. While the ambient noise profile used with the agency's detection model is typical of ambient environments in which pedestrians would generally be attempting to detect HVs and EVs, requiring sounds emitted by these vehicles to meet all the one-third octave bands in Table 12 would increase the chance that these vehicles will be detectable in ambient noise environments different from the one used in the loudness model.

The fact that ICE vehicles also produce sound in one-third octave bands outside those listed in Table 12—which may contribute to the detectability of these vehicles—makes it difficult to compare sounds produced by ICE vehicles with specifications for synthetic sounds to be emitted by HVs and EVs. Because the sounds produced by ICE vehicles include signal content in a far broader range of frequencies than listed in Table 12, we believe the proposed minimum one third-octave band requirements represent a reasonable approach to ensure that HVs and EVs are at least as detectable as ICEs. The specifications in Table 12 were developed so that the synthetically generated sounds that manufacturers add to vehicles to meet the requirements of this standard would be detectable, recognizable, and would not contribute to noise pollution.

The agency believes that requiring EVs and HVs to produce sounds meeting the acoustic requirements in Table 12 will reduce the risk of crashes between EVs and HVs and pedestrians to same risk level of crashes between ICE vehicles and pedestrians. Numerous studies by motor vehicle manufacturers and academics have found that sound, or lack thereof, influences pedestrians' decisions about when to cross a street. The agency's Phase 2 research showed that sounds with certain acoustic characteristics were at least as detectable to the study participants as the sound produced by ICE vehicles. Some studies have shown that sounds designed using psychoacoustic principals are more detectable than the sounds produced by ICE vehicles.[102] To date no studies have linked the increase in the detectability of a sound to a reduction in the risk of crashes between EVs and HVs and pedestrians.

The agency believes that sounds meeting the requirements in Table 12 will be as detectable as an ICE vehicle. If the sound produced by EVs and HVs is detectable to pedestrians, they will be able to respond to the presence of a vehicle thereby avoiding a collision. The agency plans to conduct additional research before issuing a final rule to confirm that sounds meeting the requirements in Table 12 will be detectable at the distances predicted in the detection model. We seek comment to improve the specifications in Table 12 to make the sounds more detectable and to increase the effectiveness of the specifications in reducing collisions between EVs and HVs and pedestrians.

Requiring EVs and HVs to emit sound meeting the minimum levels in every one-third octave band in Table 12 will also enhance pedestrians' ability to recognize the sounds emitted by EVs and HVs because pedestrians associate low-frequency signal content with ICE vehicles.

For the reasons discussed above, as an alternative to requiring EVs and HVs to meet the minimums for every one-third octave band listed in Table 12 the agency seeks comment on requiring these vehicles to emit sounds that meet only the one-third octave band requirements for 2000 Hz and above. The one-third octave band levels in

[101] The agency notes that the acoustic specifications in Table 12 would not necessarily be an appropriate method for determining whether ICE vehicles are detectable. While the agency intends this proposal to be technology neutral, the agency recognizes that at least for vehicles that are capable of electric only propulsion, manufacturers will have to add some sound to the vehicle in order to comply with this standard.

[102] NHTSA–2011–0148–0025, *available at www.regulations.gov.*

Table 12 represent a conservative approach, from a safety perspective, to determining the sound level that an HV or EV would need to make in order to allow a pedestrian to detect the vehicle from a desired safe detection distance. Thus, it is possible that pedestrians may be able to hear these vehicles at distances farther than predicted by the agency's model. The agency plans to conduct additional research before issuing a final rule to validate the assumptions relied upon in determining the sound levels contained in Table 12. We are seeking comment on the number of bands that should contain minimum sound level requirements and what those minimum sound level requirements should be, if the agency chooses to restrict the number of one-third bands for which we would require a minimum sound pressure level. Along with comments on the specifications in Table 12, the agency is seeking recordings of sounds that manufacturers may wish to add to EV and HV vehicles. The agency plans to analyze any recordings submitted in response to this proposal along with other recordings made during further research in finalizing the acoustic performance requirements for the alert sound. For more information about submitting recordings to the agency along with comments please see the instructions for public participation in Section XII of this proposal.

The agency seeks comment of the possibility of allowing light hybrid and electric vehicles to meet the minimum sound requirements for the backing scenario with a beeping sound similar to the sound made by a backing truck. The agency has yet to determine that a backup beeping sound would be appropriate for light vehicles because this sound is normally associated with backing heavy vehicles and thus many not be recognizable as light motor vehicle. The agency also seeks comment on whether such a sound would be annoying to the public.

The agency is also seeking comment on whether we should establish a maximum sound level requirement in addition to the minimum sound level requirements contained in this proposal. The PSEA directs NHTSA to ''consider the overall community noise impact'' of the specifications contained in this proposal.[103] One way that the agency could address the overall community noise impact of this proposal would be to establish maximum sound levels for hybrid and electric vehicles. We seek comment on what the maximum levels should be were they to be included in the final rule.

The agency notes that motor vehicle manufacturers attempt to limit the noise emissions of their vehicles in response to customer preferences. The agency believes that manufacturers will limit the sound output of hybrid and electric vehicles so as not to increase the sound output of these vehicles beyond the minimum levels contained in this proposal. The agency is hesitant to establish maximum sound levels because we do not wish to increase the complexity of compliance with the standard by establish tolerances that manufacturers must meet.

In October, 2012, representatives from Nissan Motor Co., Ltd. (Nissan) presented results of the company's research to agency rulemaking staff. Nissan conducted a survey to gauge costumer acceptance of the sounds currently emitted by the Nissan Leaf. Nissan also conducted a study to evaluate the detectability of different sounds. Nissan interviewed blind pedestrians to ask them when they believed a sound at idle would and would not be useful.

In November, 2012, Ford Motor Company (Ford) met with agency rulemaking staff to present the results of human factors research conducted by the company. The experiment included both blind and sighted participants. During the experiment the participants were presented recordings of various sounds approaching either from the right or from the left. The participants were asked to identify when they heard the sound and then asked to identify the direction from which the sound was approaching. Ford compared the participants' ability to detect the sounds to the detection distances discussed in the agency's report on sound specifications for hybrid and electric vehicles.[104]

2. Recognizability Requirements

The recognizability approach analyzes the sounds produced by ICE vehicles and sets the acoustic requirements for HVs and EVs so that they would contain acoustic characteristics similar to the sounds that pedestrians associate with current ICE vehicles.

While the agency believes that the mid-range frequency specifications in Table 12 will contribute to pedestrians' ability to recognize the sounds as being produced by a motor vehicle, we believe that the requirements for low-frequency broadband and low-frequency tones in the agency's recognizability requirements adequately ensure that pedestrians will be able to recognize these sounds. Further, the low-frequency components in many ICE sounds may be masked by the ambient level chosen for our model. However, this low-frequency content contributes to recognition because it is associated with the sound perceived by the pedestrian in lower ambients and that association is remembered. Therefore, this low-frequency content does not need to be detectable in every ambient to contribute to the recognizability of a sound. Consistent with the assumption that ICE vehicles are recognizable, low frequency content of alert sounds for HVs and EVs does not need to be detectable in the 55 dB ambient to ensure that these vehicles can be recognized by pedestrians.

Recognition includes two aspects: (1) recognition that the sound is emanating from a motor vehicle that may pose a safety risk to the pedestrian, and (2) 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. Sounds that contain both broadband noise and tones can produce sounds that are recognized as vehicles. Sounds that contain only high frequencies have a synthetic (and unpleasant) character. Sounds with lower frequency tones and noise sound more like the sounds typically associated with a conventional (ICE) motor vehicle.

While the one-third octave band requirements listed in Table 12 include some requirements for lower frequency signal content for vehicle emitted sounds, low frequency tones are necessary to provide additional cues to allow pedestrians to recognize these sounds. Tones are not necessary to achieve a certain sound pressure level in a one-third octave band. A vehicle-emitted sound would be able to meet a minimum sound pressure level requirement for a one-third octave band if it contained broadband noise at a high enough level. In addition to the detectability requirements in Table 12, our proposal requires that the lowest tone of the vehicle emitted sound must have a frequency not greater than 400 Hz. Low-frequency tones are the tones that contribute the most to recognizability so tones less than 2000 Hz contribute to recognition while tones above 2000 Hz contribute to detection. ICE vehicles produce low, mid, and high-frequency tones. The lowest frequencies are related to the

[103] Public Law 111–373, § 3(b)(3), 124 Stat. 4086 (2011).

[104] *See* Hastings *et al.* (2012) ''Research on Minimum Sound Specifications for Hybrid and Electric Vehicles.'' U.S. Dept. of Transportation, Washington, DC. Available at Docket No. NHTSA–2011–0148–0048.

combustion frequency of the engine. The low frequency components contribute to the perceived power of the vehicle. Low-frequency tones in simulated sounds will contribute the most to recognition because these are closer in frequency to the low order harmonics of the engine fundamental.

The agency is also proposing a general requirement for broadband noise in the requirements designed to ensure that EV and HV emitted sounds are recognizable. Sounds produced by current ICE vehicles are broadband in nature, meaning that the sounds have some minimal signal content across a wide part of the frequency spectrum. Also, it is easier for a pedestrian to tell which direction a sound is coming from if the sound contains broadband characteristics. (Broadband sounds are also easier for pedestrians to localize than narrow band sounds.) In order for sounds emitted by EVs and HVs to provide sufficient broadband content to allow pedestrians to recognize these sounds as being produced by a motor vehicle, the agency is proposing to require these sounds to have some measurable content in each one-third octave band from 160 Hz to 5000 Hz. This means that sounds emitted by EVs and HVs are required to possess some acoustic signal content above 0 A-weighted dB at all frequencies in the one-third octave bands between 160 Hz to 5000 Hz.

In the event that the agency decides to only require minimum sound pressure levels in Table 12 for the one-third octave bands of 2000 Hz and above, the agency would retain requirements for broadband signal content in the one-third octave bands between 315 Hz and 500 Hz to ensure that the sound retained aspects that contribute to recognizability. In order to ensure that the sounds produced by EVs and HVs are recognizable to pedestrians, the agency is proposing some minimum low frequency signal content. In the event that the agency decides to limit the requirements in Table 12 to one-third octave bands above 2000 Hz, sounds produced by HVs and EVs would be required to emit a sound with a sound pressure level of 30 A-weighted dB in the one-third octave bands between 315 Hz and 500 Hz. The 30 A-weighted dB level corresponds to the one-third band levels measured for a quiet urban ambient during the agency's Phase 2 research. The agency would not expect this signal content to be detectable in the 55 dB ambient; it would only be present to assist pedestrians in recognizing the sound. The agency seeks comment on the minimum sound pressure levels of low frequency content that should be included in the agency's recognizability requirements.

The agency recognizes that the speakers that manufacturers may wish to use on EVs and HVs to meet the minimum sound requirements contained in this proposal may not be able to produce tones as low as 160 Hz. The agency believes that most of the speakers that manufacturers wish to use will be capable of producing at least some signal content in the 160 Hz one-third octave band. The agency solicits comment on the issue of whether speakers that manufacturers may wish to use to meet the requirements of this proposal are capable of producing any measurable signal content in the 160 Hz one-third octave band. The agency also solicits comment on the cost of a speaker system that is able to reproduce some measurable content at the 160 Hz one-third octave band versus a speaker system that is only capable of producing sound above 315 Hz.

Pitch shifting is also a critical element to aid in pedestrian recognition of vehicle sounds. Pitch shifting is the movement of the tones of a sound along the frequency scale. Pitch shifting mimics the behavior of an ICE vehicle as it increases speed. Based on analysis of sounds produced by ICE vehicles the agency believes that the pitch of a vehicle sound should increase with increasing vehicle speed, or decrease with decreasing vehicle speed by at least one percent per km/hr of vehicle speed.

3. Prohibition Against Modifying a Vehicle's Sound

The PSEA also requires that the FMVSS developed in this rulemaking ''prohibit manufacturers from providing any mechanism for anyone other than the manufacturer or the dealer to disable, alter, replace, or modify the sound or set of sounds, except * * * in order to remedy a defect or non-compliance.'' Our proposal extends this prohibition to any entity subject to NHTSA's authority (manufacturers, distributors, dealers, and repair businesses), allows for repair of a vehicle malfunction (in addition to the PSEA's defect and non-compliance), and also prohibits any entity subject to our authority from providing the means to defeat or change the sound emission to any other person, except for repair of a malfunction associated with the vehicle's sound emission. The goal of this section is to avoid the situation where vehicle sounds are changed, at the request of the consumer, to something individualized and no longer associated with the specific make/model of motor vehicle, or indeed even recognizable as a motor vehicle at all.

4. Phase-in Schedule

Lastly, the PSEA directs NHTSA to include a phase-in schedule for compliance with the new FMVSS. ''The Secretary shall promulgate the required motor vehicle safety standard pursuant to this subsection no later than 36 months after the date of the enactment of this Act.'' The Act further requires, at section 3(c), a phase-in period for compliance, with full compliance of all motor vehicles subject to the standard manufactured on or after the September 1 of the calendar year that begins three years after the date of the final rule. For example, if the final rule were issued on January 4, 2014, full compliance would be required for all subject motor vehicles manufactured on or after September 1, 2018. The maximum duration of the phase-in period would therefore be January 4, 2014 through September 1, 2018. Vehicle model years typically begin September 1, for example, the 2014 model year will run from September 1, 2013 to August 31, 2014. In light of this traditional production schedule, we tentatively conclude it would be unreasonable to require manufacturers to build any vehicles to the new FMVSS by September 1, 2014, for the 2015 model year, in this example. However, most manufacturers are now involved in planning some form of sound emission for vehicles they know will be affected by the new standard. Changes to any sounds provided before the final rule date will likely be made by software, not hardware, changes and manufacturers will be familiar with the test procedure through the use of the SAE J2889–1.

We therefore tentatively conclude that the following phase-in schedule is reasonable for manufacturers and allows the fastest implementation of the standard for pedestrian safety:

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

Small volume manufacturers will not need to comply with the requirements of this proposal until the end of the phase-in period. We seek comment on the appropriateness of this proposed schedule.

We have not included provisions for carry-forward credits in the proposed regulatory text; however, we seek comment on allowing carry-forward credits in the phase-in schedule to give manufacturers flexibility in meeting the phase-in requirements.

E. Compliance Test Procedure

The compliance test procedure proposed in this notice is consistent with the Society of Automotive Engineers Surface Vehicle Standard J2889–1, ''Measurement of Minimum Noise Emitted by Road Vehicles,'' September 2011.[105] Several sections of the SAE Standard are incorporated by reference into our proposed FMVSS. This industry standard was developed for use by manufacturers to test their own vehicles. The compliance test procedure proposed by the agency must deviate, however, in some respects so that it can be used by a third-party testing entity with little or no detailed knowledge of all of the vehicle's systems and their development.

Some particular differences between the SAE J2889–1 and our proposed test procedure are:

• This proposal is limited to outdoor testing, while the SAE standard has an alternative for indoor testing.

• The SAE procedure contains different methods for different vehicle operating modes, and for vehicles fitted with external sound generating systems versus vehicles without. Our proposal is uniform for all vehicles and stated in technology neutral terms so that it can be applied to any new motor vehicle to which the requirements in this proposal would apply.

1. Test Condition

SAE J2889–1 paragraph 6.2 specifies the ambient weather conditions under which the acoustics testing should be conducted. The ambient weather conditions should be measured at the microphone height. SAE J2889–1 specifies an ambient temperature between 5 degrees Celsius (°C) (41 degrees Fahrenheit (°F)) and 40 °C (104 °F). The ambient weather conditions are restricted to ensure accurate repeatable measurement. SAE J2889–1 states that the ambient temperature may need to be restricted to a narrower temperature range so that all key vehicle functions can be run in their quietest state per the manufacturer's specifications.

The agency has found during the course of research conducted in support of this rulemaking that tests that occur within the temperature range specified in SAE J28889–1 can produce divergent results when a vehicle is tested at different temperatures. In high ambient temperatures, the battery cooling fan on pure electric vehicles activates intermittently while the vehicle is operating. The agency has 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 believes that it has addressed repeatability issues caused by battery cooling fans, as stated in SAE J2889–1, it is possible that there are other vehicle functions that produce varying sound levels based on the ambient temperature level. Therefore, we are soliciting comment on the other vehicle functions that produce varying noise levels at different ambient noise levels. The agency is also soliciting comment on specifying a low ambient temperature for acoustics testing of between 5 °C (41 °F) and 20 °C (68 °F) to ensure that the vehicle will be in its quietest state during testing. The disadvantage of doing so is that it further limits the number of outdoor testing days available. The agency tentatively concludes that we have 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.

SAE J2889–1 test conditions specify a maximum wind speed of 5 m/s (11 mph) because wind speeds higher than this level can interfere with acoustic measurement. We have adopted this condition in our test conditions.

SAE J2889–1 specifies that the ambient noise at the test site should be measured for at least 10 seconds before and 10 seconds after a series of vehicle tests. The measurements of the minimum A-weighted sound pressure level and one-third octave band frequency content of the ambient noise level are made using the same microphones in the same locations used to measure the vehicle sound as specified in Figure 1 of SAE J2889–1.

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 we are proposing requirements on the one-third octave band basis we believe that ambient corrections should also be calculated on the one-third octave band basis. In order to ensure accurate measurements SAE J2889–1 contains a procedure for correcting the overall sound pressure level measurement to remove any ambient influences. 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 we are proposing requirements on a one-third octave band basis we believe that ambient corrections should also be calculated on a one-third octave band basis. In order to ensure accurate measurements, SAE J2889–1 contains a procedure for correcting the overall sound pressure level measurement to account for ambient influences. Because the variance of a signal is greater on a one-third octave band basis than on the overall, it may be difficult to apply the ambient correction procedure in SAE J2889–1 to ambient corrections on a one-third octave band basis. SAE J2889–1 requires a peak-to-peak variation of less than two dB in order to do a valid correction. Even if the peak fluctuation of the overall sound pressure level of the ambient is less than two dB, the fluctuation in individual one-third octave bands would likely be higher. In meetings with agency rulemaking staff, manufacturers have stated that it would be difficult to apply the method for correcting for the ambient in SAE J2889–1 to one-third octave bands.

In response to these concerns we are proposing to include a procedure that allows for ambient correction if the peek-to-peek fluctuation of the ambient is less than eight dB when the signal that is being measured is more than six dB higher than the ambient in that one-third octave band or less than six dB when the signal that is being measured is more than three dB higher than the ambient in that one-third octave band. These criteria were chosen in order to provide a high degree of confidence that contamination due to an unobserved, random fluctuation will not impact the final reported level by more than one half of one decibel.

We believe 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. We believe that this approach will increase flexibility in the locations and times when outdoor testing can be conducted without significantly compromising the accuracy of measurements.

In October of 2012, members of the SAE VSP committee presented research to the agency regarding the use of the test procedures in SAE 2889–1 and issues related to correcting for the influence of the ambient in measurements on the one-third octave band basis. The VSP committee also

[105] The agency recognizes that SAE published an updated version of J2889–1 in May 2012. We have not yet evaluated this new version, but intend to do so before publishing a final rule.

raised issues regarding measuring pitch shifting and the influence of ambient noise and tire noise on pitch shifting measurements. Members of the VSP committee stated that analyzing pitch shifting measurements will require a narrowband analysis. The VSP committee stated that the procedure for correcting measurements of the overall sound pressure level of a signal for the influence of ambient should not be applied to measurements of individual one-third octave bands. The VSP committee stated that outdoor testing raised issues regarding interference with measurements by the ambient. Members of the VSP committee also expressed concern that manufacturers would not be able to sufficiently attenuate the low frequency tones discussed in the agency's research to prevent those tones from intruding into the occupant compartment. Members of the VSP committee stated that pass-by measurements at 20 km/h (12 mph) and 30 km/h (18 mph) are influenced by tire noise. Members of the VSP committee believe that issues related to the influence of ambient noise on measurements of the vehicle and issues related to measuring pitch shifting can be solved by the use of indoor testing to measure regulatory compliance. We seek comment on the points raised by the VSP Committee.

The agency is considering whether the procedures for analyzing the frequency spectrum in SAE J2889–1 are sufficient to ensure that the results of the acoustic measurements are recorded in a consistent manner. The agency has the following questions about the measurement correction procedure and the recording of results of acoustic measurements:

- What roll-off rates have been used?
- Have entities conducting research on minimum sound emitted by quiet vehicles completed the ⅓ octave band analysis of their measurements in the frequency domain or the time domain?
- Volpe staff have been using an exponential window (to be consistent with SAE procedures for the measurement of overall levels) when conducting frequency analysis. In the presentation by VSP committee a committee member discussed using a Hanning window for the analysis. Does the agency need to provide additional procedures for conducting the one-third octave band analysis?

The agency has tentatively concluded that outdoor acoustics testing is preferable to indoor testing in hemi-anechoic chambers. Outdoor testing is more representative of real world vehicle-to-pedestrian interactions. Also, the agency is concerned 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.

Outdoor tests, especially pass-by tests at speed, 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 some level of ''outdoor ambient'' background noise and with Doppler shift when the vehicle is moving relative to the pedestrian. Pass-by tests allow a recording of vehicle sound parameters (levels, content, phase, etc.) against a trace of time and distance from the pedestrian's location.

Conversely, 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. It is unclear how representative the tire noise generated during rotation on the curved dynamometer test wheels is of actual tire-road noise. The vehicle approach and passing of the microphones can be simulated by phasing a row of microphones next to the vehicle, and interior tire noise can be digitally replaced with exterior tire noise recordings. However, the agency has not determined the fidelity of such methods.[106]

The agency also believes that specifications for outdoor testing have a more detailed history of objective and repeatable performance than specifications for indoor testing. A substantial amount of development and refinement has gone into the test procedures and facilities used for outdoor vehicle noise testing. For instance, outdoor tests such as the ISO 362 ''Acoustics Measurement of noise emitted by accelerating road vehicles—Engineering method'' [107] have been in use since its issuance in 1994 for measurement of maximum vehicle noise. One key to achieving repeatable test results with ISO 362 at multiple testing locations was the standardization of a common road test surface. The 1994 and subsequent versions of ISO 10844 ''Acoustics—Specification of test tracks for measuring noise emitted by road vehicles and their tyres'' [108] specify test surface materials, absorption, texture, and compaction to allow comparable test results from different outdoor noise test pads.

SAE J2889–1 contains specifications on the cut-off frequency of the indoor hemi-anechoic test facility and requirements to meet ISO 3745 ''Acoustics—Determination of sound power levels of noise sources using sound pressure—Precision methods for anechoic and hemi-anechoic rooms,'' or ISO 26101 ''Acoustics—Test methods for the qualification of free-field environments.'' However, the agency is not aware of 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.

The agency intends to specify performance requirements for vehicle-emitted sounds that are detectable and recognizable to a pedestrian as a motor vehicle in operation. Therefore, 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 cross-over speed are important facets of the vehicle's sound performance.

The agency is 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 U.S., most of which were available for paid use by outside parties. 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.

The agency found limited availability of indoor hemi-anechoic chambers that had four-wheel dynamometer drive capabilities. Additionally, the availability of indoor hemi-anechoic dynamometer chambers that can accommodate all motor vehicles covered by the PSEA, such as motorcycles, trucks, buses, etc., was found to be far more limited. While indoor testing does not have the seasonal downtimes of some outdoor test facilities, and may be more predictable and time efficient, we believe the cost of test time at indoor test facilities will be higher than at outdoor proving ground noise pads. There may also be difficulties locating

[106] *http://www.bksv.com/Products/PULSEAnalyzerPlatform/PULSESolutionsOverview/AcousticApplications/PassbyNoiseTesting/IndoorPassbyNoiseTesting.aspx.*

[107] *http://www.iso.org/iso/iso_catalogue/catalogue_ics/catalogue_detail_ics.htm?csnumber=25971.*

[108] *http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=45358.*

and scheduling indoor facilities large enough to accommodate the heavy vehicles subject to this rule.

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. Indoor pass-by testing in a hemi-anechoic chamber would capture elements of the vehicle sound profile (including aerodynamic and tire noise) that contribute to the recognizability of the vehicle's sound signature until the vehicle reaches the cross over 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. An indoor pass-by procedure would be the same as the pass-by procedure contained in Section 7.3.2.2 of SAE J2889–1 SEP2011 except that 50 meter radius free of reflecting objects around the test track would not apply. The provision in SAE J2889–1 SEP2011 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 would not interfere with the vehicle's sound measurement.

The agency is not aware of the availability of hemi-anechoic chambers that are large enough to accommodate indoor pass-by tests. The agency believes that the existence of such facilities is limited. The agency seeks 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.

The agency realizes 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 pass-by testing. It is possible that 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 seeks comment on including a test procedure for indoor hemi-anechoic chamber acoustics measurement in this standard.

The agency's test procedure specifies that the acoustic measurements for all test conditions shall be conducted on a test 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 coming from the vehicle. Doing so helps to minimize test variability between repeat tests of the same vehicle at the same facility and variations in measurements taken at different facilities.

Instruments used to make the acoustical measurements required under our proposal must meet the requirements of paragraph 5.1 of SAE J2889–1. This paragraph also 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. Manufacturers, in meetings with agency rulemaking staff, have stated that the filter roll-off rate can affect the results of acoustic measurement at the one-third octave band level. Paragraph 7.1.6.2 of SAE J2889–1 requires conformance with ANSI S1.11, which specifies a wide range for filter roll-off rates. (See ANSI S1.11 Table1, Figure 1, and Annex B.) Filters with roll-off rates at the two extremes of the range could produce different results. The agency seeks comment on whether the test procedure in this proposal should specify a maximum roll-off rate that is not infinite.

The test site envisioned by our proposal must be established per the requirements of S6.1.1 of SAE J2889–1, including Figure 1, ''Test Site Dimensions'' with the definitions of the abbreviations in Figure 1 as given in Table 1, S4 of SAE J2889–1. All references to microphone line PP′ and vehicle centerline CC′ are per Figure 1 of SAE J2889–1. Microphones are to be set on the PP′ line on both sides of the vehicle, two meters from the vehicle centerline (CC′). Use of the test set up described in the SAE's Figure 1 will ensure repeatable test measurements from run to run, vehicle to vehicle, and among various test facilities.

2. Vehicle Condition

The agency's goal in measuring the vehicle's sound level in the test procedure is to measure the vehicle at its quiet state. The test procedure in the agency's proposal contains a specification for vehicle condition to ensure that there is no variability in the results of the acoustics testing and that the vehicle will be tested at its quietest state. The vehicle condition specifications state that the tires should be pressurized per the tire placard and conditioned by driving, clockwise and counterclockwise, 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. This removes mold sheen from new tires. The SAE J2889–1 test procedure used in our research has a further requirement that tires have at least 80 percent of their tread depth. NHTSA has not included such a requirement because we are proposing that only new vehicles with less than 100 miles on their odometers at the start of testing be used. This is the normal agency protocol for compliance testing in general. The vehicle condition specifications also state that the tire treads should be free of debris, because pebbles and other objects in the vehicle's tire tread can produce a clicking sound that can increase the vehicle's sound level and interfere with acoustics measurements during pass by testing.

The vehicle test condition states that all doors should be shut and locked before commencement of testing. This step is included in the proposed vehicle condition specifications because some vehicles are equipped with automatic locks that lock the vehicle once the vehicle reaches a certain speed. The sound produced by the locking doors can introduce variability into the test results.

The proposed vehicle test condition specifies that all the accessory equipment on the vehicle should be turned off. This step is included because the vehicle's air conditioning system, heating system, and windshield wipers can all produce sound when activated that can introduce variability into the acoustic measurements in S7 of the proposed regulatory text.

The agency wishes to measure the sound produced by the vehicle with the ICE off because we are attempting to measure the sound of HVs and EVs in those vehicles' quietest states. This proposal is designed to ensure that these vehicles emit a minimum level of sound in situations in which the vehicle is operating in electric mode because in that mode the vehicle did not provide sufficient sound cues for pedestrians. Therefore, we propose 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 states when testing a hybrid vehicle with an ICE that runs intermittently, measurements that contain sounds emitted by the ICE are not considered valid.

As discussed below, the agency is not requiring that HVs meet the requirements of this proposal for a given operating condition if they are not capable of operating in EV only mode in that condition. The agency's method for determining whether a vehicle is incapable of operating in EV mode above a certain speed requires that the batteries on the vehicle be fully charged at the beginning of the test sequence; otherwise the vehicle may be improperly exempted from meeting the requirements for a given condition. The agency believes that the hybrid vehicles to which this proposal would apply are equipped with an indicator that provides information on the state of charge of the propulsion batteries. The agency is also considering adding a vehicle charging procedure to charge the vehicle's propulsion batteries prior to each test sequence. This procedure would involve a set of vehicle maneuvers designed to charge the vehicle propulsion batteries. The agency seeks comment on whether there are HVs to which this proposal would apply that do not visually indicate their propulsion batteries state of charge to the driver. The agency also seeks comment on whether a battery charging procedure should added to the test procedure.

3. Test Procedure

The agency proposal contains steps for measuring the sound of the vehicle at startup, stationary but activated, reverse, 10 km/h (6 mph) pass by, 20 km/h (12 mph) pass by and 30 km/h (18 mph) pass by. The agency has tentatively concluded that EVs and HVs should produce a minimum sound at least until they reach a speed of 30 km/h (18 mph). 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.'' [109] Because we intend for the proposed standard to be technology neutral, we are not including a requirement for when an alert sound added to a vehicle must be active in the regulatory text. Instead, the proposed standard includes required minimum sound pressure levels that vehicles subject to the standard are required to meet at different test speeds so that these vehicles will make sufficient sound to allow pedestrians to detect them.

The agency established the proposed top crossover of 30 km/hr (18 mph) by examining the speed at which EVs and HVs produce a similar amount of sound to their peer ICE vehicles. In comparing the sound produced by HVs and EVs to the sound produced by ICE vehicles, the agency sought to determine the speed at which the ICE was no longer the dominant sound source of the vehicle and tire and wind noise were the main source of vehicle sound output. We also examined the crash statistics from the State Data System to determine if there was a speed at which the rate of pedestrian crashes for HVs and ICE vehicles were the same.

NHTSA's research indicates that the speed at which the sound levels produced by HVs and EVs and the sound levels produced by those vehicles' ICE peers become indistinguishable differs depending on make and model. The difference in sound pressure level between sounds is not distinguishable to humans over time if the sounds are within 3 A-weighted dB of each other.[110] The sound level of three of the HVs tested during the agency's Phase 1 research were within 3 A-weighted dB of their ICE peer vehicles at 16 km/h (10 mph) with the sound levels for all HVs meeting those of their peer ICE vehicles at 32 km/h (20 mph).

During the agency's Phase 3 research, an EV (Nissan Leaf) and three HVs with prototype sound systems and their ICE peer vehicles were tested to compare the sound levels of HVs and EVs and their ICE peers when stationary but activated, 10 km/h (6 mph), 20 km/h (12 mph), and 30 km/h (18 mph).[111] Only one of the HVs tested during the Phase 3 research was within 3 A-weighted dB of its ICE peer at 20 km/h (12 mph), the same hybrid produced a sound level 3.5 A-weighted dB above its ICE peer at 30 km/h (18 mph). The sound level produced by the Nissan Leaf was 5 A-weighted dB lower than its ICE peer, the Nissan Versa, at 20 km/h (12 mph) and 4 A-weighted dB lower than the Versa at 30 km/h (18 mph) with its sound generation system turned off. The other HV tested was 5 A-weighted dB lower than its ICE peer at 20 km/h (12 mph) and 4 A-weighted dB lower than its ICE peer vehicle at 30 km/h (18 mph). The sound levels produced by the Nissan Leaf and the HVs were not as high as the overall levels of sounds that would meet the proposed requirements for every one-third octave band listed in Table 12 at 20 km/h (12 mph) (see Table 12). Both HVs produced sound levels as high as sounds meeting the requirements for every one-third octave band in Table 12 at 30 km/h (18 mph) and the Nissan Leaf produced a sound only 2 A-weighted dB lower.

The acoustic measurements for the agency's Phase 3 research were conducted on a test surface conforming to ISO 10844 (1998) and acoustic measurements conducted during Phase 1 research were taken on the VRTC test track which does not conform to ISO 10844 (1998). Even though the Phase 1 and Phase 3 measurements were taken on different surfaces the direct comparison between the EV or HV and its ICE peer remains valid, as EVs and HVs were measured on the same test surface as their respective ICE peer vehicles.

Our research data from Phase 1 and Phase 3 shows that the sound level gap between HVs or EVs and their ICE peer vehicles still exists at 20 km/hr (12 mph) and becomes much smaller or negligible in some tests at 30 km/hr (18 mph). Also, the EVs and HVs tested in Phase 3 research did not meet our minimum sound pressure level detectability requirements at 20 km/hr (12 mph). For these reasons, NHTSA tentatively concludes that ensuring EVs and HVs produce a minimum sound level until they reach a speed of 30 km/hr (18 mph) will ensure that these vehicles produce sufficient sound to allow pedestrians to detect them. The agency believes that the minimum sound level requirements will ensure that these vehicles produce sufficient sound to allow for safe pedestrian detection at this speed. Thus, the requirements in this proposal, if made final, would require that EVs or HVs that do not currently produce enough sound for pedestrians to detect them while traveling at 30 km/hr (18 mph) would have to increase their sound output. The agency solicits comments on the determination of 30 km/hr (18 mph) as the appropriate upper limit for light EVs/HVs and additional data on similar tests performed on the same type of vehicles.

At speeds greater than 30 km/hr (18 mph), the agency has tentatively concluded that EVs and HVs produce sufficient sound for safe pedestrian detection. The agency believes that vehicles that will require a countermeasure sound to meet the minimum sound requirements at 30 km/hr (18 mph) will continue to produce those countermeasure sounds at higher speeds so that the added sound will phase out at speeds greater than the crossover speed. The agency believes that manufacturers are likely to gradually phase the countermeasure sound off at speeds above the crossover

[109] Public Law 111–373, § 2(3), 124 Stat. 4086 (2011).

[110] Springer Handbook of Acoustics, Thomas D. Rossing (Ed.), Springer Science and Media LLC, New York, 2007, page 472.

[111] One of the HVs tested during the Phase 3 research was excluded from the crossover speed analysis because the agency was not able to deactivate the vehicle's sound alert system. Because the sound alert system on that vehicle remained active the agency was not able to compare the sound level of the vehicle while operating in electric mode to sound level emitted by the vehicle's ICE peer.

speed to avoid annoyance caused by a sharp drop in sound level if the countermeasure was terminated exactly at 30 km/hr (18 mph).

The crashes used in our statistical analysis discussed earlier came from areas where the posted speed limit was less than or equal to 35 mph. As discussed previously, this analysis indicated that the odds ratio of an HV being involved in a crash with a pedestrian was 1.38 when the vehicle in question completed a low speed maneuver immediately prior to the crash.[112] This means that HVs and EVs were 38 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 tentatively concludes that a crossover speed of 30 km/hr (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. The odds ratio of a HV being involved in a pedestrian crash while going straight is 0.96. This means that HVs are no more likely to be involved in pedestrian crashes when going straight than ICE vehicles.

The agency does not believe that establishing a crossover speed of 30 km/h will have any noticeable impact on ambient noise levels. As discussed in Section X.D, NHTSA has conducted an EA to analysis the environmental effects of this rulemaking. The EA shows 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 would be negligible. A single EV or HV travelling at 30 km/h that produced sound meeting the requirements of this proposal would not be noticeable to a person standing 7.5 meters from the roadway in a 55 A-weighted dB ambient environment representative of urban areas.

The guidance document developed by UNECE recommends that EVs and HVs emit pedestrian alert sounds beginning when the vehicle starts moving and continuing until the speed of the vehicle reaches 20 km/hr (12 mph). The Alliance of Automobile Manufacturers also suggested 20 km/hr (12 mph) as the crossover speed.[113]

During QRTV's eighth meeting, the Japan Automobile Standards Internationalization Center (JASIC) presented its research on crossover speed.[114] It determined the crossover speed by measuring when the tire noise was dominant over engine noise for several vehicles. JASIC concluded that the tire noise was dominant for every ICE vehicle and HV they tested at speeds that exceeded 20 km/h (12 mph). It also concluded that the difference between sound levels of HVs and ICEs occurred at speeds below 20 km/h (12 mph). The agency solicits comments on whether 20 km/h (12 mph) should be considered the crossover speed, as an alternative to the 30 km/h (18 mph) crossover speed as well as additional research data that support this speed.

In the absence of more detailed analysis supporting another crossover speed, the agency tentatively concludes that a crossover speed of 30 km/hr (18 mph) will 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 while also minimizing community noise impact by ensuring that the sound is not active when it is no longer necessary.

In order to ensure that HVs and EVs produce a minimum level of sound to be detectable by pedestrians until the crossover speed, the agency is proposing to measure the minimum sound of the vehicle at 30 km/hr (18 mph). Because the agency's proposal is technology neutral, a manufacturer can choose how to comply with the minimum level sound requirements at the 30 km/hr (18 mph) pass by. Thus, no countermeasure sound would be required if a vehicle subject to the requirements of this standard produces sound sufficient to meet the requirements in section S5 of our proposed regulatory text at 30 km/hr (18 mph).

For all operating conditions, our proposed test procedure (and that of SAE J2889–1) specifies that four consecutive valid measurements be within 2 A-weighted dB. 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 normal operating sound.

The test procedure also specifies that test runs in which the vehicle's ICE, (for HVs), or battery cooling system activate must be discarded. As stated earlier, it is the agency's goal to measure the minimum sound levels of vehicles subject to this standard in their quietest state. It is because these vehicles are capable of very quiet operation that the agency is requiring a minimum sound level to ensure pedestrians can detect them.

The agency also found that a hybrid vehicle's ICE engine turning on during the test can introduce variability into the test results. 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 pure electric vehicles or the ICE engines on hybrid vehicles to be activated whenever the vehicle is turned on or moving this would be a satisfactory manner for a manufacturer to comply with the minimum sound level requirements. The fact that both the battery cooling fans and the ICEs on hybrid-electrics are only running intermittently means that sounds produced by these vehicle functions cannot be relied on to provide sound to pedestrians under all conditions. While the specifications requiring four valid measurements with 2 A-weighted dB would to some extent address repeatability issues caused by intermittent vehicle noise, the agency wants 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.

The agency realizes 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 this proposal would specify requirements. Because the agency would be testing HVs in their quietest state, the test procedure and requirements in this proposal are not designed to test a vehicle that is producing added sound while its ICE is operating. Therefore, the agency would not require that HVs meet the requirements of this proposal for a given operating condition if they are not capable of operating in EV only mode in that condition. For example, if a vehicle is not designed to operate in EV only mode above 25 km/h it would not be required to meet the requirements in this proposal at any speed above that (*e.g.* at the typical 30 km/h crossover speed).

The test procedure in S7 calls for 4 valid consecutive measurements and tests in which the vehicle's ICE is running are not considered valid. Thus, according to these test procedure, it would not be possible to test vehicles that do not operate in EV only mode in one of the conditions for which we are

[112] See footnote 36.

[113] *http://www.regulations.gov/#!documentDetail;D=NHTSA-2011-0148-0022.*

[114] *http://www.unece.org/trans/main/wp29/wp29wgs/wp29grb/qrtv_8.html.*

proposing minimum sound requirements. Therefore, we have included a provision in the proposal that excludes an HV from meeting the minimum sound requirement for a given operating condition after 10 consecutive tests during which the vehicle's ICE is on for the entire test.

a. Start-Up

The proposed regulatory text in Section XIII of this notice would require that the vehicle's stationary but activated sound commence within 500 milliseconds of when the vehicle's starting system engages. The proposal does not currently contain specifications for a separate ''start-up'' sound. The requirement that the stationary but activated sound commence within 500 milliseconds of when the vehicle's starting system engages establishes how soon the vehicle must meet the requirements of the proposal after it is turned on. The agency believes it is important for the pedestrian to be aware of a vehicle as soon as its starting system is activated. We believe 500 milliseconds is adequate time for the vehicle's starting system to engage after the driver has initialized the process by whatever method is used on that vehicle (*i.e.,* turning a key or pressing a button) and for the staring system to communicate with other vehicle systems. We seek comment on whether 500 milliseconds is a sufficient amount of time for the alert sound to activate after the vehicle's starting system is engaged. We also seek comment on whether 500 milliseconds is an appropriate amount of for the alert sound to activate after the vehicle's staring system is engaged from a safety prospective.

While the agency has not included separate acoustic requirements in Section XIII to signal that the driver has turned on the vehicle, the agency is considering whether we should include such requirements in the final rule. If the agency decides to include a different acoustic cue to signal that the driver started the vehicle, we would require that the sound start within 500 milliseconds of the driver initializing the starting process and continue for two seconds. The sound pressure levels that the agency measured for vehicle starting sounds during the Phase 2 research were between 65 A-weighted dB and 75 A-weighted dB. The startup sounds that the agency measured during the Phase 2 research were 11 A-weighted dB to 15 A-weighted dB louder than the sound produced by those vehicles when stationary but activated. The agency recognizes that a start-up sound of 75 A-weighted dB is probably higher than necessary to alert pedestrians to the presence of a starting vehicle. Were the agency to require a different start-up sound, the agency would want the difference between the start-up sound and the sound produced by the vehicle when stationary but activated to mirror the difference in sound pressure levels between stationary but activated and start-up in ICE vehicles so that a pedestrian would be able to differentiate between the two operating conditions. Thus, a start-up sound for HVs and EVs would be 11 to 15 A-weighted dB higher than the requirements proposed for stationary but activated in Section XIII (see Table 1, S5.1.1 of the proposed regulatory text). The agency solicits comments on whether a start-up sound should be included as an operating condition for which the agency should establish minimum sound requirements as well as the acoustic requirements that are different from the requirements for the stationary but activated sound.

The microphone position for the start-up sound test is the same as the microphone position for the stationary but activated condition test described below.

b. Stationary But Activated and Directivity

The test procedure used to measure the compliance of the vehicle to the startup, stationary but activated, and directivity requirements of Section 5 of the proposed regulatory text is based on the ''stopped condition'' test of paragraph 7.3.2.1 of SAE J2889–1. The front plane of the vehicle is positioned at the microphone line (PP'), the vehicle is stationary and four consecutive 10 second measurements are taken. Measurements are considered invalid if they contain sounds emitted by any component of the vehicle's battery thermal management system (cooling fans or pumps), or they come from an ICE on an HV equipped with an ICE that runs intermittently. These provisions help to ensure that the vehicle is measured in its quietest state. The pass/fail requirements for this test, as for all the tests, are a set of sound pressure level measurements in each of eight one-third octave bands, which were chosen for their ability to contribute to detectability without unnecessarily adding to the overall sound pressure level of the vehicle in that condition.

The agency is proposing that the vehicle be tested for minimum sound level at the stationary but activated operating condition with the vehicle's gear selection in park (for vehicles fitted with a park position). The agency has decided to test at the stationary but activated condition while the vehicle is first turned on and while the vehicle is in park instead of testing while the vehicle's gear selection is in drive because the agency believes that the vehicle must produce a sound level while at park that is sufficient to allow pedestrians to avoid collisions with vehicles pulling out of parking spaces and driveways. The agency believes that the alert sound activating when the vehicle is shifted into drive will provide insufficient warning of the presence of a vehicle that is about to pull out of a parking space or a driveway. It is likely that drivers will shift into drive and commence vehicle motion with minimal delay. In this situation, an alert sound that activated when the vehicle was shifted into drive would provide little to no warning that there was a nearby vehicle. The agency believes that testing the vehicle's minimum sound level while in drive would reduce the effectiveness of the requirement of a sound when stationary but activated and testing the vehicle's sound level while the vehicle is in park will decrease the number of collisions between EVs and HVs and pedestrians caused by the vehicle's quietness.

In an email to the Director of the Office Crash Avoidance Standards the NFB expressed concern that establish minimum sound requirements for when the vehicle's gear selection was in drive but not in park would mean that blind and visually impaired pedestrians would not be able to detect the presence of nearby vehicles that had just been turned on in ''a parking space, driveway, or other location.''[115] Representatives from motor vehicle manufacturers have urged the agency to establish minimum sound requirements for the stationary but active scenario when the vehicle's gear selection is in drive.

The agency realizes that a sound in park may not be necessary for safety in situations in which a vehicle is stationary for long periods of time. This includes situations in which the vehicle is in park but still ''on'' while the driver is preparing to exit the vehicle or while the driver is waiting for someone. In these situations, the vehicle is unlikely to commence movement at a moment's notice, which lessens the need for the vehicle to emit some minimum sound level. The agency solicits comment on approaches that could be adopted to ensure that the vehicle is not producing sounds in situations in which the sound is not needed for pedestrian safety. One of the approaches that the agency is considering for mitigating noise caused

[115] NHTSA–2011–0148–0031.

by idling vehicles would be to allow the countermeasure sound to deactivate when the vehicles is shifted from drive into park. Another option would be for the sound to deactivate after the vehicle has been in park for some amount time such as two or five minutes. We seek comment on how to mitigate unnecessary noise from vehicles idling for long periods of time, while preserving the stationary but activated sound when needed for pedestrians' safe navigation.

Our proposal contains a requirement and a test procedure for measuring the directivity of the sound emitted by the vehicle because the stationary but activated and pass by tests measure the sound at two microphones two meters on either side of the vehicle's centerline. The pedestrian, however, will be passing in front of the vehicle. We want to ensure that there is 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 pedestrian hears the sound. The directivity measurement involves placing a third microphone at the vehicle's centerline, two meters in front of the vehicle. This measurement is done when stationary but activated and the sound that is measured by the center microphone must meet the same sound pressure level requirements in the same one-third octave bands as the sound measured by the side microphones.

c. Reverse

Our proposal contains a requirement and a test procedure for sound while the vehicle is backing because this is one of the critical operating scenarios we have identified in our research and statistical studies. The requirement is limited to vehicles capable of rearward self-propulsion. This means that motorcycles (and other motor vehicles, possibly low speed vehicles) constructed without a reverse gear, such that they cannot move rearward under their own power will not be required to make a sound when moving backward (presumably by being pushed). For all other vehicles, whenever the gear selection control is in reverse, the vehicle must emit a sound meeting the specified sound pressure level in each of eight one-third octave bands. These sound pressure level requirements are greater than those when stationary but activated, but less than those for the 10 km/hr (6 mph) pass by test, because, while we know the vehicle will be moving while backing, we know it will almost always move at less than 10 km/hr. The test for backing is done when stationary but activated with the rear plane of the vehicle on the microphone line because it is very difficult for a test driver to reliably and repeatedly back a vehicle through the test area at any constant speed.

d. Constant Speed Tests

Constant speed pass by tests are required at 10 km/hr (6 mph), 20 km/hr (12 mph), and 30 km/hr (18 mph). The vehicle passes through the measurement area specified in SAE J2889–1 at a constant speed and the sound profile is captured at the microphone line. Four consecutive valid measurements are required and must be within 2 A-weighted dB of each other. As in the stationary but activated test, invalid measurements are those that contain sounds emitted by any component of a vehicle's battery thermal management system, or that come from the ICE on a hybrid vehicle with an ICE that runs intermittently. The requirement is stated as a set of sound pressure levels in each of eight one-third octave bands, at any speed greater than or equal to10 km/hr (6 mph), but less than 20 km/hr (12 mph). The constant speed pass by tests at 20km/hr (12 mph) and 30 km/hr (18 mph) are conducted in the same manner as the 10km/hr (6 mph) test but each have their own set of required sound pressure levels. Requirements are in the same eight one-third octave bands, but sound pressure levels are higher than the 10km/hr (6 mph) test, because the pedestrian needs a longer detection distance to avoid a faster moving vehicle. As discussed above, an HV would not be required to meet the requirements for a given test speed if it was not capable of operating in EV only mode at that speed.

e. Pitch Shifting

Our proposal contains a requirement for pitch shifting to signify acceleration and deceleration. Sounds to alert pedestrians to acceleration and deceleration are required by the language of the PSEA. Pitch shifting gives the pedestrian information about the acceleration or deceleration of an approaching vehicle. This information is important to the pedestrian in making a decision about whether or not to cross in front of a vehicle. An accelerating vehicle does not intend to stop. A decelerating vehicle on a path parallel to the pedestrian may be slowing to make a right turn into the pedestrian's path if she or he were to cross the street. The proposed requirement is that the fundamental frequency of the sound emitted by the vehicle increase with speed by at least one percent per km/hr between 0 and 30 km/hr (18 mph). There is no test procedure associated with this requirement. Pitch shifting is verified by comparing the fundamental frequency from the stationary but activated, 10 km/hr (6 mph), 20 km/hr (12 mph), and 30 km/hr (18 mph) tests.

The agency is aware that the pitch of the sound produced by a traditional ICE vehicle does not increase linearly because as a vehicle transitions to a higher gear, the revolutions per minute of the engine drop, and therefore so does the frequency of the sound produced by the engine. The agency notes that it is possible that the sound produced by an HV or EV may not increase linearly in pitch because the sound output may change as the vehicle transitions from a lower gear to a higher gear. The agency does not believe that this phenomenon will have a significant impact on the agency's method for measuring pitch shifting because a majority of the electric motors on vehicles subject to this proposed standard have single gear transmissions.

While the pitch shifting requirement contained in this proposal does not exactly mimic the sound produced by a traditional ICE vehicle, increasing pitch is a characteristic that pedestrians associate with an accelerating vehicle based on experience. Because the pitch shifting requirement only applies while the vehicle is traveling at speeds between 0 km/hr and 30 km/hr (18 mph), the sound produced by a vehicle meeting the requirements of this proposal will be similar to the sounds produced by a traditional ICE vehicle. The agency believes that the pitch shifting requirement contained in this proposal will approximate the acoustic behavior of traditional ICE vehicles closely enough to provide pedestrians with valuable information about a vehicle's change in speed.

Manufacturers and their representatives, in meetings with NHTSA staff, have expressed concerns that it is difficult to measure the change in pitch of a sound produced by a vehicle on a vehicle level during a pass by test. Manufacturers have requested that the agency measure pitch shifting using a component level test.

The agency is hesitant to include a component level test because we want the standard to be technology neutral and because we do not wish to limit technological innovation. Further, the agency is aware that manufacturers plan to use different technologies to comply with this standard so defining the component subject to the component level test could prove difficult. The agency is aware that some sounds produced by a vehicle do not necessarily shift in pitch as the vehicle increases speed. However, the agency believes that it is possible using the test procedures in S7 to accurately measure the change in pitch of a sound added to a vehicle for purposes of complying with this proposed standard.

The agency seeks comment on including a component level test to measure pitch shifting in the test procedure. If the agency included a component level test in the final rule, it would apply to devices added to a vehicle to generate sound for purposes of complying with this proposed standard. A sound generation device would be defined as a device that is not connected to the vehicle's propulsion source or drive train that is installed on a vehicle for the purposes of generating sound. Under such a test the agency would place a microphone one meter in front of the sound generating device mounted 0.5 m above the floor. The agency would then input into the device a signal corresponding to the vehicle speeds 0 km/hr, 10 km/hr (6 mph), 20 km/hr (12 mph), and 30 km/hr (18 mph) and make 5 second recording of the output of the sound generating device at each speed. The measurement would have to be conducted under the conditions in S6.1 with the instruments specified in S6.3.1. The performance requirements for a component level pitch shifting measurement would be the same as the proposed requirements in S5.1.6.

The agency's proposed method for measuring pitch shifting depends on the presence of a strong tone in the sound. The pitch of a sound is verified by tracking this tone as it increases in frequency for each pass by test as the vehicle increases speed. It is difficult to verify a sound's increase in pitch if the sound does not have any strong tones.

The agency has some concerns about identifying the tone of a sound and tracking this tone as the vehicle increases speed. The agency plans to conduct further research to verify that it is possible to track a tone's increase in frequency as the vehicle increases speed. If it is not possible to identify a tone to track in order to verify the increase in a sound's pitch, the agency may use a different method to verify the increase in a sound's pitch. Possible methods to quantify pitch shifting include in-situ and bench tests of constant speed or accelerating pass-by events. A method to track tonal components is needed. Additional measurements, not currently being collected in the compliance test procedure, such as engine RPM may be required in order to apply the verification procedure for pitch shifting to spectrally complex sounds. We request comments on this issue.

f. Recognizability

The PSEA also requires that our new standard have performance requirements that ensure the sound emitted by an HV or EV is one that is recognizable as a motor vehicle. Our proposal includes requirements to address recognizability. The sound emitted by the vehicle to meet requirements for each of the critical operating scenarios must contain at least one tone, and at least one tone no higher than 400 Hz. 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. The criteria set for determining the appropriate tone-to-noise ratio could be refined. Possible refinements to the tone-to-noise ratio criteria to better suit the current application include a) reduction in the bandwidth, or b) inclusion of all tones within the band for the tone-to-noise calculation, and c) possibility of changing the 6 dB criterion.

The sound must also have broadband content in each one-third octave band from 160 Hz to 5000 Hz. Broadband components are those that have energy at all frequencies within a one-third octave band. This broadband component requirement could be met, for example, by Gaussian distributed random noise, a set of damped sine waves whose damping and spacing covers a one-third octave band, or a combination of tones and noise.

g. Vehicles of the Same Make and Model Emitting the Same Sound

Pursuant to the PSEA, NHTSA is required to ensure that vehicles of the same make and model emit the same sound or set of sounds. We interpret a vehicle model as a specific grouping of similar vehicles within a vehicle line. 49 CFR part 541, *Federal Motor Vehicle Theft Prevention Standard,* defines 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.

The proposed standard would require vehicles of the same make and model to emit the same sound or set of sounds for a particular model year. Thus a 2012 Prius Two could have a different sound than a 2012 Prius Four. A 2012 Prius Two could also have a different sound than a 2013 Prius Two. All Prius Twos from the 2012 model year would be required to emit the same sound or set of sounds.

We are only proposing to require that only sounds added to vehicles for the purpose of complying with this proposed standard be the same. The requirement that sounds emitted by vehicles of the same make and model be the same does not apply to sounds generated by a vehicle's tires or body design or sounds generated by the mechanical functions of the vehicle. Because NHTSA intends only to test whether sounds added to a vehicle for purposes of complying with this standard are the same, we propose to test for this requirement at the stationary condition. Testing at the stationary condition will ensure that the agency is able to test sound added to the vehicle without interference from other sources of vehicle noise. We seek comment on testing to ensure that sound produced by two different vehicles of the same make and model is same at additional test scenarios other than idle. We also seek comment on the extent to which changing a vehicle's tires or body design would affect the vehicle's sound profile.

The agency proposes to consider the sounds produced by two vehicles to be the same if, when tested according to S7.2, the sound emitted by the two vehicles has a sound pressure level within 3 A-weighted dB for every one-third octave band between 315 Hz and 5000 Hz. The agency seeks comment on this method for determining if two sounds are the ''same.''

VIII. Alternatives Considered But Not Proposed

As discussed below, the reason that the agency did not propose many of the alternatives described in this section was because of difficulties in compliance testing. These alternative methods for developing sounds could be used so long as the resulting sounds meet the requirements of the proposal. The agency believes that allowing multiple compliance alternatives would make compliance testing unduly complicated. The agency seeks comment on modifications to the acoustic specifications contained in Section XII of this proposal. To the extent that the suggested modifications allow for increased flexibility without a decrease in safety, the agency will consider adopting the comments in the final rule.

A. Requiring Vehicle Sound To Be Playback of an ICE Recording

The agency considered specifying that the alert sound used on EVs and HVs be a recording of an ICE peer vehicle. After further consideration and based on comments on the NOI, the agency concludes that a recording based on an ICE vehicle is not a viable regulatory option for ensuring that EVs and HVs produce sound levels sufficient to allow pedestrians to safely detect them. The agency believes that it is not practical to require that the alert sound be a recording of an ICE vehicle because of concerns about enforcing such a standard, because the recording of an ICE engine might not be as detectable as the sounds that the agency is proposing, and because of the expense of creating and replaying the recording. In addition manufacturers have expressed a desire for flexibility in developing pedestrian alert sounds and this approach is unnecessarily limiting in that aspect.

The agency believes that requiring an alert sound based on a recording of an ICE vehicle would unnecessarily complicate the agency's compliance testing. Under the compliance test that the agency was considering for an alert sound based on a recording of an ICE vehicle, manufacturers would be required to report to the agency which vehicle the alert sound was recorded from. The agency would then test both the vehicle the alert sound was recorded from and the EV or HV on which the alert sound was installed and compare the acoustic profiles of the two sounds. Testing two vehicles would double the time and expense of conducting compliance testing. While the agency does not require manufacturers to conduct any testing to certify their vehicles, the agency recognizes that many manufacturers choose to follow the test procedure in the agency's standards to be assured of compliance. Thus, increasing the amount of vehicles tested would also increase manufacturers' testing costs.

The agency does not believe that the recording of an ICE would be as detectable as the sounds meeting the specifications in S5 of this proposal. Most of the frequency content produced by an ICE is in the lower frequency part of the spectrum where the ambient is highest. Because ICE sounds have a significant amount of low frequency signal content, they are more likely to be masked by the ambient than sounds with higher frequency tones or high frequency broad band. The agency's Phase 2 research indicated that sounds that contain only elements produced by the fundamental combustion of the ICE are relatively ineffective in providing adequate detection. An alert sound that was based on a recording of an ICE vehicle would not allow manufacturers to use sounds that had tones in frequencies for which the ambient is not very strong and that might be more detectable than a recording of an ICE.

In their comments on the NOI, manufacturers have stated that it can be more expensive to create and replay an alert sound based on a recording of an ICE vehicle than to create and replay a synthetic sound. Manufacturers have stated that they would have to conduct recordings at several vehicle speeds and then process the sound so that when played through a speaker system mounted on the vehicle it would produce a smooth sound that mimics the sound produced by the ICE vehicle on which the recording was based.

Creating the recording at several different speeds adds an additional expense in creating the sound that is not present in synthetic sounds. The recordings would have to be captured by multiple vehicle pass bys or through recordings conducted indoors in hemi-anechoic dynamometer chambers, both of which would entail significant cost.

Playing back the sound so that it sounded like an ICE vehicle would likely require costly high performance signal processing. High performance signal processing is necessary for systems to be able to accurately reproduce sounds for acceleration and deceleration. One commenter also stated that the vehicle on which the alert sound was installed would have to have a larger data storage capacity to replay an alert sound recorded from an ICE vehicle. The commenter stated that the vehicle would require this additional storage capacity because the system would have to retain a recording of the ICE at each speed below the crossover speed in order to reproduce the recording. This additional storage would lead to additional expense for the alert sound system.

Commenters also stated that a recording of an ICE played back over a speaker mounted on an EV or HV would not sound exactly like the recorded vehicle because speaker systems that manufacturers would be using cannot reproduce sound with that level of accuracy. The inability of speakers mounted on vehicles to reproduce the sound of the recorded vehicle at a high level would diminish the advantages in the level of pedestrian recognition of the alert sound that the agency had hoped to gain in requiring that the alert sound be a recording of an ICE vehicle.

In comments on the NOI and in meetings with NHTSA staff, manufacturers have stated that they wish to have a certain degree of flexibility to develop sounds that pedestrians will find recognizable and detectable but will also be pleasing to the driver. Given the other difficulties present in requiring an alert sound based on a recording of an ICE vehicle, the agency does not believe that the benefit gained from requiring an alert sound based on a recording of an ICE vehicle justifies restricting manufacturer choice regarding the sounds that can be used as alert sounds especially since some of the sounds that manufacturers may wish to use could be more detectable than recordings of ICE vehicles.

Given that alert sounds based on recordings of ICE sounds would be more expensive to test, create, and replay than the sounds fitting the parameters in Section XIII and the marginal benefit to pedestrians in recognizing ICE sounds that might be gained from using a recording of an ICE as an alert sound, the agency believes that the specifications in Section XIII present a more feasible approach to establishing minimum sound levels for EVs and HVs.

B. Requiring That the Alert Sound Adapt to the Ambient

The agency considered requiring that the sound level of the alert sound vary based on the ambient noise level in the environment surrounding the vehicle. The agency is aware that technology is available for back-up alarms for heavy vehicles and construction equipment that vary the sound pressure level of the alert sound based on the sound pressure level of the ambient.

The agency decided not to pursue this approach because it was not justified based on safety need, because of concerns about the impact of environmental noise, and because of concerns about the sophistication of this technology. Based on conversations with the groups representing the visually-impaired community and a review of literature describing navigation by visually-impaired individuals, we have tentatively concluded that pedestrians who are visually impaired are taught not to attempt to cross intersections using hearing alone in urban environments with a high ambient noise levels.[116] The agency believes that sounds meeting the specifications in Section XIII will provide adequate detectability for pedestrians in ambient environments in which sound cues are necessary to assist pedestrians in avoiding collisions with

[116] See footnote 8.

vehicles. The agency is concerned that an alert sound that reacts to the ambient noise level could contribute to an increase in the overall ambient noise level and contribute to noise pollution. An alert sound that would be detectable over a high urban ambient sound level would raise the overall ambient level simply by its presence. Multiple vehicles with variable noise alert devices would contribute to noise pollution by driving the ambient sound pressure level higher and higher by reacting to the sound being produced by other vehicles. The agency is concerned that this technology is not at a stage where it can avoid the feedback effect of two equipped vehicles reacting to each other and thereby increasing the overall noise level.

Because an alert sound that adapted to the ambient environment would provide little additional safety benefit and could lead to increases in noise pollution, the agency decided that such a device should not be required in this rulemaking.

C. Acoustic Profile Designed Around Sounds Produced by ICE Vehicles

The agency is hesitant to set the minimum sound level requirements for quiet vehicles to mean levels produced by ICE vehicles. Setting the minimum sound requirements for HVs and EVs at the mean levels produced by ICE vehicles could have the effect of cutting off efforts by manufacturers to reduce vehicle noise emissions. This would also serve to increase the overall levels of vehicle noise emissions because vehicles that had been quieter would now be required to produce sound at the mean sound level of ICE vehicles.

Acoustic requirements based on the sound level of ICE vehicles also include a pitch shifting requirement, as we have proposed in this notice.

The agency is also hesitant to set the minimum sound levels for HVs and EVs at 3 (or 2) standard deviations below the mean sound level produced by ICE vehicles because then sound levels may not be high enough to allow pedestrians to detect these vehicles. The agency has yet to determine whether all ICE vehicles produce sound levels that are sufficient enough to allow pedestrians to readily detect them. Because the PSEA requires the agency to study whether quiet ICE vehicles pose an increased risk of collisions with pedestrians, the agency does not believe that it is in a position to assume that very quiet ICE vehicles are easily detectable by pedestrians.

As discussed in Section VI.C of this notice, in our Phase 3 research we developed a set of minimum sound level criteria for HVs and EVs based on the sounds produced by current ICE vehicles. While we are not proposing acoustic specifications based on the sound profile of ICE vehicles at this time we seek comment on the acoustic specifications below.

As discussed in section VII.D.1, the following one-third octave bands were identified as critical for vehicle detectability: 315, 400, 500, 2000, 2500, 3150, 4000, and 5000 Hz. A total of 152 measurements of stationary but activated and 10 km/hr (6 mph) forward pass-by events were analyzed to determine levels for these two operations. Data came from three different sources (the International Organization of Motor Vehicles Manufacturers (OICA), Phase 2 as described above, and Phase 3 research). Sound levels for backing were derived from the 10 km/hr (6 mph) forward levels but adjusted downward by 3 dB to account for directivity. In particular, the sound pressure level in the rear of an ICE vehicle is about 3 dB lower than what is measured at the SAE 2889–1 microphones. Two versions of potential requirements based on measured ICE levels are provided below. Table 13 shows minimum A-weighted sound levels based on the mean levels of ICE vehicles in the dataset. Table 14 shows minimum A-weighted sound levels based on the mean levels minus one standard deviation. Mean levels minus two standard deviations were also considered, however, these levels are not expected to be sufficiently detectable in many cases.

TABLE 13—MINIMUM A-WEIGHTED SOUND LEVELS BASED ON ICE MEAN LEVELS

One-third octave band center frequency, Hz	Stationary but activated	Backing	10 km/hr	20 km/hr	30 km/hr
315	40	42	45	52	55
400	41	44	47	53	57
500	43	45	48	54	59
2000	44	46	49	55	59
2500	44	46	49	53	56
3150	43	44	47	52	54
4000	41	42	45	49	51
5000	37	40	43	45	48
Overall A-weighted SPL Measured at SAE J2889–1 PP'line	52	54	57	62	66

TABLE 14—MINIMUM A-WEIGHTED SOUND LEVELS BASED ON ICE MEAN LEVELS MINUS ONE STANDARD DEVIATION

One-third octave band center frequency, Hz	Stationary but activated	Backing	10 km/hr	20 km/hr	30 km/hr
315	34	37	40	48	52
400	35	40	43	49	53
500	37	42	45	51	56
2000	39	42	45	50	54
2500	39	41	44	49	51
3150	39	40	43	47	49
4000	36	37	40	42	44
5000	29	34	37	38	40
Overall A-weighted SPL Measured at SAE J2889–1 PP'line	46	49	52	58	61

Note, neither the mean nor the mean minus one standard deviation have levels that are as high as those for our proposed requirement specification (Table 12) at the low frequencies. This does not indicate a disagreement between the two approaches, but rather indicates that low frequencies of typical ICEs are not as detectable in the ambient used in the modeling as typical ICE high-frequency components. Finally, Table 14 has levels that are as high as Table 12 for stationary but activated only at 3150 and 4000 Hz. Again, this does not mean that vehicles with levels below the mean will never be detectable, but rather that they will not likely be detectable for the ambient that was used in the modeling.

D. Acoustic Profiles Suggested by Manufacturers

The Alliance of Automotive Manufacturers (the ''Alliance'') submitted acoustic specifications that could serve as minimum sound requirements for HVs and EVs.[117] The Alliance proposed that the agency specify that HVs and EVs emit a sound with frequency content between 150 Hz and 3000 Hz. The Alliance proposal would require that sound emitted by HVs and EVs have at least two one-third octave bands with a sound pressure level of 44 A-weighted dB within this frequency range with one of the one-third octave bands being above 500 Hz and an overall sound pressure level of 48 A-weighted dB.

The agency believes that specifications for sound levels in only two one-third octave bands would not guarantee that sounds produced by HVs and EVs would be detectable in the range of ambient conditions in which the agency believes that pedestrians would need to detect them. If a sound has a greater number of one-third octave bands, it is more likely to be detectable at a given ambient. Sounds containing only one or two one-third octave bands with elevated sound pressure levels would be masked by ambient sound with strong spectral content in the same one-third octave bands which would hinder the ability of pedestrians to detect the sound. If a sound has elevated sound pressure levels at a wide range of one-third octave bands, it is less likely that an ambient will mask all of the bands that would increase the likelihood that the sound would be detectable.

We do not believe that the suggestion submitted by the Alliance specifies the one-third octave bands for which a minimum sound level is required in enough detail. The placement of one-third octave bands in the frequency spectrum influences the detectability of a sound. While the Alliance's suggestion would require one of the one-third octave bands to be at a frequency band above 500 Hz, the agency does not believe that this specification would ensure that the sounds would be loud enough for pedestrians to detect them at speeds above 0 km/hr. Based on the agency's detection model, a one-third octave band with a sound pressure level of 44 A-weighted dB would not be detectable at 10 km/hr (6 mph) if the frequency of the one-third octave band was below 3150 Hz. A sound with two one-third octave bands with a sound pressure level of 44 A-weighted dB would be masked by the ambient if those one-third octave bands were both positioned in mid-range frequencies for which the ambient level is highest.

We believe that the agency's proposal would better ensure that sounds produced by HVs and EVs would be recognizable to pedestrians as a motor vehicle in operation. The Alliance's suggestion does not include requirements for broadband, low frequency sound that contributes to recognizability.

These suggestions have been considered, but they do not meet either the requirements of the PSEA or the safety need because the suggestions are not specific enough about the placement of required one-third octave bands in the frequency spectrum to adequately ensure the detectability of the sound and they do not contain specifications for recognition. However, we will consider any further comments from the Alliance and all other commenters to this proposal with regard to the sound that should be made and, to the extent those comments are persuasive, they will be useful in creating the final rule. The agency seeks 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.

In its comments on the NOI, Nissan described the acoustic profile of the sound that is emitted by the Nissan Leaf. Nissan described the Leaf sound as having two peaks in sound pressure level with one peak near 2500 Hz and one peak near 600 Hz. Nissan stated that it included the 2500 Hz peak in sound pressure level to provide enhanced detection for pedestrians with normal hearing and the 600 Hz in sound pressure level to provide detection for pedestrians with age related hearing loss. The Leaf sound does not include mid-range one-third octave bands so that sound does not contribute to overall increases in ambient noise.

As discussed above, the agency believes that sound should be present in multiple high frequency one-bands to increase the likelihood that a pedestrian will be able to detect the sound in multiple ambients with differing acoustic profiles. Like the Leaf sound, the acoustic specifications in this proposal do not contain requirements for the one-third octave bands that would contribute to the greatest increase in overall levels. The one-third octave band levels in Table 12 would ensure that pedestrians with age related hearing loss would be able to detect the sounds meeting these requirements. They would have a significant amount of detectable content below 2000 Hz which, according to Nissan, is the threshold for age related hearing loss.

The agency believes that the acoustic specifications for minimum sound level requirements for HVs and EVs in the agency's proposal will provide manufacturers flexibility to develop alerts that are detectable and recognizable to pedestrians and pleasing to drivers. While the specifications described in the agency's proposal are more detailed than those contained in proposals that the agency received from manufacturers and their representatives, the agency believes that the specifications in its proposal place a greater emphasis on recognizability than specifications submitted by manufacturers. The agency's specifications will also ensure that sounds produced by HVs and EVs will be detectable in a wider range of ambient sounds than would be the case in suggestions submitted by manufacturers because specifications for a wider range of one-third octave bands increases the likelihood that the sound pressure level in any one one-third octave band will exceed the ambient for that frequency.

E. International Guidelines for Vehicle Alert Sounds

As discussed in Section VI.D above, the Japanese government issued voluntary guidelines for manufacturers to use when installing alert sounds on HVs and EVs. The ECE has also adopted these guidelines for use on a voluntary basis. In their comments on the NOI, several manufacturers stated that the agency should use these guidelines as a basis for ensuring that HVs and EVs produce sound levels sufficient to allow pedestrians to detect these vehicles.

[117] A presentation given at a meeting with NHTSA staff with the details of the proposal is available in the rulemaking docket accessible through regulations.gov. NHTSA–2011–0148–0022.

The agency does not believe that these guidelines have the level of detail necessary to serve as the basis for an FMVSS. The guidelines do not contain objective minimum requirements that manufacturers would be required to meet. The guidelines state that levels of sounds produced by HVs and EVs should not exceed the levels produced by ICE vehicles of the same class. The agency does not believe that this description of the sound levels would adequately ensure that these vehicles will be detectable by pedestrians or provide manufacturers with a set of requirements that they would be expected to meet.

The guidelines also do not contain an objective description of the acoustic characteristics that the sound should possess. Rather, the guidelines list what the sounds should not sound like. The guidelines state that vehicle emitted sounds should not sound like ''siren[s], chime[s], bells, melody, horn[] sounds, animals, insects, [or] sound[s] of natural phenomenon such as wave[s], wind, [or] river current[s].'' We do not believe that we would be able to tell whether a sound fell within one of the exclusions by means of an objective acoustic measurement because these descriptions do not contain any measurable values.

F. Suggestions in Comments to the NOI That Did Not Satisfy the Statement of Purpose and Need for the Rulemaking

Several of the commenters to the NOI suggested that the agency either take no action or address HV and EV collisions with pedestrians by other means. The PSEA requires the agency to establish an FMVSS that sets minimum sound requirements for HVs and EVs so taking no action was not a viable alternative.

One commenter suggested that the agency use advanced pedestrian crash avoidance technologies as a means of addressing collisions between HVs and EVs and pedestrians. While these technologies offer a promising means of preventing collisions between pedestrians and all vehicles, they are not yet mature or widespread enough for the agency to be able to consider making these devices a mandatory piece of safety equipment on a vehicle at this time. Furthermore, requiring advanced pedestrian crash avoidance devices on HVs and EVs would not meet the requirements of the PSEA.

G. Possible Jury Testing for Recognizability of a Synthetic Sound

The PSEA requires the agency to develop performance requirements to determine whether pedestrian alert sounds required by the standard are recognizable as being emitted by a motor vehicle in operation. The agency has tentatively decided that a compliance test for recognizability based solely on acoustic measurements over spectral distribution detailed above is the best way to ensure recognizability while, at the same time, allowing manufacturers the flexibility to design sounds representative of each make/model of vehicle. While the agency believes that sounds that fall within the agency's acoustic parameters will be recognizable to the public as a motor vehicle in operation, it is possible that manufacturers may wish to use sounds that would be equally as recognizable as those sounds meeting the agency's proposed specifications but would fail to satisfy the requirements proposed.

Notwithstanding the agency's tentative decision to use a set of sound parameters to achieve recognizability, we solicit comment on the possibility of allowing another compliance procedure designed to ensure that pedestrian alert sounds are recognizable and detectable. We are considering, but not proposing, allowing compliance through jury testing of sounds that would not meet the agency's acoustic specifications for recognizability. Allowing jury testing of sounds may give manufacturers greater flexibility in meeting the requirements of the standard. We specifically are soliciting comment on the desirability and the feasibility of a jury testing procedure for ensuring that sounds would be recognizable as a motor vehicle.

While the agency believes that human subject testing could provide an accurate evaluation of the recognizability of the pedestrian alert sound, the agency recognizes jury testing poses its own challenges. While the agency has tentatively concluded that jury testing is objective and repeatable as required by the Motor Vehicle Safety Act, manufacturers have expressed technical concerns about compliance testing by the agency using human subjects.

Under the jury testing framework envisioned by the agency, manufacturers would be required to submit information to NHTSA demonstrating that the sounds emitted by their vehicles are recognizable as a motor vehicle in operation. Under this framework, manufacturers would conduct a jury test according to procedures established by NHTSA and then submit to NHTSA documentation of the results of the jury and a certification that the jury test was conducted according to the procedures established by the agency.

After NHTSA received documentation of the manufacturer's jury test, the agency would examine the documents to ensure that the test was conducted properly. The agency would also include the same performance test for detectability in the standard as is proposed today.

While the agency believes that a compliance test using jury testing is objective and repeatable, manufacturers have expressed concerns in discussions with the agency about being subjected to a jury based performance standard. We recognize that automobile manufacturers face significant penalties in the event that they are determined to be noncompliant with a FMVSS. In an effort to provide manufacturers with regulatory certainty and in acknowledging that the agency does not currently specify any jury-based compliance testing, we have concluded that the most feasible approach to jury testing at this time would be for the agency to require manufacturers to conduct the jury tests themselves and submit their results to NHTSA as part of their vehicle certification. Thus, the manufacturers' records that the jury test was conducted properly with the jury determining that the sound was recognizable would constitute the manufacturers' certification.

The agency believes that a certification procedure outlined above would be objective and repeatable, as required by the Motor Vehicle Safety Act. While recognizability may be described as a subjective concept, the procedure envisioned by the agency for determining whether a sound is recognizable as a motor vehicle would be stated in objective terms. The standard would specify the composition of the jury, the jury size, how to conduct the jury test, and pass fail criteria. The jury procedure would be repeatable because the underlying statistics dictate that if the required percentage of jurors finds the ICE control sound and non-ICE sound recognizable as a motor vehicle, a different jury would make the same determination of whether the non-ICE sound is recognizable or not. In conducting a compliance test to determine if the sound complied with the standard, NHTSA would not conduct its own jury testing; instead the agency would review the manufacturer's documentation of its jury process to ensure the testing performed by the manufacturer was conducted according to the standard. Thus, a manufacturer would not be subject to the possibility that a jury test done by NHTSA would come to a different conclusion about the sound than the jury test conducted by the manufacturer.

The jury testing procedure envisioned by the agency would provide an objective, repeatable method for determining compliance as required under the United States Court of Appeals for the District of Columbia Circuit's interpretation of the Motor Vehicle Safety Act in *Chrysler* v. *Department of Transportation.*[118] As discussed above, this jury test procedure would not subject the manufacturer to any subjective determination regarding compliance. Manufacturers would be assured of compliance if they conducted their jury test according to the agency's procedure and properly documented the process and results.

The jury of human subjects would be comprised of a sample size to make the jury results as repeatable as possible across multiple juries. Under the jury testing framework that the agency would mandate, the jury members would be exposed to two different sounds, a control sound and the sound that the manufacturer wished to use to meet the requirements of this standard.

The jury members would be asked to identify whether each sound was a regular and detectable vehicle sound or not. The jury size that the agency would require under this alternative certification procedure would depend on the statistical power the agency wished to achieve, the recognition rate of the ICE-like control sound, and recognition rate that the agency would specify for non-ICE sounds.

Assuming a 90 percent statistical power, a 90 percent ICE recognition rate and a minimum candidate sound recognition rate of 65 percent, (that is, 65 percent of the jury would have to find the candidate sound recognizable and detectable for the manufacturer to certify the vehicle with the candidate sound) the jury sample size would need to be at least 28 people to provide results that would be repeatable. If the statistical power and ICE recognition rate were 90 percent and the minimum candidate sound recognition rate was changed to 75 percent, the size of the jury would increase to 54 people. If the ICE recognition rate was lowered to 85 percent and the statistical power was maintained at 90 percent, a minimum recognition rate of 65 percent for the candidate sound would require a jury of 45 people. A minimum recognition rate of 75 percent for the candidate sound under the same circumstances would require a jury of 140 people. Thus, the size of the jury increases as the gap between ICE recognition rate and the candidate sound recognition rate closes.

In the event that the agency were to adopt a jury based approach in the pedestrian alert sound standard for determining recognizability, the jury size would be determined based on the agency's decision of the statistical power, ICE-recognition rate, and minimum candidate sound recognition that the agency believes will ensure that pedestrians will be able to safely recognize the vehicle equipped with the candidate alert sound. We have tentatively concluded that jury testing to determine the recognizability of sounds should be conducted at a 90 percent statistical power. The agency seeks comment on the general approach to jury testing that the agency is considering as discussed above. Specifically, the agency would like comment on the appropriate size of the jury for testing to determine whether sounds are recognizable as a motor vehicle, the statistical power that should be used for the test, the reference ICE recognition rate that should be required, and the minimum candidate sound recognition rate that should be required.

If the agency were to specify a jury test for recognizability, the agency would specify the specific demographic composition of the jury to ensure that the jury testing results would be repeatable across all segments of the public. The standard would require the jury to be composed of adults between the ages of 18 and 69 years old, with equal numbers of male and female participants.[119] Subjects from the 18–29 year-old, 30–49 year-old age, and 50–69 year-old age groups would each make up one-third of the jury. Subjects would be required to be willing to be screened for hearing threshold shift in the 500 Hz to 8,000 Hz frequency range. Subjects with an estimated hearing loss of 20 dB or more above the normal range for the 500 Hz to 8,000 Hz range would be excluded from the study. Jury subjects would also be prohibited from being employees of the manufacturer conducting the testing or otherwise interested in the outcome of the test.

A jury test for recognizability of pedestrian alert sounds specified by the agency would be conducted using headphones in an audiometric test room. The jury test procedure would specify a maximum acceptable ambient for the audiometric test room in which the jury test would be conducted similar to the acceptable ambient for audio testing described in ANSI S3.1–1991, *Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms,* American National Standard. NHTSA would also require that jury testing be conducted with high quality head phones. NHTSA has concluded that headphones are preferable to a test utilizing loudspeakers. Headphones allow for greater flexibility in the setup of the jury room. Further, jury members listening to the sounds via headphones would not be influenced by their seating position or the room's acoustics.

The manufacturer conducting the jury test would be required to use a vehicle of the same make to create the ICE control sound used in the jury testing and would be required to submit that sound to NHTSA as part of its certification documentation. The audio file played for the subjects would be required to include synthetic urban noise, filtered according to a specification developed by Torben Pedersen in ''White Paper on External Sounds of Electric Cars,'' [120] as background to simulate ambient that pedestrians would encounter when attempting to detect an EV or HV in the everyday environment. The audio file used for jury testing should be created using a binaural recording technique that accurately reproduces the qualities of a moving sound source. This is ordinarily accomplished by making recordings of actual vehicle pass-bys. The agency believes that the operating scenario under which the vehicle was recorded will influence whether the jury members will think the sound is recognizable. The agency believes that the sound used for the jury evaluation should be recorded while the vehicle is accelerating. The sound of a vehicle accelerating provides many of the sound cues that the agency is addressing through the acoustic specifications for recognizability The agency included specifications for pitch shifting in today's proposal so that when the vehicle is accelerating the vehicle is providing acoustic cues about its changing speed The agency also believes that pitch shifting contributes to recognizability. Because the sounds that manufacturers may want to evaluate using this alternative framework should continue to provide pedestrians with cues that the vehicle is changing speed and because information provided by the sound that a vehicle makes while it is accelerating contributes to recognizability, the agency believes that the jury should evaluate the sound produced by the vehicle while it is accelerating, in addition to constant speed pass-by.

[118] 472 F.2d 659 (D.C. Cir. 1972).

[119] The jury composition requirements would allow for a slight deviation from the requirement that the jury be composing of equal numbers males in females in the event that the jury consisted of an odd number of subjects.

[120] Available at *http://media.wix.com/ugd/64a49a_43313ad70e7c40f43150cf747b2e5c44.pdf?dn=A520040+-+DSTN+-+White+paper+electric+cars+-+av122410+-+ECT+LR.pdf.*

The sample of the pedestrian alert sound played to the jury should be 10 seconds in length for both the ICE control sound and the candidate sound the manufacturer is attempting to certify. The control sound and the candidate sound the manufacturer is seeking to evaluate would be played in a random sequence for each jury member. Thus, some members of the jury would hear the control sound first while others would hear the candidate sound first. The agency would specify the loudness at which the sound would be played for the jurors as well as the level of the synthetic ambient noise.

Responses would be recorded using bubble-in survey forms with the bubbles representing yes or no for each sound for both the ICE control sound and the sound the manufacturer is seeking to certify. These forms would require minimal training for jury members as most jury members would likely be familiar with these forms. The jury instructions would consist of the following statement:

In this evaluation you will be presented a pair of sounds. You are asked to indicate whether you believe that each of the sounds is recognizable as a motor vehicle sound or not. Select the response listed on the form that corresponds with your view of that sound. If you think that sound A is recognizable as a motor vehicle sound select yes, if you do not think that sound A is recognizable as a motor vehicle select no. After you have made your selection for sound A, evaluate sound B and check the box that corresponds with your view on whether Sound B is recognizable as a motor vehicle sound. If you think that sound B is recognizable as a motor vehicle sound select yes, if you do not think that sound B is recognizable as a motor vehicle select no. Since the objective of the experiment is to understand the individual's reaction to the sounds, there are no right or wrong answers.

The agency seeks comment on the jury instructions outlined above. The agency is specifically interested in instructions that result in a yes or no answer and that would not lead members of the jury to prejudge the sound. The agency recognizes that asking whether the sound is a regular and detectable vehicle sound may influence the jury to a certain degree. However, in order for the results of the jury test to be repeatable, jury responses would need to come in the form of yes or no answers.

The validity of the jury test would be dependent on the jury members identifying the ICE control sound at the percentage required by the standard. If the jury members do not recognize the ICE control sound with the specificity required in the standard, the jury results must be discarded and the test invalidated. If the required percentage of jurors found both the candidate sound and ICE control sound to be recognizable as a motor vehicle in operation at the required recognition rates, the manufacturer would be able to certify the vehicle to the pedestrian alert standard.

IX. NHTSA's Role in the Development of a Global Technical Regulation

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 (UN/ECE) 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 US, 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 UN/ECE World Forum for Harmonization of Vehicle Regulations (WP.29) administers the 1998 Agreement. Four committees coordinate the activities of WP.29: AC.2 manages the coordination of work of WP.29, while AC.3 is the ''Executive Committee'' for the 1998 Agreement. There are also six permanent subsidiary bodies of WP.29, known as GRs (Groups of Rapporteurs) that assist WP.29 in researching, analyzing and developing technical regulations.

At 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 US has 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 US, along with Japan, is the co-chair of the informal working group 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 expected establishment of the new GTR in November 2014.

Prime Minister Stephen Harper and President Barack Obama created the U.S.-Canada Regulatory Cooperation Council (RCC) on February 4, 2011 to increase regulatory cooperation between the United States and Canada. One of the action items of the RCC is to work to develop joint plans to address hybrid and electric vehicles and pedestrian safety. Pursuant to the RCC, the agency has been collaborating with Transport Canada on areas of research of mutual interest regarding sound produced by hybrid and electric vehicles.

X. 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 V), the use of data from 16 states cannot be used to directly estimate the national problem size and, an analysis of pedestrian fatalities 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 rate for hybrid and electric vehicles was 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.

First, injury estimates from the 2006–2010 National Automotive Sampling System—General Estimates System (NASS–GES) and 2007 Not in Traffic Surveillance (NiTS) were used 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 2010.

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, for a total of 200.8 crashes.

Table 15 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 15—QUIET CARS TARGET POPULATION INJURIES REPORTED (GES, NITS) 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)	75,401	12,490	2,561	613	248	91,313
Light Trucks & Vans (LTV)	51,761	8,627	1,771	423	171	62,753
Total Light Vehicles (PC+LTV)	127,163	21,116	4,332	1,037	419	154,067
Reported (GES+NiTS) and Unreported Injured Pedalcyclists						
Passenger Car (PC)	43,795	6,329	1,105	247	88	51,564
Light Trucks & Vans (LTV)	28,840	4,184	730	162	58	33,974
Total Light Vehicles (PC+LTV)	72,635	10,513	1,835	409	146	85,538

The estimates in Table 15 are based on the current make-up of the fleet for all propulsion types. This means that the total target population described above across 2006 to 2010 is not only the result of 100% of the combined sales of all vehicle propulsion types, but also it is assumed to be equal to 100.67% of the injuries resulting from a fleet comprised of only ICE vehicles (due to the increased rate of these incidents for EVs and HVs). The estimated injuries in Table 16 are created by combining the percentage of annual sales of hybrid and electric vehicles with the odds ratio of 1.19, representing the increased risk of an HV being involved in a pedestrian crash, and the odds ratio of 1.44, representing the increased risk of an HV being involved in a pedalcyclist crash.[121] Thus, when considering pedestrians injured by MY2016 vehicles and assuming these pedestrian and pedalcyclist crashes occurred because the pedestrians and pedalcyclists failed to detect these vehicles by hearing, the rulemaking is responsible for the 1,223 injury difference between that theoretical ICE-only fleet (153,271 injuries) and the estimated lifetime injuries from the MY2016 fleet (154,494). When considering pedalcyclists injured by MY2016 vehicles, the rulemaking is responsible for the 1,567 injury difference between that theoretical fleet (84,516 injuries) and the estimated lifetime injuries from the MY2016 fleet (86,084). The rule would also reduce 5 pedestrian injuries over the lifetime of the MY 2016 fleet of LSVs and 5 pedalcyclist injuries over the lifetime of the MY 2016 fleet of LSVs.

[121] See footnote 42.

TABLE 16—ENHANCED INJURY RATE (EIR) FOR PEDESTRIANS FOR 2016 MODEL YEAR [122]

	Mild hybrids (percent)	Strong hybrids (percent)	EVs + fuel cell (percent)	ICEs (percent)	Total (percent)	Injuries assuming 100% ICE fleet	Injuries assuming predicted fleet	Benefits
Passenger Car	4.46	5.79	0.50	90.18	100.92	90,706	91,545	839
Light Trucks & Vans	5.62	3.85	0.04	91.11	100.61	62,565	62,949	384
Total						153,271	154,494	1,223

ENHANCED INJURY RATE (EIR) FOR PEDESTRIANS FOR 2016 MODEL YEAR [123]

	Mild hybrids (percent)	Strong hybrids (percent)	EVs + fuel cell (percent)	ICEs (percent)	Total (percent)	Injuries assuming 100% ICE fleet	Injuries assuming predicted fleet	Benefits
Passenger Car	4.46	7.01	0.50	90.18	102.14	50,777	51,865	1,087
Light Trucks & Vans	5.62	4.66	0.04	91.11	101.42	33,739	34,219	480
Total						84,516	86,084	1,567

The agency has not estimated the benefits associated with applying the requirements of this proposal to hybrid and electric vehicles with a GVWR over 4,536 kg (10,000 pounds), and electric motorcycles because the agency was unable to determine separate pedestrian collision rates for these vehicle types. The agency is unsure whether using the difference in rates between light ICE vehicle pedestrian crashes and light HV and EV pedestrian crashes would be an appropriate means of calculating the benefits of applying the requirements of this proposal to these other classes of vehicles. As discussed in the Preliminary Regulatory Impact Analysis (PRIA), MAIS injury levels are converted to dollar amounts. The benefit of reducing 2,800 pedestrian and pedalcyclist injuries, or 35 equivalent lives saved, is estimated to be $ 178.7M at the 3 percent discount rate and $146.3M at the 7 percent discount rate for the light vehicle and LSV fleet.

The agency calculated the benefits of this proposal 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. NHTSA also assumes the sound added to hybrid and electric vehicles will be as effective in providing warning to pedestrians as the sound produced by a vehicle's ICE. NHTSA seeks comment on the underlying assumptions used in calculating the benefits of this proposal.

In addition to the benefits in injury reduction due to this proposal there is also the benefit to blind individuals of continued independent mobility. The increase in navigational ability resulting from this proposal 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, 2011 there were 306,882 hybrid engine installations in light vehicles (74% were in passenger cars and 26% were in light trucks) in MY 2010 (these were 2.8% of sales in 2010 of 10,796,533). There were a small number of electric vehicles (an estimated 852 from NHTSA's data not Ward's) sold in 2010, the larger sellers (GM Volt and Nissan Leaf) were introduced later. The Annual Energy Outlook (AEO) for 2011 provides estimates of the fleet by year for hybrid and electric vehicles.[124] The number of vehicles that the agency projects will be required to meet the standard is shown in TABLE 17.

TABLE 17—ESTIMATED/PREDICTED HYBRID AND ELECTRIC VEHICLE SALES PROPOSED TO BE REQUIRED TO PROVIDE AN ALERT SOUND

	Estimated 2010 sales	Predicted 2016 sales	2016 sales for costing purposes
Low-Speed Vehicles	1,500	2,500	2,500
Light Vehicles Electric	852	46,200	
Fuel Cells	0	2,900	
Light Vehicles Hybrid	289,282	671,300	671,300

[122] Table values may be off by one due to rounding.

[123] Table values may be off by one due to rounding.

[124] In calculating the costs of this proposal 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 proposal.

TABLE 17—ESTIMATED/PREDICTED HYBRID AND ELECTRIC VEHICLE SALES PROPOSED TO BE REQUIRED TO PROVIDE AN ALERT SOUND—Continued

	Estimated 2010 sales	Predicted 2016 sales	2016 sales for costing purposes
Light Vehicles Total	290,143	720,400	
Medium and Heavy Truck	2,000	21,500	21,500
Buses	3,000	5,000	5,000
Motorcycles	1,500	5,000	5,000
Total Sales	298,143	754,400	705,300

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 would have provided an alert sound system on their own and, therefore, for costing purposes we assumed that this is not a cost of the proposal. However, those vehicles' alert sounds may not meet the proposed standard and, the rulemaking may force a change in a manufacturer's sound alert. We assume that manufacturers would incur no incremental cost for that change, as it is anticipated to be a simple software modification. Thus, the incremental number of light vehicles that have to add an alert sound system for costing purposes for MY 2016 is 720,400-46,200–2,900 = 671,300.

Based on informal discussions with suppliers and industry experts, the agency estimates that the total consumer cost for a system that produces sounds meeting the requirement of this proposal is around $30 per vehicle. This estimate includes the cost of a dynamic range speaker system that is protected from the elements and attached with mounting hardware and wiring to both power the speaker 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 status). We seek comment of the cost of a speaker system used to produce sounds meeting the requirements contained in this proposal. We assume there will be no other structural changes or installation costs associated with complying with the rule's requirements and seek comment on this assumption. We believe the same system can be used for both low-speed vehicles and light vehicles. We estimate that the added weight of the system would increase fuel costs for light vehicles around $5 over the life time of the vehicle.

TABLE 18—TOTAL COSTS

	3% Discount rate	7% Discount rate
Passenger Cars Per Vehicle	$34.73	$33.83.
Light Trucks Per Vehicle	$35.33	$34.23.
All Passenger Cars	$15.27 Million	$14.87 Million.
All Light Trucks	$8.19 Million	$7.93 Million.
Total for Light Vehicles	$23.45 Million	$22.80 Million.
Low-speed Vehicles Per Vehicle	$30.24	$30.24.
Low-speed Vehicles Total Cost	$0.08	$0.08.
Partial Costs for All Medium/Heavy Trucks, Buses, and Motorcycles	$1.48 Million	$1.48 Million.
Total	$25.00 Million	$24.36 Million.

In addition to the quantifiable costs discussed above, there may be a cost of adding sound to quiet vehicles to owners who value quiet. NHTSA does not know how to put a value on quiet for a driver's own vehicle. We are also unsure of the extent to which the added sound will reach the passenger compartment of the vehicle and request comment on this issue. Nor does the agency know how to put a value or a cost on the increase in noise that the alert sound from other vehicles would produce.

As explained further in the Draft Environmental Assessment (Draft EA) that the agency has analyzed the potential environmental effects of this rulemaking, we expect that the increase in noise from the alert sound will be no louder than that from an average ICE vehicle and that there will not be an appreciable aggregate sound from these vehicles. 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. Nevertheless, we ask commenters whether the increase in noise brought about by this proposal has any cost and how to value it. NHTSA also seeks comment on whether manufacturers are taking any actions beyond adding speakers and typical noise reduction efforts in response to adding sound to quiet vehicles and the cost of such actions. NHTSA has not found any way to value the increase in noise, and, thus it is a non-quantified cost.

C. Comparison of Costs and Benefits

Because we have calculated the costs of this rule to all applicable hybrid and electric vehicles, but not calculated the benefits of applying this proposal to the medium and heavy duty trucks and buses and electric motorcycles the comparison of costs and benefits only takes into account light vehicles and low-speed vehicles. Comparison of costs and benefits expected due to this rule provides a cost of $0.83 to $0.99 million per equivalent life saved across the 3 and 7 percent discount levels. This falls under NHTSA's value of a statistical life of $6.3M, and therefore this rulemaking is assumed to be cost beneficial. Since the lifetime benefits of MY2016 light vehicles is expected to be between $145.8M and $178M, the net impact of the rule is a positive one, even with the estimated $20.1M required to install speakers [125] and $3M in lifetime fuel costs.

TABLE 19—DISCOUNTED BENEFITS MY 2016, 2010$

3% Discount	Total monetized benefits	Total ELS
TOTAL PED + CYC		
(PC)	$122,747,591	19.41
(LTV)	55,265,495	8.74
Total	178,013,086	28.15
7% Discount	Total monetized benefits	Total ELS
TOTAL PED + CYC		
(PC)	$102,366,052	16.19
(LTV)	43,422,889	6.87
Total	145,788,941	23.06

TABLE 20—TOTAL COSTS 2010$

3% Discount	Total cost/veh	Total costs
(PC)	$34.70	$15,253,618
(LTV)	35.30	8,178,471
Total	34.91	23,432,088
7% Discount	Total cost/veh	Total costs
(PC)	$33.80	$14,857,991
(LTV)	34.20	7,923,618
Total	33.94	22,781,608

TABLE 21—NET IMPACTS 2010$

3% Discount	Net impact/veh	Net impact	Net costs/ELS (in $M)
(PC)	$244.53	$107,493,974	0.79
(LTV)	203.24	47,087,024	0.94
Total	230.28	154,580,998	0.83
7% Discount	Net impact/veh	Net impact	Net costs/ELS (in $M)
(PC)	$199.07	$87,508,062	0.92
(LTV)	153.22	35,499,271	1.15
Total	183.25	123,007,333	0.99

The net impact of this proposal to LSVs is also expected to be positive. The net benefits of the minimum sound requirements for these vehicles is $662,971 at the 3 percent discount rate and $542,959 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.

TABLE 22—COSTS AND SCALED BENEFITS FOR LSVS, MY2016 [126]

Discount rate	Sales ratio LSV to light vehicle	Sales	Scaled costs	Scaled injuries (undisc.)	Scaled ELS	Scaled benefits	Scaled benefits minus scaled costs
3%	0.37%	2,500	$87,268	10.39	0.1049	$662,971	$575,703
7%	0.37%	2,500	84,845	10.39	0.0859	542,959	458,114

D. Environmental Effects

The agency has prepared a Draft Environmental Assessment (Draft EA) to analyze and disclose the potential environmental impacts of a reasonable range of potential 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, which is the Preferred Alternative and is equivalent to the agency's proposal, 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 the Draft EA, 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. National Household Travel Survey data for 2009 shows that non-urban households account for 31 percent of all vehicle miles traveled (VMT) but just 14 percent of VMT associated with trips at an average speed of less than 20 km/h, indicating that these households spend a much smaller percent of travel time at slow speeds associated with congested traffic than do households in urban areas. The Draft EA estimates the direct and indirect impacts of the alternatives in both urban and non-urban areas by taking into

[125] Based on the assumption in this analysis that manufacturers will install speakers to meet the proposal.

[126] Scaled benefits and costs for low speed vehicles are estimated directly proportional to light vehicles based on sales. Scaled costs include both installation costs for the system and fuel costs.

account the higher percentage of total VMT that takes place in non-urban areas, the lower percentage of VMT traveled at slow speeds in non-urban areas, and the lower percentage of EV/HV sales expected in non-urban areas.

In the Draft EA, NHTSA estimated the amount of total annual U.S. passenger vehicle driving time spent in the stationary but active operating condition, at speeds up to 20 km/h, and at speeds between 20 and 30 km/h. Using forecasts of EV/HV deployment levels in 2035, NHTSA projected the percentage of total U.S. light duty driving hours that would be impacted by the standards (*e.g.,* vehicles driven at speeds that would enable the alert sound). Based on these assumptions, NHTSA projects that under Alternative 2 (the Preferred Alternative), 2.3 percent of all urban and 0.3 percent of all non-urban light vehicle travel hours would be affected by the minimum sound requirements in 2035. Under Alternative 3, 0.9 percent of all urban and 0.1 percent of all non-urban light vehicle travel hours would be affected by the minimum sound requirements in 2035.

The agency's analysis also shows that in either urban or non-urban environments, assuming EV/HV deployment levels of either 10 percent and 20 percent, the agency's Preferred Alternative would have negligible to minimal effects on overall community noise levels. Under the Preferred Alternative, in a simulated high-traffic condition, the agency found a difference in sound level of no greater than 0.3 dB(A), as measured by a receiver 7.5 meters from a roadway, at all speeds and under all conditions compared to the No Action Alternative. Even if EVs/HVs were to reach 50 percent deployment, Alternative 2 is projected to amount to a maximum difference of 0.9 dB above the sound level under the No Action Alternative in non-urban environments and 0.7 dB in urban environments. Because differences in sound pressure of less than 3 dB are generally not noticeable by humans, the environmental impacts of this proposal are expected to be negligible. Although sound level differences are greater for single vehicle pass-by events the difference would be similar to the existing variation that results from differences between ICE vehicle models. Thus, although the individual event may be noticeable, overall the noticeable noise levels in the case of single-car pass-by are considered to cause only a minor impact.

XI. 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 PRIA.

We estimate the total fuel and installation costs of this proposal to the light EV, HV and LSV fleet to be $23.5M at the 3 percent discount rate and $22.9M at the 7 percent discount rate. The estimated total installation cost for hybrid and electric heavy and medium duty trucks and buses and electric motorcycles is $1.48M meaning that the total costs for this rule are between $25 and $24.36 million, depending on the discount rate. We have only calculated the benefits of this proposal for light EVs, HVs and LSVs because we do not have crash rates for hybrid and electric heavy and medium duty trucks and buses and electric motorcycles. We estimate that the impact of this proposal in pedestrian and pedacyclist injury reduction will be 28.15 equivalent lives saved at the 3 percent discount rate and 23.06 equivalent lives saved at the 7 percent discount rate. The benefits of this proposal for the light EV and HV and LSV fleet are $178.7M at the 3 percent discount rate and $146.3M 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.

NHTSA requests public comment on whether (a) ''regulatory approaches taken by foreign governments'' concerning the subject matter of this rulemaking and (b) the above policy statement have any implications for this rulemaking.

National Environmental Policy Act

Concurrently with this NPRM, NHTSA is releasing a Draft 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 Draft EA to analyze and disclose the potential environmental impacts of the proposed minimum sound requirements for HVs and EVs and a range of alternatives. The Draft EA analyzes direct, indirect, and cumulative impacts and analyzes impacts in proportion to their significance.

Because this proposal would increase the amount of sound produced by a certain segment of the vehicle fleet, the Draft EA considers the possible impacts of increased ambient noise levels on both urban and rural environments. The Draft EA also describes potential environmental impacts to a variety of resources. The resources that may be affected by the proposed action and alternatives include biological resources, noise, and environmental justice.

The agency's analysis in the Draft EA shows that in either urban or non-urban environments, assuming EV/HV deployment levels of either 10 percent and 20 percent, the agency's Preferred Alternative would have negligible to minimal effects on overall community noise levels. Even if EVs/HVs were to reach 50 percent deployment, the agency's Preferred Alternative is projected to amount to a maximum difference of 0.9 dB above the sound level under the No Action Alternative in non-urban environments and 0.7 dB in urban environments. Because differences in sound pressure of less than 3 dB are generally not noticeable by humans, the environmental impacts of this proposal are expected to be negligible.

For additional information on NHTSA's NEPA analysis, please see the Draft EA.

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.'' [127] 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 proposal will not have a significant economic impact on a substantial number of small entities.

I hereby certify that this proposed rule would not have a significant economic impact on a substantial number of small entities. We believe that the rulemaking would 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 ($30) is small in proportion to the overall vehicle cost for most small vehicle manufacturers.

This proposal would directly affect motor vehicle manufacturers and final-stage manufacturers. The majority of motor vehicle manufacturers will not qualify as a small business. There are five manufacturers of light hybrid and electric vehicles that would be subject to the requirements of this proposal that are small businesses.[128] Similarly, there are several manufacturers of low-speed vehicles[129] and electric motorcycles that are small businesses.

We believe there are very few manufacturers of heavy trucks in the United States which can be considered small businesses. The agency is aware that many manufacturers of medium duty trucks are small businesses. The agency is aware of at least two small manufacturers who are producing electric trucks with a GVWR over 10,000 lb.[130] In addition to the two manufacturers of medium duty electric vehicles identified by the agency, we believe that there may be other small manufacturers who are currently producing these vehicles.

NHTSA believes there are approximately 37 bus manufacturers in the United States. Of these, 27 bus manufacturers are large business and 10 are small businesses. Three of these small manufacturers produce electric buses—E-bus Inc., Enova Systems, and Gillig Corporation.

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 ($30) is a small proportion of the overall vehicle cost for even the least expensive electric vehicles.

(2) This proposal would provide a three year lead-time and would allow 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 proposed 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 proposed 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

[127] 13 CFR 121.105(a).

[128] CODA, Fisker Automotive Inc., Via, Phoenix, and Tesla. However, it is our view that the manufacturers of electric vehicles would face little costs due to this rule because they would have installed alert sounds in their vehicles without this proposed rule.

[129] In the low-speed vehicle group there are Columbia ParCar Corp., Club Car, LLC, Miles Electric Vehicles LLC, STAR Electric Car Sales, Tomberlin, Wheego Electric Cars, Inc., Wildfire, GTT Electric and others.

[130] Boulder Electric Vehicle and Smith Electric Vehicles are producing or have plans to produce electric vehicles with a GVWR over 10,000 lb.

structure of the regulatory text) and objectives of today's proposed rule and finds that this proposed rule, like many NHTSA rules, would prescribe only a minimum safety standard. As such, NHTSA does not intend that this proposed rule would preempt state tort law that would effectively impose a higher standard on motor vehicle manufacturers than that established by today's proposed rule. Establishment of a higher standard by means of State tort law would not conflict with the minimum standard proposed 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 PRE. We estimate the annual total fuel and installation costs of this proposal to the light EV, HV and LSV fleet to be $23.5M at the 3 percent discount rate and $22.9M at the 7 percent discount rate. The estimated total installation cost for hybrid and electric heavy and medium duty trucks and buses and electric motorcycles is $1.48M. Therefore, this proposal 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 $136M 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 NPRM 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, motorcycles and low speed vehicles subject to the phase-in schedule to provide motor vehicle production data for the following three years: September 1, 2015 to August 31, 2016; September 1, 2016 to August 31, 2017; and September 1, 2017 to August 31, 2018.

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, motorcycles and low-speed vehicles. The agency estimates that there are about 73 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 146 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.

The procedure for the evaluation of vehicle sounds by human subjects contained in Section VIII.G of this proposal would also constitute a collection of information for the purposes of the PRA. If the agency decides to adopt the procedure described in Section VIII.G in the final rule then agency would submit an ICR to OMB before the final rule is issued in compliance with the PRA.

Executive Order 13045

Executive Order 13045 [131] 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 proposed rule would not pose such a risk for children. The primary effects of this proposal 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 proposal. 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 this proposal 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. As discussed in Section VII.E.1, the proposal does not include a procedure for indoor testing because of the limited availability of indoor test facilities and because test surfaces for indoor testing are not sufficiently specified.

Executive Order 13211

Executive Order 13211 [132] 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.

The proposed 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 proposed 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.

Plain Language

Executive Order 12866 requires each agency to write all rules in plain language. Application of the principles of plain language includes consideration of the following questions:

- Have we organized the material to suit the public's needs?
- Are the requirements in the rule clearly stated?
- Does the rule contain technical language or jargon that isn't clear?
- Would a different format (grouping and order of sections, use of headings, paragraphing) make the rule easier to understand?
- Would more (but shorter) sections be better?
- Could we improve clarity by adding tables, lists, or diagrams?
- What else could we do to make the rule easier to understand?

If you have any responses to these questions, please include them in your comments on this proposal.

Privacy Act

Anyone is able to search the electronic form of all comments received into any of our dockets by the name of the individual submitting the comment (or signing the comment, if submitted on behalf of an organization, business, labor union, etc.). You may review DOT's complete Privacy Act statement in the **Federal Register** published on April 11, 2000 (Volume 65, Number 70; Pages 19477–78) or you may visit *http://www.dot.gov/privacy.html.*

Public Participation

How do I prepare and submit comments?

Your comments must be written and in English. To ensure that your comments are correctly filed in the Docket, please include the docket number of this document in your comments. Your comments must not be more than 15 pages long.[133] We established this limit to encourage you to write your primary comments in a concise fashion. However, you may attach necessary additional documents to your comments. There is no limit on the length of the attachments.

Please submit your comments by any of the following methods:

[131] 62 FR 19885 (Apr. 23, 1997).

[132] 66 FR 28355 (May 18, 2001).

[133] *See* 49 CFR § 553.21.

• *Federal eRulemaking Portal:* go to *http://www.regulations.gov.* Follow the instructions for submitting comments on the electronic docket site by clicking on ''Help'' or ''FAQ.''

• *Mail:* Docket Management Facility, M–30, U.S. Department of Transportation, West Building, Ground Floor, Rm. W12–140, 1200 New Jersey Avenue SE., Washington, DC 20590.

• *Hand Delivery or Courier:* West Building Ground Floor, Room W12–140, 1200 New Jersey Avenue SE., between 9 a.m. and 5 p.m. Eastern Time, Monday through Friday, except Federal holidays.

• *Fax:* (202) 493–2251.

If you are submitting comments electronically as a PDF (Adobe) file, we ask that the documents submitted be scanned using Optical Character Recognition (OCR) process, thus allowing the agency to search and copy certain portions of your submissions.[134]

Please note that pursuant to the Data Quality Act, in order for substantive data to be relied upon and used by the agency, it must meet the information quality standards set forth in the OMB and DOT Data Quality Act guidelines. Accordingly, we encourage you to consult the guidelines in preparing your comments. OMB's guidelines may be accessed at *http://www.whitehouse.gov/omb/fedreg/reproducible.html.* DOT's guidelines may be accessed at *http://dmses.dot.gov/submit/DataQualityGuidelines.pdf.*

How can I be sure that my comments were received?

If you submit your comments by mail and wish Docket Management to notify you upon its receipt of your comments, enclose a self-addressed, stamped postcard in the envelope containing your comments. Upon receiving your comments, Docket Management will return the postcard by mail.

How do I submit acoustic recordings?

If you wish to submit acoustic recordings along with your comments please sent the recordings to NHTSA at the address given above under **FOR FURTHER INFORMATION CONTACT**. If you wish to request confidential treatment of the records please follow the instructions listed below.

In order to be of use to the agency, NHTSA is requesting that any recordings submitted to the agency be 16-bit with a sampling frequency of 44.1 kHz or better and made with a stationary binaural head facing perpendicular to the vehicle's trajectory. As well as any recording made using a binaural head, it would be useful to the agency, if possible, for recordings submitted to include a recording from a monaural microphone made according to SAE J2889–1. The agency requests that a Calibration Tone be included in each set of recordings. The agency also requests that the level and frequency of the Calibration Tone be indicated, *e.g.* 94 dB at 1000 Hz.

In order to be of use in the agency's analysis, we request that idle recordings be at least 30 seconds long and preferably 60 seconds long. Constant speed pass-by recordings should include at least 15 seconds of approach towards the microphone and at least 5 seconds departing from the microphone. Ideally the recording will start before the vehicle is audible. We are requesting the recording of time after departure so that we have additional data for analysis of tone-to-noise ratio, Doppler shifts, and Head-Related Transfer Function (HRTF) effects, but do not need recordings up until the point at which the vehicle is no longer audible. The agency requests that commenters identify the distance of vehicle from microphone at start of recording as well as the distance between the microphone and the vehicle center line. The agency requests that commenters identify the operating scenario of the vehicle when the recording was made.

In order to help us with our analysis, we request that commenters submit information about the make, model and year of the vehicle being recorded along with the recording. We also request that commenters identify whether the recording is of an ICE vehicle or an EV/HV equipped with an alert sound. The agency requests that commenters submit the minimum A-weighted level and maximum A-weighted level while using a fast (125 ms exponential) time weighting of the sound produced by the vehicle along with the recording.

In order to assist the agency in analyzing recordings submitted in response to the NPRM we request that commenters inform the agency whether the recording was conducted on an ISO noise pad, in a semi-anechoic chamber or on a test bench. For outdoor testing it would be useful for commenters to provide measurements of the air and pavement temperature, and wind speed at the time of the recording as well as photographs of the test site if available. For more information about how the agency collected data for its research please see Chapter 4.1.5, Data Collection Protocol, in the agency's Phase I research report.

How do I submit confidential business information?

If you wish to submit any information under a claim of confidentiality, you should submit three copies of your complete submission, including the information you claim to be confidential business information, to the Chief Counsel, NHTSA, at the address given above under **FOR FURTHER INFORMATION CONTACT**. When you send a comment containing information claimed to be confidential business information, you should include a cover letter setting forth the information specified in our confidential business information regulation.[135]

In addition, you should submit a copy, from which you have deleted the claimed confidential business information, to the Docket by one of the methods set forth above.

Will the agency consider late comments?

We will consider all comments received before the close of business on the comment closing date indicated above under DATES. To the extent possible, we will also consider comments received after that date. Therefore, if interested persons believe that any new information the agency places in the docket affects their comments, they may submit comments after the closing date concerning how the agency should consider that information for the final rule.

If a comment is received too late for us to consider in developing a final rule (assuming that one is issued), we will consider that comment as an informal suggestion for future rulemaking action.

How can I read the comments submitted by other people?

You may read the materials placed in the docket for this document (*e.g.,* the comments submitted in response to this document by other interested persons) at any time by going to *http://www.regulations.gov*. Follow the online instructions for accessing the dockets. You may also read the materials at the Docket Management Facility by going to the street address given above under **ADDRESSES**. The Docket Management Facility is open between 9 a.m. and 5 p.m. Eastern Time, Monday through Friday, except Federal holidays.

List of Subjects

49 CFR Part 571

Motor vehicle safety, Reporting and recordkeeping requirements, Tires.

[134] Optical character recognition (OCR) is the process of converting an image of text, such as a scanned paper document or electronic fax file, into computer-editable text.

[135] *See* 49 CFR § 512.

49 CFR Part 585

Motor vehicle safety, Reporting and recordkeeping requirements.

Proposed Regulatory Text

For reasons discussed in the preamble, NHTSA proposes to amend 49 CFR part 571 as follows:

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, paragraphs (i)(2) and (l)(50) are added to read as follows:

§ 571.5 Matter incorporated by reference.

* * * * *

(i) * * *

(2) ISO 10844:2011 ''Acoustics—Test Surface for Road Vehicle Noise Measurements,'' into § 571.141.

* * * * *

(l) * * *

(50) SAE Standard J2889–1 SEP2011, ''Measurement of Minimum Noise Emitted by Road Vehicles,'' the following sections only into § 571.141: S4, Table 1, S5.1, S5.3, S6.1.1, S6.4, S6.5, S7.1.

* * * * *

■ 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 for pedestrian alert sounds from motor vehicles.

S2. *Purpose.* The purpose of this standard is to reduce the number of deaths and injuries that result from electric and hybrid vehicles 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 vehicle passenger cars, multipurpose passenger vehicles, trucks, buses, motorcycles, and low-speed vehicles;

(b) Passenger cars, multi-purpose passenger vehicles, trucks, buses, and low-speed vehicles with more than one means of propulsion for which the vehicle's propulsion system can propel the vehicle in the normal travel mode in reverse and at least one forward drive gear without the internal combustion engine operating and;

(c) Motorcycles with 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 without the internal combustion engine operating.

S4. *Definitions.*

Broadband content means a measureable acoustic signal (greater than 0 A-weighted dB) at all frequencies within a one-third octave 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.

Fundamental frequency means, for purposes of this regulation, the lowest frequency of a valid measurement taken in S7.

Rear plane means a vertical plane tangent to the leading edge of the vehicle when the vehicle is in a condition in which it is capable of reverse self-mobility.

S5. *Requirements.* Subject to the phase-in set forth in S9 of this standard, each vehicle must meet the requirements specified in S5 under the test conditions specified in S6 and the test procedures specified in S7 of this standard.

S5.1 *Performance Requirements for critical operating scenarios.* The vehicle must satisfy the requirements of this section when tested under the test conditions of S6 and the test procedures of S7.

S5.1.1 *Start up and stationary but activated.* When measured according to the test conditions of S6 and the test procedure of S7.2, the vehicle must, within 500msec of activation of its starting system, emit a sound having at least the A-weighted sound pressure level in each of the one-third octave bands according to Table 1. The vehicle must also emit a sound meeting these requirements whenever moving at less than 10 km/h.

(a) Directivity. When measured according to the test conditions of S6 and test procedure of S7.2, the sound measured at the microphone on the line CC' must have at least the A-weighted sound pressure level in each of the one-third octave bands according to Table 1.

TABLE 1—ONE-THIRD OCTAVE BAND MIN. SPL REQUIREMENTS FOR SOUND WHEN STATIONARY BUT ACTIVATED

One-third octave band center frequency, Hz	Min SPL, A-weighted dB
315	42
400	43
500	43
2000	42
2500	39
3150	37
4000	34
5000	31

S5.1.2 *Backing.* For vehicles capable of rearward self-propulsion, whenever the vehicle's gear selection control is in the reverse position, the vehicle must emit a sound having at least the A-weighted sound pressure level in each of the one-third octave bands according to Table 2 as measured according to the test conditions of S6 and the test procedure of S7.3.

TABLE 2—ONE-THIRD OCTAVE BAND MIN. SPL REQUIREMENTS FOR SOUND WHILE BACKING

One-third octave band center frequency, Hz	Min SPL, A-weighted dB
315	45
400	46
500	46
2000	45
2500	42
3150	40
4000	36
5000	34

S5.1.3 *Constant 10 km/h pass by.* When tested under the conditions of S6 and the procedures of S7.4, the vehicle must emit a sound having at least the A-weighted sound pressure level in each of the one-third octave bands according to Table 3 at any speed greater than or equal to 10 km/h, but less than 20 km/h.

S5.1.3.1 If after a vehicle to which this standard applies according to paragraph S3(b) or S3(c) is tested in accordance with paragraphs S7.4, for ten consecutive times without recording a valid measurement because the vehicle's ICE remains active for the entire duration of the test, the vehicle is not required to meet the requirements in S5.1.3.

TABLE 3—ONE-THIRD OCTAVE BAND MIN. SPL REQUIREMENTS FOR 10 KM/H PASS-BY

One-third octave band center frequency, Hz	Min SPL, A-weighted dB
315	48
400	49

TABLE 3—ONE-THIRD OCTAVE BAND MIN. SPL REQUIREMENTS FOR 10 KM/H PASS-BY—Continued

One-third octave band center frequency, Hz	Min SPL, A-weighted dB
500	49
2000	48
2500	45
3150	43
4000	39
5000	37

S5.1.4 *Constant 20km/h pass by.* When tested under the conditions of S6 and the procedures of S7.5, the vehicle must emit a sound having at least the A-weighted sound pressure level in each of the one-third octave bands according to Table 4 at any speed greater than or equal to 20 km/h but less than 30 km/h.

S5.1.4.1 If after a vehicle to which this standard applies according to paragraph S3(b) or S3(c) is tested in accordance with paragraphs S7.5, for ten consecutive times without recording a valid measurement because the vehicle's ICE remains active for the entire duration of the test, the vehicle is not required to meet the requirements in S5.1.4.

TABLE 4—ONE-THIRD OCTAVE BAND MIN. SPL REQUIREMENTS FOR 20 KM/H PASS-BY

One-third octave band center frequency, Hz	Min SPL, A-weighted dB
315	54
400	55
500	56
2000	54
2500	51
3150	49
4000	46
5000	43

S5.1.5 *Constant 30km/h pass by.* When tested under the conditions of S6 and the procedures of S7.6, the vehicle must emit a sound having at least the A-weighted sound pressure level in each of the one-third octave bands according to Table 5 at 30 km/h.

S5.1.5.1 If after a vehicle to which this standard applies according to paragraph S3(b) or S3(c) is tested in accordance with paragraphs S7.6, for ten consecutive times without recording a valid measurement because the vehicle's ICE remains active for the entire duration of the test, the vehicle is not required to meet the requirements in S5.1.5.

TABLE 5—ONE-THIRD OCTAVE BAND MIN. SPL REQUIREMENTS FOR 30 KM/H PASS-BY

One-third octave band center frequency, Hz	Min SPL, A-weighted dB
315	59
400	59
500	60
2000	58
2500	56
3150	53
4000	50
5000	48

S5.1.6 *Pitch shifting to signify acceleration and deceleration.* The fundamental frequency of the sound emitted by the vehicle must vary with speed by at least one percent per km/h between 0 and 30 km/h.

S5.2 *Performance requirements for recognition as a motor vehicle.*

S5.2.1 The sound emitted by the vehicle to meet the requirements in S5.1.1 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.

S5.2.2. The sound emitted by the vehicle to meet the requirements in S5.1.1 must have at least one tone no higher than 400 Hz.

S5.2.3 The sound emitted by the vehicle to meet the requirements in S5.1.1 must have broadband content in each one-third octave band from 160 Hz to 5000 Hz.

S5.3 Any two vehicles of the same make, model, and model year (as those terms are defined at 49 CFR 565.12) must emit the same sound as measured by the test required in S5.1.1 within 3 A-weighted dB in each one-third octave band from 160 Hz to 5000 Hz

S6. *Test Conditions.*

S6.1 *Weather conditions.* The ambient conditions required by this section must be met at all times during the tests described in S7. Conditions must be measured with the accuracy required in S6.3.3 at the microphone height required in S6.4 +/− 2.54 cm.

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 must be measured and reported as in S6.4 of SAEJ2889–1 (incorporated by reference, see § 571.5).

S6.2 *Test surface.* Test surface shall meet the requirements of ISO 10844:2011 (incorporated by reference, see § 571.5).

S6.3 *Instrumentation.*

S6.3.1 *Acoustical measurement.* Instruments for acoustical measurement must 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 S7.4 and S7.5 of this standard must be capable of continuous measurement within ± 1.0 km/h over the entire test distance in S7.4 and S7.5.

S6.3.3 *Meteorological instrumentation.* Instruments used to measure ambient conditions at the test site must meet the requirements of S5.3 of SAE J2889–1 (incorporated by reference, see § 571.5).

S6.4 *Test site.* The test site must be established per the requirements of S6.1.1 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 1, S4 of SAE J2889–1 (incorporated by reference, see § 571.5). Microphone positions must meet the requirements of S7.1 of SAE J2889–1 (incorporated by reference, see § 571.5).

S6.5 *Test set up for directivity measurement* must 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) Tires will be fitted and pressurized per the vehicle's tire placard. Tire tread will be free of all debris. Tires will be conditioned according to the following procedure:

(1) Drive the test vehicle 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.

(b) The vehicle's doors are shut and locked and windows are shut.

(c) All accessory equipment (air conditioner, wipers, heat, HVAC fan, audio/video systems, etc.) 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.

(d) Test weight of the vehicle 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. Do not exceed the GVWR or GAWRs of the vehicle.

(e) Vehicle's electric propulsion batteries, if any, are fully charged.

S6.7 *Ambient correction*

S6.7.1 Measure the background noise for at least 30 seconds before and after a series of vehicle tests.

S6.7.2 A 10-second sample taken from these measurements will be used to calculate the reported background noise.

S6.7.3 The 10-second sample selected will include background levels that are representative of the background levels that will occur during the vehicle measurement.

S6.7.4 The minimum A-weighted SPL in the selected 10-second sample as the overall background noise level, L_{bgn} will be reported. The average A-weighted SPL in the same 10-second sample will also be noted.

S6.7.5 The minimum A-weighted ⅓ octave band levels (OBLs) (per ANSI S1.11, Class 1) in the selected 10-second sample will be reported as the ⅓ octave band background noise level, $OBL_{bgn,\ fc}$. The average A-weighted ⅓ octave band level in the same 10-second sample for each ⅓ octave band will also be noted.

S6.7.6 each ⅓ octave band of the measured jth test result within a test condition $OBL_{test,j,fc}$, will be corrected according to Table 6 to obtain the noise-corrected level $OBL_{testcorr,\ j,\ fc}$ which is the $OBL_{test,\ j,\ fc}$ minus the correction factor, L_{corr}.

TABLE 6—CORRECTIONS FOR BACKGROUND NOISE

⅓ Octave band noise level $OBL_{bgn,fc}$	* Peak-to-Peak ⅓ octave band background noise level $OBL_{bgn,fc,p\text{-}p}$	⅓ Octave band level of jth test result, ith frequency, minus ⅓ octave band noise level DL = $OBL_{test,j,fc} - OBL_{bgn,fc}$	Correction L_{corr}
≥ 25 dB(A)	**	> 10 dB	0 dB.
	< 8 dB	> 8–10 dB	0.5 dB.
		> 6–8 dB	1.0 dB.
	< 6 dB	> 4.5–6 dB	1.5 dB.
		> 3–4.5 dB	2.5 dB.
		≤ 3 dB	Do not correct, but report $OBL_{testcorr,j} < OBL_{testj}$.
< 25 dB(A)		≤10 dB	Do not correct, but report: $OBL_{testcorr,j} < OBL_{testj}$.
	**	> 10 dB	0 dB.

* Ensure that maximum allowable peak-to-peak variation occurs in not more than one measurement for each operation during the portion of the measurement that will be reported, *e.g.* within the second prior to pass-by or during an entire active but stationary measurement.

** Ensure that the background level is at least 10 dB below the measurement during any portion of the measurement that will be reported, *e.g.* within the second prior to pass-by or during an entire active but stationary measurement.

S7. Test Procedure.

S7.1 *Vehicle stationary but activated*

S7.1.1 Position the vehicle stationary with the front plane at the line PP', the centerline on the line CC' and the starting system deactivated.

For vehicles equipped with a Park position, place the vehicle's gear selection control in ''Park''. For vehicles not equipped with a Park position, place the vehicle's gear selection control in ''Neutral'' and engage the parking brake. Activate the starting system to energize the vehicle's starting system.

S7.1.2. The vehicle minimum sound pressure level shall be measured per S7.3.2.1 and S7.4.1 of SAE J2889–1 (incorporated by reference, see § 571.5) and corrected for the ambient sound level in each ⅓ octave band according to the procedure in S6.7 and the correction criteria given in Table 6.

S7.1.3.1 Four consecutive valid measurements must be within 2 A-weighted dB Measurements that contain sounds emitted by any component of a vehicle's battery thermal management system are not considered valid. When testing a hybrid vehicle with an internal combustion engine that runs intermittently, measurements that contain sounds emitted by the ICE are not considered valid.

S7.2 *Backing.* Test the vehicle per S7.1, except that the rear plane of the vehicle is placed on line PP'.

S7.3 *Pass-By test at 10km/h*

(a) Measure the sound emitted by the vehicle at a constant 10 km/h (+/− 1 km/h) throughout the measurement zone specified in S6.4 between lines AA' and PP'. 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.

(b) Four consecutive valid measurements must be within 2 A-weighted dB. Measurements that contain sounds emitted by any component of a vehicle's battery thermal management system are not considered valid. When testing a hybrid vehicle with an ICE that runs intermittently, measurements that contain sounds emitted by the ICE are not considered valid. The test result shall be corrected for the ambient sound level in each ⅓ 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.

S7.4 *Pass by test at 20 km/h.* Repeat the test of S7.3 at 20 km/h.

S7.5 *Pass by test at 30 km/h.* Repeat the test of S7.3 at 30 km/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 *Vehicles manufactured on or after September 1, 2015, and before September 1, 2016.* For vehicles manufactured on or after September 1, 2015, and before September 1, 2016 the number of vehicles complying with this standard must not be less than 30 percent of:

(a) The manufacturer's average annual production of vehicles manufactured on or after September 1, 2012, and before September 1, 2015; or

(b) The manufacturer's production on or after September 1, 2015, and before September 1, 2016.

S9.2 *Vehicles manufactured on or after September 1, 2016, and before September 1, 2017.* For vehicles manufactured on or after September 1, 2016, and before September 1, 2017, the number of vehicles complying with this standard must not be less than 60 percent of:

(a) The manufacturer's average annual production of vehicles manufactured on or after September 1, 2013, and before September 1, 2016; or

(b) The manufacturer's production on or after September 1, 2016, and before September 1, 2017.

S9.3 *Vehicles manufactured on or after September 1, 2017, and before September 1, 2018.* For vehicles manufactured on or after September 1, 2017, and before September 1, 2018, the number of vehicles complying with this standard must not be less than 90 percent of:

(a) The manufacturer's average annual production of vehicles manufactured on or after September 1, 2014, and before September 1, 2017; or

(b) The manufacturer's production on or after September 1, 2017, and before September 1, 2018.

S9.4 *Vehicles manufactured on or after September 1, 2018.* All vehicles manufactured on or after September 1, 2018 must comply with this standard.

S9.5 *Vehicles produced by more than one manufacturer.*

S9.5.1 For the purpose of calculating average annual production of vehicles for each manufacturer and the number of vehicles manufactured by each manufacturer under S9.1 through S9.3, a vehicle produced by more than one manufacturer must be attributed to a single manufacturer as follows, subject to S9.6.2:

(a) A vehicle that is imported must be attributed to the importer.

(b) A vehicle manufactured in the United States by more than one manufacturer, one of which also markets the vehicle, must be attributed to the manufacturer that markets the vehicle.

S9.5.2 A vehicle produced by more than one manufacturer must be attributed to any one of the vehicle's manufacturers specified by an express written contract, reported to the National Highway Traffic Safety Administration under 49 CFR Part 585, between the manufacturer so specified and the manufacturer to which the vehicle would otherwise be attributed under S9.6.1.

S9.6 *Small volume manufacturers.*

Vehicles manufactured during any of the three years of the September 1, 2015 through August 31, 2018 phase-in by a manufacturer that produces fewer than 5,000 vehicles for sale in the United States during that year are not subject to the requirements of S9.1, S9.2,S9.3 and S9.5.

S9.7 *Final-stage manufacturers and alterers.* Vehicles that are manufactured in two or more stages or that are altered (within the meaning of 49 CFR 567.7) after having previously been certified in accordance with Part 567 of this chapter are not subject to the requirements of S9.1 through S9.5. Instead, all vehicles produced by these manufacturers on or after September 1, 2018 must comply with this standard.

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.
585.128 Scope.
585.129 Purpose.
585.130 Applicability.
585.131 Definitions.
585.132 Response to inquiries.
585.133 Reporting requirements.
585.134 Records.

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, low-speed vehicles, and motorcycles 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, low-speed vehicles, and motorcycles.

§ 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* is used as defined in § 571.141 of this chapter.

§ 585.132 Response to inquiries.

At any time during the production years ending August 31, 2016, August 31, 2017, and 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 each of the production years ending August 31, 2016, August 31, 2017, and 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 (d) 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 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.

Note: The following appendices will not appear in the Code of Federal Regulations.

Appendix A—Glossary of Sound Engineering Terms

Acoustic Pressure: A pressure variation about a medium's mean pressure caused by a sound wave.

Acoustic Wave: A wave that propagates acoustic pressure through a medium, such as air.

Ambient (also called ambient noise or background noise): Relating to the immediate environment or surroundings. Generally refers to unwanted sounds. In an acoustic measurement, after the main sound being studied is suppressed or removed, this is the remaining sum of sounds taken from the environment of the measurement.

Amplitude: The value of the sound pressure at any instant.

Amplitude Modulation: When the amplitude of a sound changes as a function of time.

Attenuation: A decrease in the intensity of a sound.

Auditory Filter: A measure of the auditory systems frequency selectivity. An auditory filter is a band pass filter that closely approximates the shape of a rounded exponential filter or, to a lesser degree, a one-third octave band filter.

Auditory Flutter/Flicker: Auditory sensation produced when a continuous sound is disturbed at a slow, intermittent rate.

Auditory Fusion: Series of short successive sounds that are perceived as one continuous sound.

A-weighting: A filter that attenuates low and high frequencies and amplifies some mid-range frequencies. The A-weighting curve approximates the equal loudness contour at 40 dB.

Bandwidth: Range of frequencies. For example, a speaker may have an effective bandwidth from 150 to 5000 Hz. Alternatively, it is the minimum frequency subtracted from the maximum frequency. For the above example, this would be 5000—150 or 4850 Hz.

Band-Pass Filter: A type of filter that only allows a specific range of frequencies to pass through while attenuating all other frequencies. For example, a one-third octave band filter centered at 1000 Hz would pass sounds with frequencies from about 890 to 1120 Hz while attenuating frequencies outside this range.

Band Pressure Level: The pressure level of a sound wholly contained within a particular frequency band.

Band-Stop Filter: A type of filter that attenuates a particular range of frequencies while allowing frequencies outside the band to pass through.

Basilar Membrane: A membrane inside the cochlea that supports the organ of corti and vibrates as a response to sound.

Broadband: Signal with a spectrum that covers a broad range of frequencies.

Broadband levels: Levels regarding signal quantities that cover a wide range of frequencies.

Cochlea: A small snail shell-shaped tube within the inner ear that houses the receptor organs responsible for converting mechanical vibration into electro-chemical signals for the brain to process.

Condenser: Type of microphone that uses acoustic pressure to change the distance between two plates of a capacitor. The changing distance between the two plates causes the voltage across the capacitor to change.

Consonant: Auditory experience where sounds are harmonic.

Dichotic: Event in which sounds heard by both ears are different.

Diffraction: The bending of waves as they travel around an object or across an impedance change.

Digital Recorder: A device that converts acoustic waves into electric signals and stores them in its memory to be replayed back.

Dipole: Usually constructed with two monopoles with equal but opposing strengths.

Directivity: The relative proportions of acoustical energy that are emitted from a source as a function of direction, typically expressed in polar coordinates.

Dissonant: An auditory experience where sounds are in-harmonic, usually referred to as noise.

Divergence: The physical spreading of the sound waves over an area. Divergence attenuates a sound as a function of distance. See also ''Line Source'' and ''Point Source''.

Decibel (dB): Ten times the logarithmic ratio of a physical quantity to a reference value. For example,

$$\text{Sound Pressure Level} = 10 \log_{10}(P^2/P_{ref}^2)$$

where P is the acoustic pressure and P_{ref} is equal to 20 □Pa for air.

Doppler Effect: Change in the frequency of a sound wave due to the relative velocity between the source and the observer. As the sound source approaches the observer, the frequency is perceived to be higher and as it moves away it is perceived to be lower.

Dull: A semitone less than the natural pitch of a given tone. Sound composed of a greater proportion of low frequencies.

Dynamic Microphone: Type of microphone that uses a small metal coil positioned to be within a particular magnetic field attached to a diaphragm. Acoustic pressure causes the diaphragm to move the coil through the magnetic field and a current is generated.

Equivalent Rectangular Bandwidth (ERB): An idealized rectangular filter with a bandwidth defined such that it passes the same energy as an associated auditory filter. A set of contiguous ERB filters can be used to represent the frequency scale in a psychoacoustic sense. For example, an auditory filter centered at 1000 Hz has an equivalent rectangular bandwidth of 132 Hz and it takes 15.6 contiguous equivalent rectangular bandwidths to cover the auditory range below 1000 Hz. An auditory filter centered at 4000 Hz has an equivalent rectangular bandwidth of 456 Hz and it takes 27.1 contiguous equivalent rectangular bandwidths to cover the auditory range below 4000 Hz.

Equal Loudness Contour: A contour of levels (y-axis) versus frequency (x-axis) such that tones of different frequency and different level are judged to be equally loud.

Equal Loudness Principle: Mid-range frequencies (approx. 320—5120 Hz) are perceived with greater intensity than lower (20 to 320 Hz) or higher frequencies (5000 to 20,000 Hz).

Filter: A system that selectively passes some elements and attenuates others as a function of frequency.

Flat Response: A flat frequency-response curve, *i.e.* a response that does not change with frequency, sometimes referred to as Z or un-weighted.

Free Field: A sound field without boundaries such that sound is not reflected or scattered.

Frequency: Number of times a particle in a medium contracts and expands (cycles) per unit of time. Typically expressed in Hertz (Hz); one cycle per second is equal to 1 Hz. Humans can detect sound waves with a wide range of frequencies, nominally ranging between 20 to 20,000 Hz.

Frequency Response: The response of a system to an input as a function of frequency. The response can be characterized by including both the magnitude as a function of frequency and the phase as a function of frequency. The magnitude describes the amplitude of the output relative to the input while the phase describes the time delay between the input and output of the system.

Frequency Modulation: Changing frequency as a function of time.

Fundamental Frequency: The lowest frequency of a waveform.

Hair Cells: Sensory receptors found in the organ or corti on the basilar membrane in the cochlea that have hair-like structures (stereocilia). Hair cells transform sound waves into nerve impulses.

Half-power Point: Frequency at which the power output of an amplifier reduces to half of its mid-band level.

Harmonics: Components of a sound that are integer multiples of a fundamental frequency in the sound.

Harmonic Distortion: The ratio (normally expressed as a percentage) of the sum of the acoustic power of all of the harmonics generated by the device under test to the power of the fundamental, pure tone being produced. Harmonic distortion increases rapidly as a device is driven close to its maximum output capability or when a speaker is driven at frequencies outside its intended range.

Head-Related-Transfer-Function (HRTF): Essentially a frequency response that is also a function of angle. It accounts for how a sound changes to an observer due to the relative position of the source and the head, pinna, and torso of the observer.

Hertz (Hz): The unit associated with frequency. One cycle per second equals one Hertz.

In-harmonic: A frequency component that is not an integer multiple of another frequency.

Inner Ear: The innermost portion of the ear located behind the middle ear. It contains the cochlea and the vestibular system.

Line Source: A sound source that geometrically forms a line. Line sources attenuate at 3 dB per distance doubling perpendicular to the source. One example is roadway noise; another is a stack of speakers at a concert.

Longitudinal waves: Waves moving in the same direction as it is being propagated.

Loud: Producing much noise, being easily audible.

Loudness: Attribute of an auditory sensation that humans can use to judge sound intensity. Loudness is used to rank sounds on a scale from quiet to loud.

Malleus: One of the three ossicles (bones) in the middle ear, it is attached to the tympanic membrane (ear drum) and the body of the incus (anvil).

Masking: Phenomenon when the perception of a sound is diminished by the presence of another sound.

Microphone: A device that converts acoustic waves into electrical signals.

Middle Ear: Air cavity behind the tympanic membrane (ear drum) and before the inner ear.

Minimum Audible Field: the threshold for detecting sound in a sound field.

Minimum Audible Threshold: Also known as the absolute threshold of hearing, it refers to the minimum sound level of a pure tone that the average ear with normal hearing can hear without any other sound in its environment.

Modulation: A change in the dimension of a stimulus. For example see ''Amplitude Modulation'' or ''Frequency Modulation''.

Monopole: A single point in space that is an acoustic source.

Narrow band: A limited range of frequency, as opposed to a wide band, which tends to include frequencies from the low to high end, a narrow band focuses in on a particular range.

Natural Frequency: Frequency at which a system has maximum, or near maximum, response.

Noise: Sound wave(s) that is made up of random sounds. Sound wave(s) that is viewed as an undesirable sound.

Octave (also called octave band): Interval between two frequencies that have a ratio of 2:1. The range of human hearing covers approximately 10 octaves. For example, if the first octave is 20 to 40 Hz the next octave is 40 to 80 Hz, the next is 80 to 160 Hz, etc.

One-third Octave Band: Frequency band that is one-third of an octave band or whose lower and upper limits are 2⅓ times the center frequency apart, as defined by their half-power points. For example a one-third octave band centered at 1000 Hz has upper and lower cutoff frequencies at about 890 and 1120 Hz and a bandwidth of 230 Hz. A one-third octave band centered at 4000 Hz has upper and lower cutoff frequencies at about 3560 and 4490 Hz and a bandwidth of 930 Hz.

Organ of Corti: Also known as the spiral organ, it is located in the inner ear and contains hair cells, which act as receptors to sound waves.

Outer Ear: The visible outer part of the ear that directs sound waves through the canal within the temporal bone and delivers them to the tympanic membrane (ear drum).

Pascal: Unit used to measure pressure; it is equal to 9.8692×10^{-6} atm.

Period: The time interval in which successive occurrences of a recurring or cyclic phenomenon occur. The reciprocal of frequency.

Phase: The time relationship between two or more sounds reaching a receiver. The sounds are in phase when their amplitudes add. The sounds are out-of-phase when their amplitudes subtract.

Phon: A unit used to measure the loudness level of a sound in dB.

Pink Noise: A random noise whose amplitude is inversely proportional to frequency. Pink Noise sounds more natural than white noise.

Pinna: External part of the human ear, also known as the auricle.

Pitch: The sensation of a frequency. Attribute of an auditory sensation that humans can use to order sounds on a musical scale. A high pitch sound corresponds to a high frequency sound wave. A low pitch sound corresponds to a low frequency sound wave.

Pitch Strength: Perception of how strong a pitch seems to be according to a listener. Two sounds with equal frequencies can be perceived to have different strengths.

Point Source: A sound source whose dimensions are sufficiently small that it can be treated as a point. Point sources attenuate at 6 dB per distance doubling. One example is of a point source is a stationary ICE vehicle at idle.

Power: A measure of energy supplied or consumed per unit of time, usually expressed in Watts (W). A sound with a power of only one-trillionth of one W can be audible in an otherwise quiet environment; a jackhammer has an acoustic power output of about 1 W.

Propagation: The advancement of a sound wave in a particular direction traveling through a medium.

Psychoacoustics: A branch of psychophysics that studies the psychological correlations between acoustic and psychological parameters.

Pure Tone: A sound characterized by the fact that it is comprised of only one frequency.

Quiet: Causing little to no noise.

Reflection: A change in the direction of propagation of a wave due to boundary, for example pavement.

Refraction: Bending of waves due to a change in the speed of sound in the medium, for example, due to a temperature change in the air.

Resonance: The response of a system to input at a natural frequency.

Reverberation: Repetition of sound resulting from reflected sound waves.

Reverberant Field: A sound field resulting from a large number of reflections from boundaries within an enclosed area.

Ribbon: A type of microphone that converts sound into an electrical signal by placing a ribbon between the two poles of a magnet to generate electromagnetic induction.

Roll-off Rate: The steady attenuation that occurs on either end of a frequency range which is typically expressed in dB/octave or in dB/decade.

Roughness: Level of dissonance.

Sharp: A semitone above the natural pitch of a given tone. Sound composed of a greater proportion of high frequencies.

Sinusoid (Sine): Used to graphically represent a sound wave. A trigonometric function of an angle describing the ratio between the length of the opposite side of the triangle from which the angle is drawn, and the length of the adjacent side of the triangle.

Sone: Unit of subjective loudness on a linear scale. A sound that is 14 sones is twice as loud as a 7 sone sound.

Sound Intensity: The sound power passing through an area in a sound field, expressed as Watts per square meter.

Sound Intensity Level: The logarithmic measurement of sound intensity with respect to a reference level.

$$\mathrm{SIL} = 10 \log_{10}(I^2/I_{ref}^2)$$

where I is the acoustic intensity and I_{ref} is equal to 10^{-12} W/m² for air.

Sound Pressure Level (SPL): Level of a sound relative to a reference pressure and measured in decibels.

$$\mathrm{SPL} = 10 \log_{10}(P^2/P_{ref}^2)$$

where P is the root mean square of the acoustic pressure and P_{ref} is equal to 20 microPascals (μPa) for air. Examples of a-weighted sound pressure levels include: threshold of human hearing (0 dB(A)), quiet office (40 dB(A)), noisy restaurant (70 dB(A)), rock concert (110 dB(A)), pain (140 dB(A))

Sound Level Meter: Instrument used to measure sound pressure levels, often used for noise pollution studies.

Spectral Balance: The relative pressure levels of components of a sound at various frequencies. This is often described by a spectral plot with frequency in the horizontal axis and sound pressure level/Hz on the vertical axis.

Stationary Sound: A sound whose root mean squared amplitude does not change with time. Examples include a fan running at a constant speed, a waterfall, and a constant tone or hum.

Tonalness (tonality): Harmonic effect of being in a certain key.

Transverse Waves: Waves moving in right angles to their propagation.

Tympanic Membrane: Also known as the ear drum, a membrane in the inner ear that vibrates as a response to sound, or changes in air pressure.

Un-weighted Spectrum: A spectrum recorded with uniform amplification at all frequencies. In contrast, many spectra are recorded after the signal is processed through filters that approximate the variation in sensitivity with frequency that occurs in human hearing (*e.g.,* the A-weighted filter). See also ''Flat Response''.

.wav: Waveform Audio File Format, a type of file format used to storing audio.

White Noise: Noise with spectrum level that does not vary as a function of frequency.

Appendix B. Acoustic Primer

This primer introduces and describes what sound is, its components, how it is perceived by humans and how the different components of a sound can be measured. Sound can be described using physical principles but is also a perceptual phenomenon. Humans can perceive various qualities of sound, not all of which have established quantitative measures. Humans can also perceive the direction, distance and movement of sound sources. The information included here provides background and context to concepts put forth in the NPRM.

What is sound?

A sound is said to exist when the static pressure of a medium (typically air) is disturbed by periodic pressure variations (sound waves) that propagate through the medium and are perceived by a listener. The pressure variations in the medium are due to the compression and rarefaction of molecules in the medium. In regions of compression, the density of molecules is high and the number of molecule collisions increases relative to the static pressure condition. In regions of rarefaction, the density of molecules is low and the number of molecule collisions decreases relative to the static pressure condition. Over time, the pressure in a given region will increase and decrease as the sound wave propagates through the medium. The change in pressure relative to the static pressure is called the acoustic or sound pressure.

In the simplest case, sound pressure can be represented as a function of time by a sinusoidal wave for a specific location in space, as shown in Figure 1.[136] Here, the baseline represents the static pressure. The difference in pressure from the baseline to the peak of the wave is the peak amplitude of the acoustic pressure; the higher the amplitude, the louder the sound. As time progresses, the pressure increases and decreases cyclically for this location. The period of the wave can be defined by the time that it takes to go from one peak to the next; a longer period indicates a lower pitch. Another way to quantify the rate of change of a wave is by its frequency. The frequency of a wave is the inverse of the period and the unit is Hertz (Hz); the lower the frequency, the lower the pitch. The wavelength of a sound wave is similar to the period of the wave, except that rather than considering the *time* to go from one peak to the next for a given location in space, one considers the *distance* to go from one peak to the next for a given instant in time. The wavelength is mathematically related to the period by $\lambda = cT$, where λ is the wavelength, c is the speed of sound in the medium and T is the period.

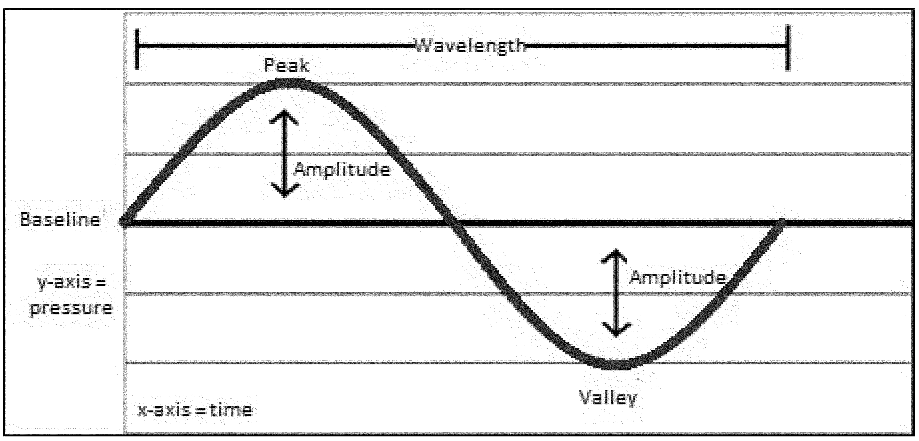

Figure 1. Graphical representation of a sinusoidal wave.

The relative location of sound source and listener in an environment can have a strong effect on the final sound that is received by the listener. As a sound propagates away from the source, the acoustic energy[137] is spread over a greater area in a manner similar to ripples in a pond. In a pond, the ripple's diameter becomes larger but the amplitude becomes smaller the further they travel from the source. Similarly, the further a sound propagates from a source, the quieter the sound will tend to be. For a point source radiating sound into free space, the intensity of that sound will diminish by a factor of four for each doubling of distance from the source to listener (inverse square law). However, in typical environments, reflections and atmospheric absorption also affect the sound level. The latter effect is greatest for high frequencies, so when a sound propagates long distances, the high frequency components of a sound will tend to decrease more than the low frequency components. This affect is most noticeable for distances greater than a hundred meters. Finally, sound propagation can be affected by intervening surfaces, which can reflect and block sound propagation. Highway barriers are a classic example of surfaces intended to block sound propagation. By placing these barriers between traffic and the listener, the sound due to the traffic can be reduced at the listener's position. A ''live'' gymnasium is an example of an environment with many reflective surfaces. Due to the reflective surfaces, sound waves can arrive simultaneously at the listener from the same source even though the sounds were emitted at slightly different times. The combination of these direct and reflected sound waves create interference patterns that can cause the level to be higher or lower. Constructive interference occurs when the sounds are ''in phase'', that is, when the peaks line up. Destructive interference occurs when the sounds are ''out of phase'', that is, when peaks line up with valleys.

How is sound perceived?

Amplitude and frequency of sound pressure are physical attributes of sound that can be related to perceptual dimensions such as loudness, pitch, and timbre.[138] Humans interpret these psychological dimensions subjectively, but some of them can be quantified through psychoacoustic modeling. Psychoacoustics is the study of how humans

[136] While it is convenient to represent sound waves as transverse waves, where the motion is perpendicular to the wave propagation, they are in actuality longitudinal waves, where the motion is parallel to the wave propagation.

[137] Acoustic energy is *equal* to the acoustic intensity integrated over the area. In an environment with no reflecting boundaries, the acoustic intensity is proportional to the acoustic pressure squared.

[138] Since timbre includes all other perceptual characteristics other than the loudness and pitch of a sound, it includes the perception of modulations, attack, decay, sharpness, roughness, etc.

perceive sound and forms the basis for extracting objective data from the physical characteristics of acoustic pressure to quantify how humans perceive the loudness, pitch, and timbre of a sound. However, some of the properties of sounds that are important to recognition or the characterization of a sound as pleasant or annoying have no established metrics.

The loudness of a sound (by definition, a subjective measure) is primarily related to the sound pressure level of a sound, but is also influenced by its frequency. Loudness (or loudness level) is measured in sones (or phons). The loudness level of a sound in phons is equal to the sound pressure level in dB of a 1000-Hz tone that is perceived to be equal in loudness to the sound of interest. For example, all sounds that are judged to be equal in loudness to a 40dB–SPL, 1000 Hz tone have a loudness level equal to 40 phons. Loudness level (phons) increases logarithmically, while loudness (sones) increases linearly. For a human to judge a sound to be twice as loud, the sound needs to be increased by roughly 10 phons or by twice the number of sones, for example the perceived loudness approximately doubles for 40, 50, 60, 70, 80 phons or 1, 2, 4, 6, 8, 16 sones. The relationship between perceived loudness and the physical acoustic pressure of a sound is non-linear in both amplitude and frequency, as illustrated in Figure 2. This means that the relative loudness (and detectability) of two sounds with the same SPL value can change substantially depending on their amplitude and frequency.

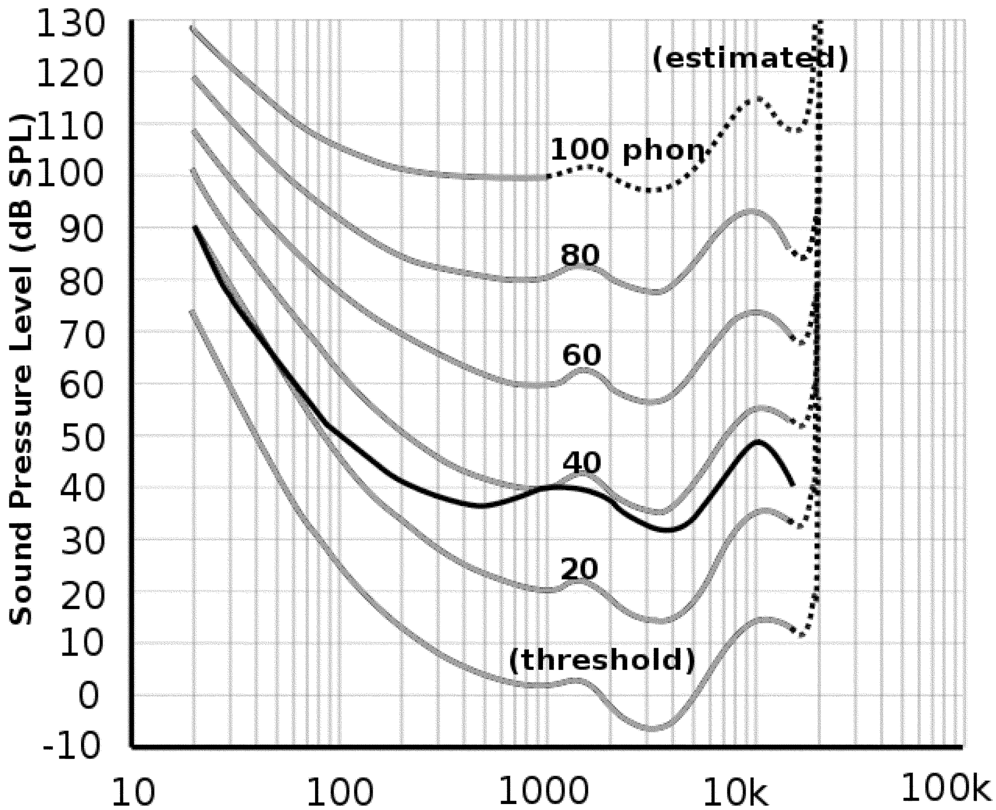

Figure 2 Equal Loudness Contours (grey) (from ISO 226:2003 revision) and Original ISO Standard (black) for 40 Phons

Pitch is directly related to frequency. Roughly speaking, humans interpret the fundamental frequency of a sound to be its pitch; the higher the frequency, the higher the pitch; the lower the frequency, the lower the pitch. A sound wave with a high frequency produces the sensation of a high, sharp pitch and a low frequency produces a low, dull pitch. Pitch strength refers to the strength of the pitch's sensation. The pitch strength is dependent on the tone-to-noise ratio. The tonal components of a sound have periodic, sinusoidal waveforms, while the noise components are random (*e.g.,* wind noise). However, if noise is constrained by some physical or electronic process to contain a relatively narrow band of frequencies, it can produce the sensation of pitch, *e.g.,* some turbine sounds. The greater the noise levels relative to the tone level, the weaker the pitch strength.

There is a strong correlation between the pitch of a sound and the spectral location of its frequency components. When there are multiple frequency components present that are integer multiples of a single lowest frequency, the sound is said to be harmonic. The lowest frequency is commonly referred to as the fundamental. If there are harmonics present, the ability to detect pitch is improved. Even when the fundamental is not present (case of the missing fundamental), the human auditory system compensates for the loss of the lower harmonic. For example, a tone complex of 600, 800 and 1200 Hz is judged to have a pitch of 400 Hz because this corresponds to the shortest common wave period.

Timbre describes the characteristics of a sound that allow the listener to differentiate two sounds with the same pitch and loudness. The timbre of a sound is based predominantly on characteristics of the sound's spectrum but is also dependent on temporal characteristics. Characteristics of the spectrum that effect timbre include: the relative strength of the tonal and noise character of the sound (pitch strength and tonality); the number of harmonics (harmonic richness); and the relative level of high frequencies and low frequencies components (sharpness and dullness). Temporal characteristics include the musical concepts of ''attack, sustain, and decay'' as well as ''vibrato'' or modulations. A violin, a muted bell, and a voice can all create a sound at the same pitch and loudness, but the violin will have a short attack, long sustain, and moderate decay. The muted bell will have a short attack, a short sustain, and a short decay. The voice will have a long attack, a moderate sustain, and a moderate decay. The violin and voice can be expressed either with or without vibrato (modulations).

Temporal effects on timbre can also be considered outside of the musical context. Humans can perceive sounds as being constant, changing or impulsive. A sound is perceived to be constant when the physical aspects, such as the tonal frequencies and levels, are unvarying and steady. An example would be standing next to an idling vehicle. Since the car is stationary and the engine speed is constant, the sound emitted from the engine does not vary significantly (assuming a well-functioning engine). Slow changes in pitch or loudness at a rate of about ½ second or longer lead to the perception of a changing sound. A good example of a changing sound is that of a siren on an emergency vehicle. If the rate of change is very quick, for example over a time less than ½ second, the sound will be perceived as impulsive. Sound with a very high rate of change such as gun fire and individual combustions produce impulsive sounds.

It is rare that humans hear only one sound at a time. This is because one sound may overshadow, very closely resemble, or interfere with the perception of another sound that does not share the same physical characteristics. When one sound interferes with the perception of another sound, it is called masking. The masking threshold is the point at which one sound's audibility or detectability is lost because of the masking sound. It can be measured in the laboratory by presenting subjects with different target sounds (stimuli) of different amplitudes and frequencies in combination with various masking sounds, and testing the subjects to determine under which conditions they can detect the targets. The level of the masking sound is used as an indicator of the amount masking the sound provided for the stimulus.

How is sound quantified?

Sound is most commonly quantified in decibels (dB). A decibel is a logarithmic unit of magnitude based on the ratio of two powers. In terms of acoustics, the ratio, commonly referred to as the sound pressure level, is between the mean-squared acoustic pressure relative to a reference mean-squared acoustic pressure. The reference for sound pressure level measurements in air is typically 20 micro-Pascals. However, when sounds are processed electronically, standard practice is to represent their intensity on a dB scale where 0 is the maximum amplitude that can be handled without distortion. In this frame of reference, levels are usually negative numbers.

Usually, acoustic equipment used for measurements is A-weighted to approximate the frequency response of human hearing (see Figure 2) to sounds of moderate loudness.

The distribution of acoustic energy in a sound can be represented graphically with a full spectrum plot, like that shown in Figure 3, or more compactly by breaking the spectrum into a relatively small number of bands, usually 30 for a one-third octave analysis, shown in Figure 4.

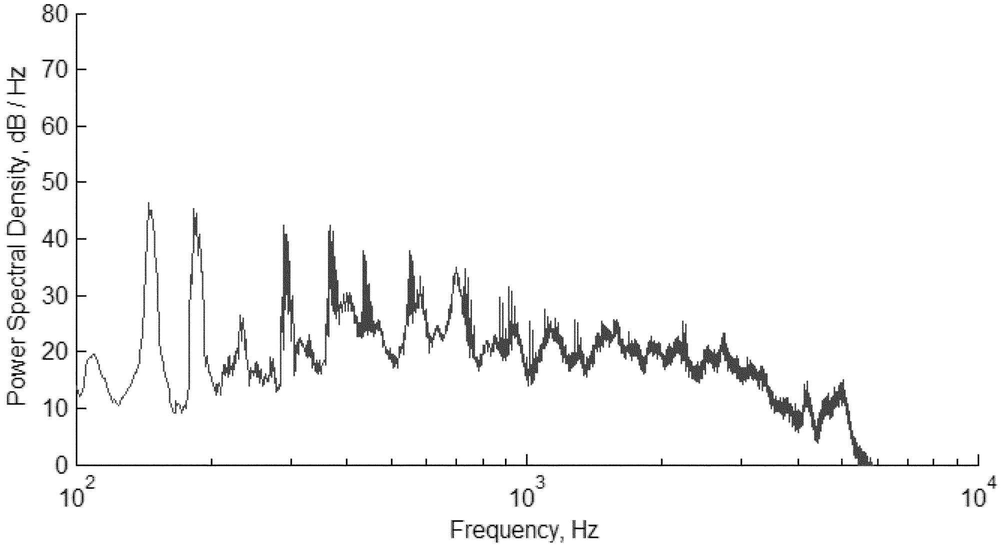

Figure 3. Full Spectrum of an Alerting Sound

(vertical scale is in dB / Hz referenced to 20 micro-Pascals: the logarithmic horizontal axis is in Hertz)

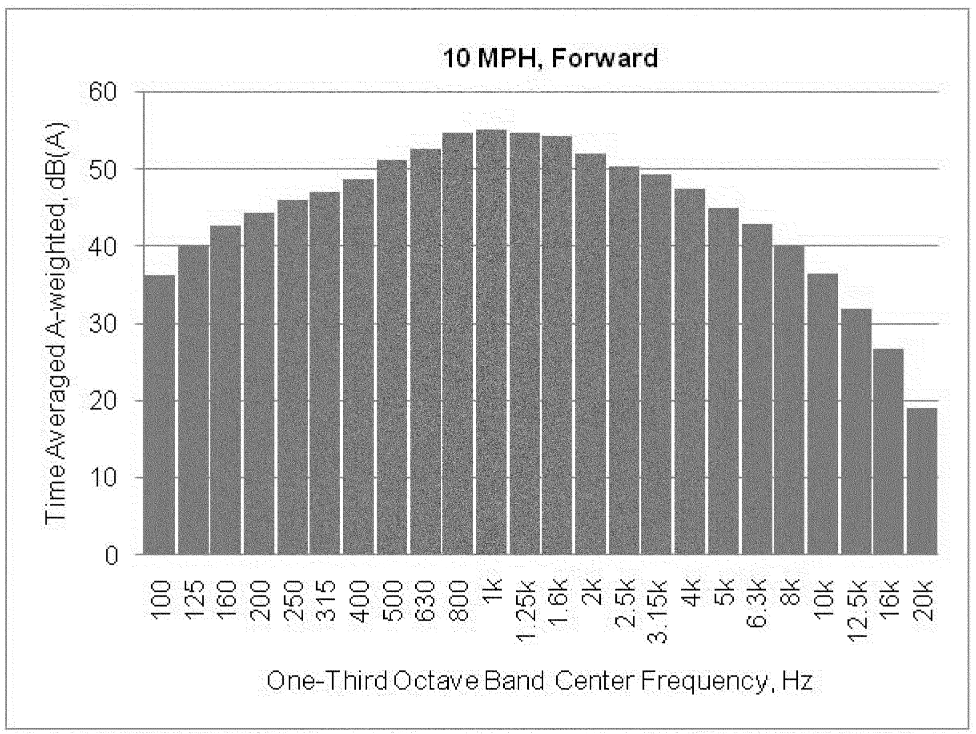

Figure 4. Example of an A-Weighted, One-Third Octave Plot of Noise Emission from a Vehicle Passing at 10 mph

Due to the breadth of this spectrum, octave bands and one-third octave band scales were created to facilitate identifying the specific frequency of sounds. Octave bands separate the range of human audible frequencies into ten bands and the one-third octave bands split each of the ten octave bands into three bands. Each scale in the breakdown provides more information about the sound being analyzed. An octave band is split by the interval between two frequencies and identified by the center frequency within the bands: 31.5 Hz, 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, 8, kHz and 16 kHz. Since there are ten octaves, there are 30 one-third octave bands. A one-third octave band extends from one-sixth of an octave below the center frequency to one-sixth above an octave frequency. The measurement of how humans perceive the loudness of a sound is dependent on the sound pressure level and can be used as a way to determine the annoyance qualities of a sound. The values from a one-third-octave analysis can also be easily presented in tabular form (Table 1), while those from a full-spectrum cannot.

TABLE 8—EXAMPLE OF ONE-THIRD-OCTAVE DATA IN TABULAR FORM: SUMMARY OF AMBIENT LEVELS DURING ICE MEASUREMENTS, A-WEIGHTED LEVEL, dB(A)

⅓ octave band center frequency, Hz	Linear average (⅓ octave band)	Min (overall A-weighted)	Max (overall A-weighted)	Min (⅓ octave band)	Max (⅓ octave band)
100 to 20k	49.6	46.1	53.4	45.3	54.7
100	34.6	30.7	34.1	30.7	38.4
125	35.5	32.4	36.8	32.4	42.1
160	36.1	32.1	37.9	32.0	41.5
200	36.9	32.7	37.9	32.7	41.2
250	36.5	33.9	38.1	33.1	40.7
315	36.5	32.5	37.6	32.1	41.5
400	36.0	31.9	38.1	31.8	39.7
500	36.7	33.6	39.8	33.1	41.1
630	38.2	34.4	41.7	34.0	42.2
800	40.2	36.0	46.1	35.8	46.1
1k	41.1	36.4	46.4	36.4	46.4
12.5k	40.0	35.3	45.1	35.3	45.1
16k	37.6	32.9	43.1	32.9	43.1
2k	34.7	30.3	37.8	30.3	37.8
2.5k	34.5	32.8	35.4	30.8	42.1
3.15k	35.5	36.9	37.1	30.0	39.6
4k	34.0	33.0	34.3	28.3	40.2
5k	29.0	25.0	29.8	24.3	32.8
6.3k	25.7	22.3	26.9	19.7	31.7
8k	20.2	16.6	22.4	14.1	24.2
10k	14.4	10.3	17.3	7.6	18.3
12.5k	8.9	5.0	11.7	3.2	13.0
16k	3.1	0.7	5.6	−0.8	8.7
20k	−1.9	−3.1	−0.4	−3.5	2.0

Summary

The acoustic science described above was intended to provide novices enough knowledge to understand the data and discussions put forth in the NPRM. Sound is a form of energy that is created when a medium vibrates, creating pressure variations (compressions and rarefactions of molecules) within a medium (such as air) which creates a pattern called a wave. Sound pressure over time creates peaks and valleys which make up the wavelength. The difference in acoustic pressure from the ambient pressure (no contraction of the medium) to the peak or valley of a wavelength is called the amplitude; the higher the amplitude, the louder the sound. The period of a wave is the time it takes for a cycle (a peak and a valley) to complete; a longer period indicates a lower pitch. The frequency of a sound is the number of complete wave cycles that pass by a given point in space every second; the higher the frequency, the higher the pitch.

The wavelength, amplitude, period and frequency are physical attributes of a sound wave that affect the human perception of loudness, pitch and timbre. These perceptions can be quantified using psychoacoustics. Psychoacoustics is the study of how humans perceive sound and forms the basis for extracting objective data from the physical characteristics of acoustic pressure (sound). Using the physical characteristics and psychoacoustic analysis, a sound is usually measured in decibels (dBs) within an octave. Octaves can be further broken down into one-third octave bands which provide more information about the spectral content of sound being analyzed. After reading this primer, the reader should understand what ''sound'' is, identify its different components, and understand how humans perceive sound and how each of these contributes to measuring sound.

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DEPARTMENT OF TRANSPORTATION

National Highway Traffic Safety Administration

49 CFR Parts 571 and 585

[Docket No. NHTSA–2011–0100]

Draft Environmental Assessment for Rulemaking To Establish Minimum Sound Requirements for Hybrid and Electric Vehicles

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

ACTION: Notice of availability.