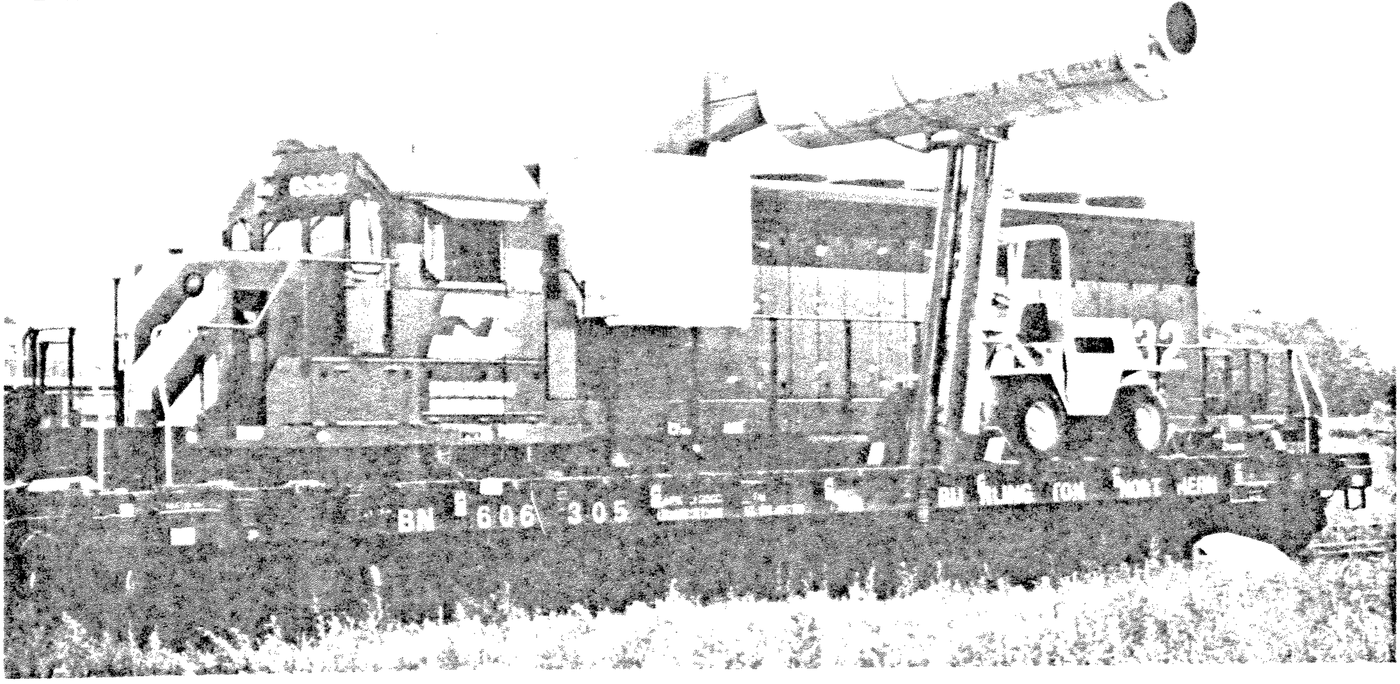
ISSN 0093-9978

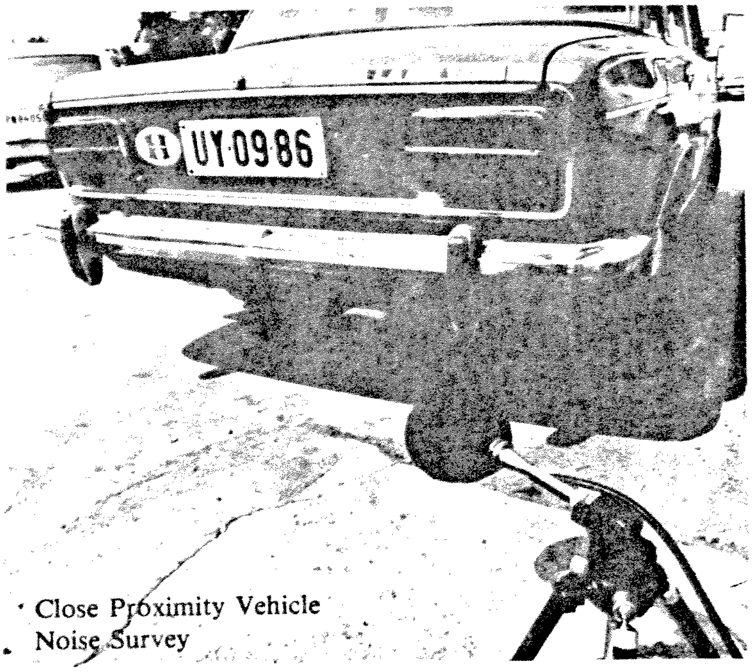
NOISE CONTROL ENGINEERING

Volume 14—Number 2

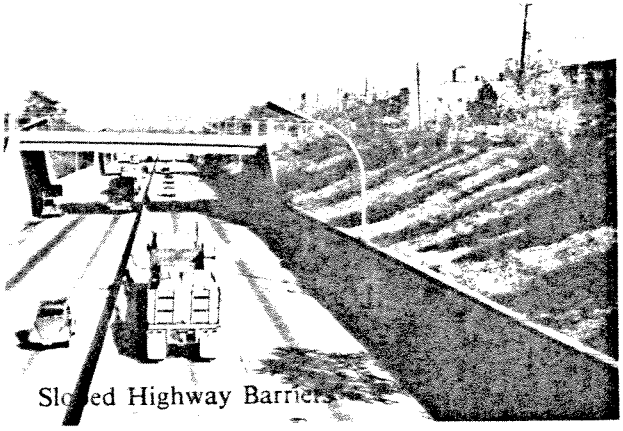
March-April 1980

Diesel Electric Locomotive Noise





Close Proximity Vehicle Noise Survey

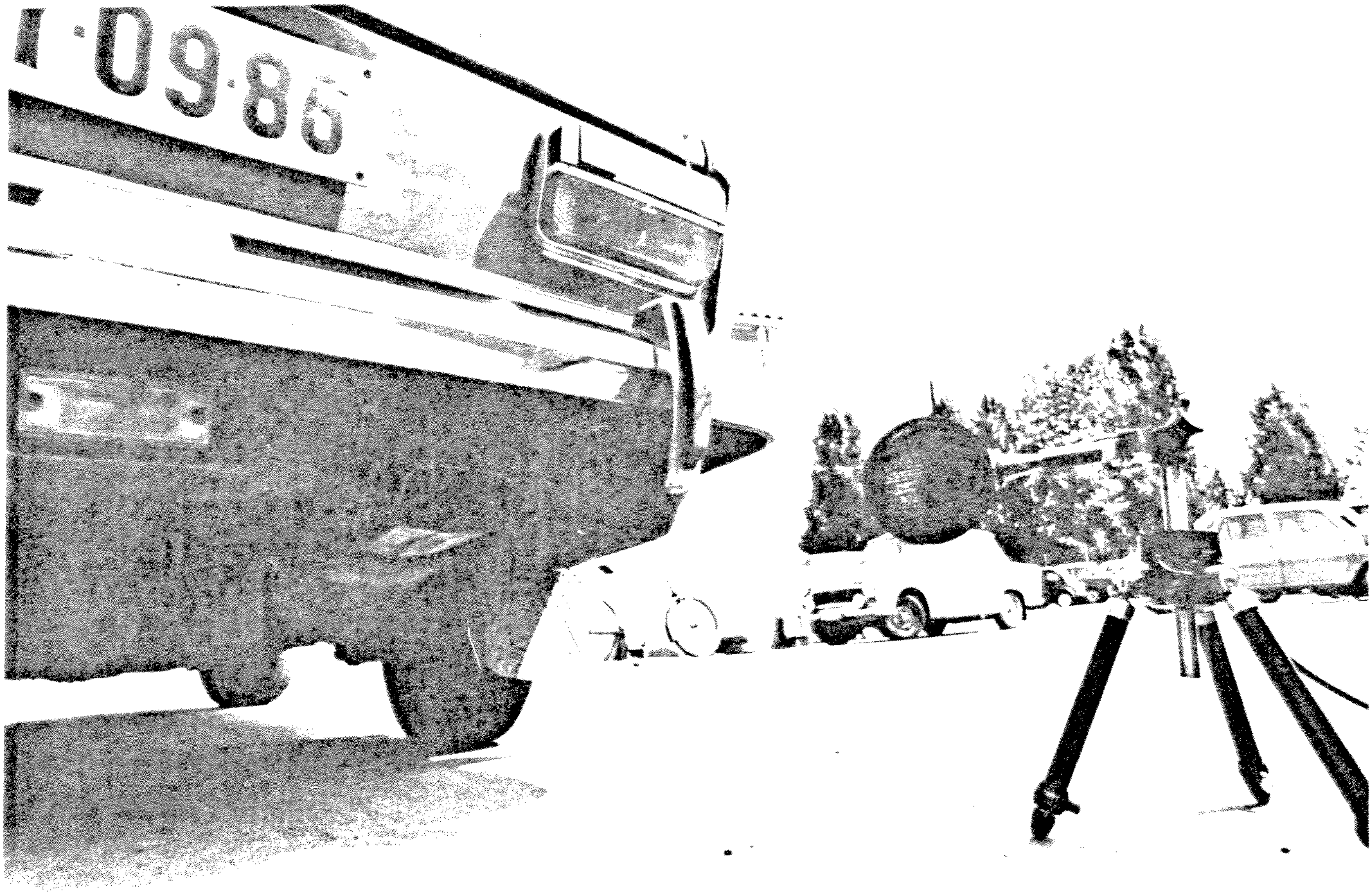


Sloped Highway Barriers

Plus:

- Acoustic Radiation from Sources
- Predicting Vibration Isolation Efficiency

An Investigation of the Close Proximity Vehicle Noise Survey Method*



The widely used passby noise measurement method of the type approval procedure is inappropriate for everyday control of the noise emission of vehicles currently in use. To enable simple, short, and yet repeatable measurements, a close proximity surveying method has been worked out by ISO. **F. Auguszinovicz**† and **B. Buna**† examined this method and found that although the measurements are carried out in the near field of one of the major noise sources of the automobile, meaningful results could be obtained. Nevertheless, the close proximity method seems to remain a supplementary measurement method only.

---

*Received 11 May 1979; revised 15 October 1979

†Research Institute for Road Transport, 1502 Budapest, Pf. 107, Hungary

There is no doubt that one of the most effective ways of controlling traffic noise is to set limits for the individual vehicles themselves. In practice, this means that measurement methods and criteria are given for certain groups of vehicles, and the limits are controlled by selecting and measuring a few samples of the group. These measurements usually take place during the type approval test. Assuming that the individual vehicle undergoing the type approval test is representative of the majority of vehicles of the same type, it can be anticipated that the noise emission of vehicles can be kept under a given level. However, this holds true for new vehicles only. It is known that the noise emission of a vehicle varies with time (that is, with running or wear). An effective noise emission control system requires that vehicles currently in use also be measured. Nevertheless, because of the relative complexity and circuitousness of type approval tests, their methods are not appropriate for routine monitoring purposes. (It is worth nothing that the present International Organization for Standardization [ISO] and Society of Automotive Engineers [SAE] type approval tests have recently been strongly criticized as being unable to give meaningful sound levels vis-à-vis normal urban operation of light motor vehicles. Thus, ISO/TC43/SC1/WG8, a number of national and international organizations including Committee of Common Market Automobile Constructors [CCMC] and the Environmental Protection Agency [EPA], as well as light vehicle manufacturing companies are working on the development of a new pass-by test.)

To be able to carry out short and simple measurements at readily obtainable sites along roads and highways, development of a new measurement method is required. This new method, generally referred to as the close proximity or near-field stationary noise test, is given in a Draft International Standard issued by ISO.[1] This method is considered to be a useful means for surveying vehicles currently in operation, and there have been favorable experiences reported in the literature.[2-5] However, a number of unresolved problems and doubts concerning the repeatability of the results as well as the scope of the method seem to remain. Before a noise surveying system for vehicles in use is set up on the basis of the close proximity monitoring method, some aspects of these problems must be studied. Accordingly, a research program was carried out at the Research Institute for Road Transport in Budapest, sponsored by the Ministry of Transport and Communication, to investigate the applicability and scope of the close proximity stationary method, its relations with the various standard measurement methods, the parameters influencing the results, some instrumentation problems, and questions relating to the establishment of the control system.

The Standard Survey Method

The draft standard previously mentioned was worked out by ISO/TC43/SC1/WG8 from 1973 to 1977. Experiments based on methods similar or identical to those described in this document have been carried out for years with success.[2-5] Regulation No. 9 issued by the Inland Transport Committee of the Economic Commission for Europe, which prescribes the type approval tests for the majority of European countries, is expected to be amended according to ISO/DIS 5130, and other national and international standards will include the same or similar methods.[6,7]

The close proximity noise test consists of two separate measurements, one in the proximity of the engine and another near the outlet pipe of the stationary vehicle. The measurement microphone is placed 0.5 m from the appropriate vehicle parts. The measurements are carried out under transient operating conditions; that is, free acceleration for the engine and deceleration for the exhaust measurements. (Further details of the measurements can also be found directly in the standard.)

The purpose of the method is the control of noise emitted by stationary road vehicles in use. This implies that the measurement of the noise level increase, caused perhaps by poor maintenance or intentional modification of the exhaust system, is satisfactory and the knowledge of the "absolute" level is of minor importance. Consequently, the results of the control measurements are compared with those of the reference measurements carried out on individual vehicles of the same type, taken, for example, during the type approval tests. To evaluate the control measurements, a maximum permissible level increase has to be established. The criterion suggested in the draft standard is 5 dB(A) or more.

The obvious purpose of the standard is to spot excessively noisy vehicles while allowing a certain noise level increase due to normal wear. Deterioration or intentional modification of the exhaust components rather than alteration of the engine are more likely to cause an excessive noise level increase. In addition, measurements in proximity of the engine require wide-open-throttle acceleration, and this poses some instrumentation problems. Accordingly, the primary test for control of noise emitted by road vehicles is that conducted near the exhaust outlet.

Measurement conditions of the survey method differ remarkably from those of the standard pass-by method. The microphone is relatively near the vehicle, and the noise of a stationary vehicle, operating under nonsteady engine conditions, is to be measured. Because of the short distance between the source and the microphone, these measurements are taken in the near field of the vehicle. The transient engine conditions also degrade the accuracy of the measurements, and a number of problems arise because of the free acceleration. It seems, therefore, utterly justified that the scope of the standard is relatively narrow. However, as will be shown, the survey method is not as inferior to other well-established methods as could be expected. It has been proved that (for a given automobile type to be discussed later) the near field is not too irregular around the vehicle. The transient operating conditions also have some advantageous characteristics relating to vehicle part diagnostics and noise emission estimation.

To enable measurements at a readily obtainable site, the signal-to-noise ratio of the measurements must be increased. This can be achieved if the distance between the vehicle and the microphone is radically decreased, which means that the microphone comes to the near field of the vehicle. (Note that in the literature there is some confusion about the term *near field* of a noise source. Throughout this article, the space consisting of points no farther than λ/4 from the extremities of the vehicle is called the near field, where λ means the wavelength of the lowest frequency component of the noise.) The very first question to arise, therefore, is whether it is possible to measure correctly in the near field.

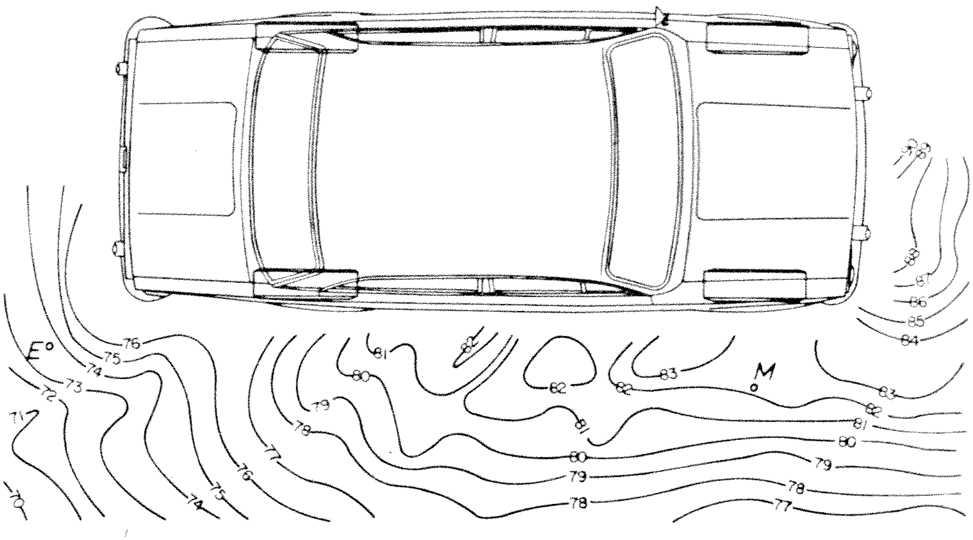


Figure 1—Contour line noise level map around the unloaded, stationary automobile at a height of 0.5 m for an engine speed of 2200 rpm. SPL is given in dB(A).

Is it Possible to Measure Correctly in the Near Field?

Fig. 1 gives some answer to the question of measurements in the near field. The figure is a contour line map showing the A-weighted sound levels as isophon curves around a stationary automobile at a constant engine speed of 2200 rpm (no load), at a height of 0.5 m. (The automobile is equipped with a four-cylinder, 1.2-litre, 62 hp/5600 rpm, front drive gas engine. This type is fairly common in Hungary, and is also characteristic of other countries in Europe. It is generally considered to be engine-noisy rather than exhaust-noisy, as is the case for many other types on the European market.[8]) Point M is the standard measurement location near the engine and point E is the projection of the microphone position near the exhaust.

The highest levels can be found around the engine, confirming the general belief that the type considered is engine-noisy. There is no doubt that true engine noise is measured at point M, but some shielding caused by the wheel is evident. It is worth mentioning that the repeatability of the measurements apparently is not deteriorated by the strong variation of the microphone position.

The sound field along the side of the automobile is relatively irregular, presumably caused by diffraction. However, level variation is not too strong. The radiation pattern becomes more and more regular as one goes toward the rear wheel. The shape of the isophon curves refer to the fact that the engine radiates a considerable amount of energy backwards between the front and the rear wheels. Considering the geometry of the automobile and the microphone position, it is likely that this radiation takes place mainly through reflection from the ground in addition to diffraction at the lower edge of the body.* This assumption was also confirmed by detailed analysis of the standard ISO pass-by measurement.[9]

The most regular radiation can be found around point E, in proximity to the exhaust outlet. The curves resemble spherical radiation, showing that the exhaust outlet acts as an acoustical point source and spherical radiation superimposes on the radiation of the engine surface and the exhaust shell. However, it must not be taken for granted that at point E, only the exhaust noise is measured.

The transition from the near field to the far field can be visualized by means of measurements along a line in the vertical plane of the front axle, assuming that the engine is the main noise source of the tested automobile. Results of the overall and one-third octave band level measurements taken at a uniform height of 0.5 m are depicted in Fig. 2. Disregarding the frequency range between 300 and 1000 Hz, the effect of distance on band levels obeys the theoretical 6 dB/doubling of distance decay rule with reasonable accuracy. (Compare the slope of the sound pressure level [SPL] versus distance functions denoted by thick lines with the thin, parallel lines representing the 6 dB/doubling of distance decay.) The relative level decrease near the automobile at medium frequencies, thought to be the consequence of wheel shielding, results in a 2 dB(A) decrease in the overall SPL with

---

*Recognition of the radiation mechanism suggests that reduction of the downward sound propagation from the engine could result in a noticeable reduction of noise emission. Abe and Shimizu published similar results, and the possibility of noise reduction for light-duty trucks by decreasing the open side area has also been proved.[11]

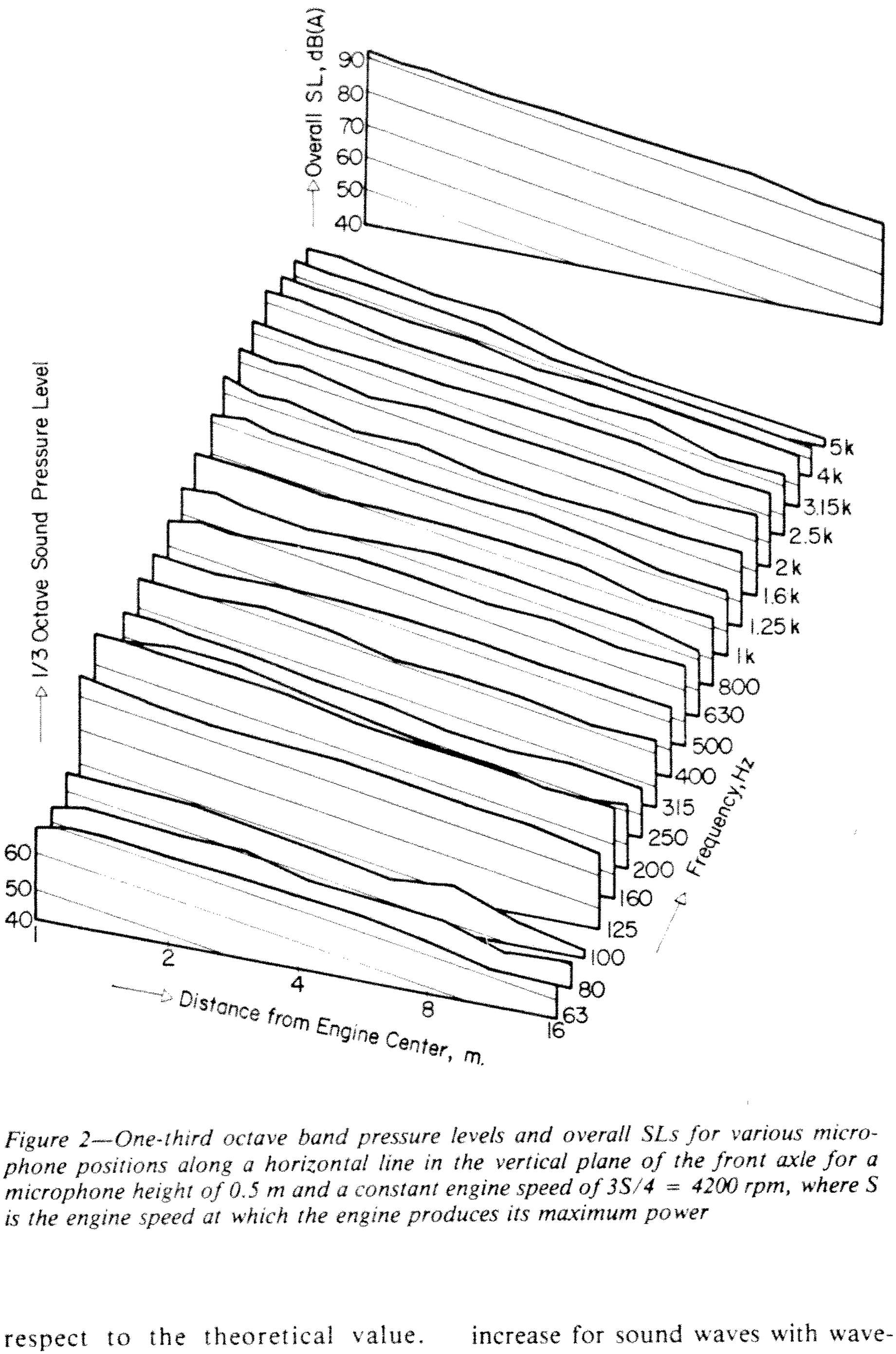


Figure 2—One-third octave band pressure levels and overall SLs for various microphone positions along a horizontal line in the vertical plane of the front axle for a microphone height of 0.5 m and a constant engine speed of 3S/4 = 4200 rpm, where S is the engine speed at which the engine produces its maximum power

respect to the theoretical value. Nevertheless, irregularities in single bands or ranges can also be found in the far field. For example, an observable increase at a distance of 8 m, just near the microphone position for the ISO standard pass-by test of 7.5 m, can be detected. This increase cannot be explained by ground plane reflections. The height of the engine and the microphone is low compared with their distance, and therefore the difference of the reflected and direct propagation path is also low. Ground plane reflections can result in an SPL increase for sound waves with wavelengths equal to or less than the path difference, but these high-frequency waves have no significant contributions to the A-weighted SPL. Similar results were found by Waters, but no sufficient explanation could be given.[10]

All of the presented data refer to the sound field of a stationary vehicle under no-load operating conditions. Wide-open-throttle engine acceleration tests with stationary and moving vehicles at near-field and far-field microphone positions gave similar results.[9] It can be concluded that the near field of the investigated automobile is sufficiently regular, enabling repeatable measurements to be carried out in the sound field of the engine and the exhaust.

According to the close proximity procedure, measurements are carried out under transient engine operating conditions. Prescriptions of the transient engine operating conditions can be verified by means of a simple sound level meter: relative to static conditions, acceleration or deceleration may cause a noticeable level increase. This increase improves the signal-to-noise ratio of the measurements; on the other hand, it is to be expected that the spectral characteristics differ significantly from those of static, unloaded or loaded operating conditions. The close proximity methods vary a lot from the present measurement practice as well as from real traffic situations, which causes concern about the effects of transient engine operating conditions.

What are the Effects of Transient Engine Operating Conditions?

The standard requires that measurements in proximity to the exhaust should be carried out during deceleration from a given revolution number. Only the highest level of the whole deceleration process should be noted. In the case of a number of automobile types and individual vehicles, the result of the measurement is identical to the level for constant engine speed. For other types this is not the case: the level versus time function is not monotonic, and immediately at the beginning of the deceleration period a level increase of up to 12 dB(A) can be detected. To learn more about the nature of this phenomenon, detailed frequency analysis of a standard deceleration period was carried out. The analysis was performed by means of a computer-controlled real time one-third octave analyzer and appropriate software. The results of one-third octave band analysis as a function of time are shown in Figs. 3 and 4 for an automobile of the same type, equipped with new and worn exhaust systems, respectively.

Disregarding the sharp ridge of Fig. 3 at the prevailing firing frequency, the band level versus time functions are essentially of a monotonic nature. The firing frequency component increases by some 18 dB at the beginning of the deceleration (that is, having closed the throttle), and this elevation lasts almost until the end of the deceleration. If an automobile of the same type is equipped with a worn exhaust system, no sharp increase at firing frequency occurs; instead, a significant increase in the frequency range between 1 and 5 kHz can be found (see Fig. 4). The systematic shifting and broadening of the level increases from firing to higher frequencies is also supported by Fig. 5. It can be seen from the figure that the behavior of the investigated exhaust system varies during its life. Its response at firing frequency decreases with time, while at higher frequencies it increases. This difference, as well as the width of the increasing or decreasing spectrum range, suggests that the response at lower and higher frequencies is governed by different effects. Experiments showed that the higher frequency response is of a pronounced resonant nature, since no frequency shift was experienced in this range for various engine speeds. Fig. 6 also stresses the existence of some type of resonance in the exhaust system. The diagram shows approximately linear exhaust noise level versus engine speed function for constant engine speeds, but a local maximum for the peak levels determined according to the standard close proximity procedure as a function of the beginning engine speed of the deceleration period.

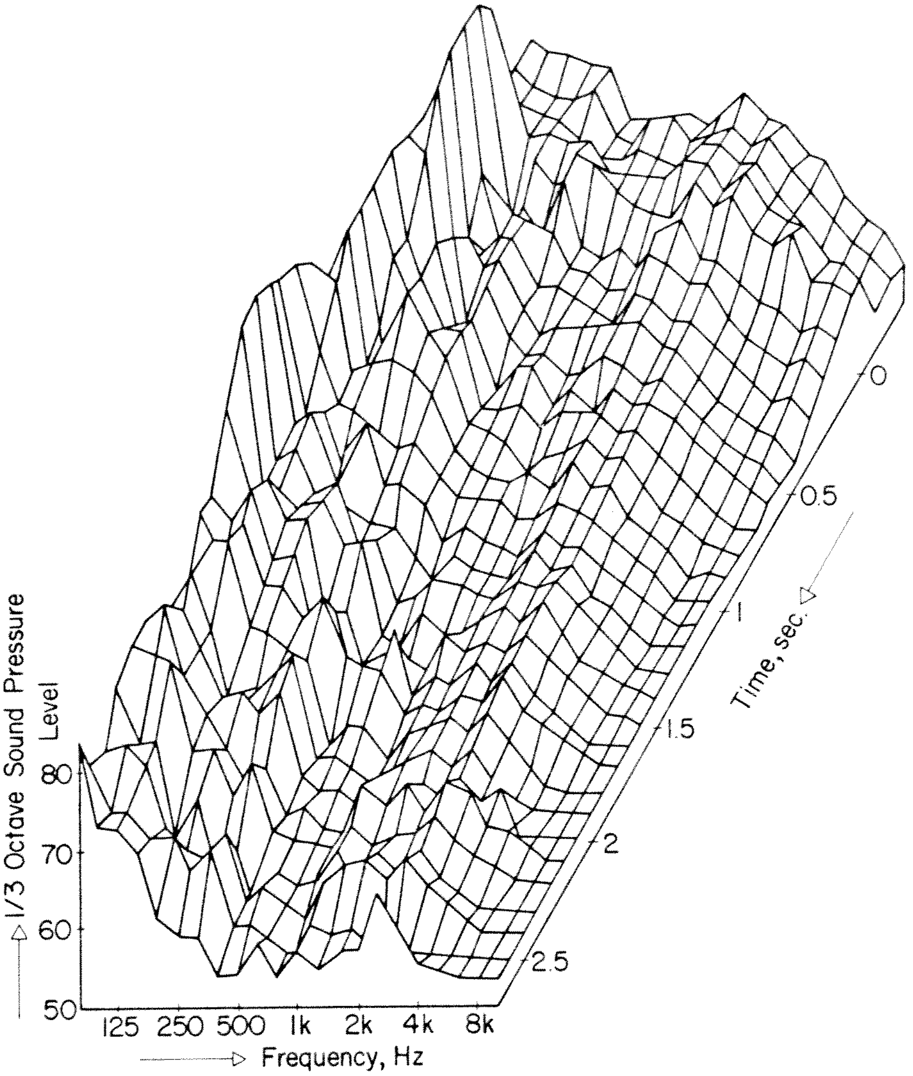


Figure 3—One-third octave frequency spectra of a near-the-exhaust deceleration test according to ISO/DIS 5130, as a function of time for a new exhaust system

These facts clarify why exhaust measurements should be made for the deceleration mode. Deceleration noise peaks, if any, improve the signal-to-noise ratio and help to spot exhaust systems in bad states of repair (Fig. 5). Wide-open-throttle acceleration also results in a certain amount of noise level increase, the spectrum of which is very similar to that which can be measured in the deceleration mode for the automobile under investigation (see Figs. 7 and 8). However, repeatability and simplicity of deceleration measurements account for controlling exhaust noise by deceleration measurements.

It seems to be most likely that the closing of the throttle at a relatively high engine speed or opening of the throttle at free acceleration results in high excitation levels at firing frequency. If the exhaust system is properly maintained, this excitation causes a sharp increase in the firing frequency component. However, because of the A-scale, this results only in a slight increase in the overall level. On the contrary, if the exhaust system is worn out, possibly of burnt-down absorbing material, the excitation mainly of firing frequency causes the exhaust system to oscillate in its eigenmodes at higher frequencies, due to a lack of proper damping. The spectral component of the oscillations falls into the most sensitive range of

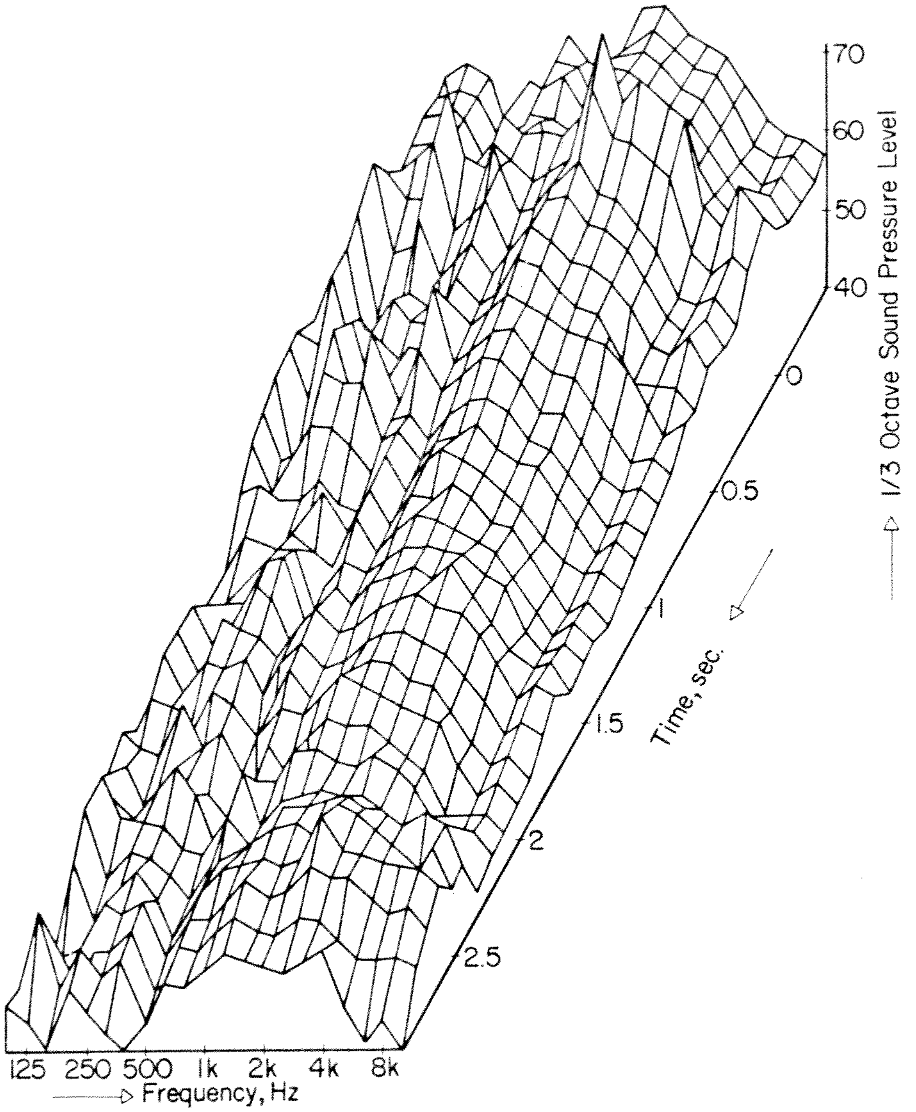


Figure 4—One-third octave frequency spectra of a test as in Fig. 3, with the same automobile type but with a worn exhaust system

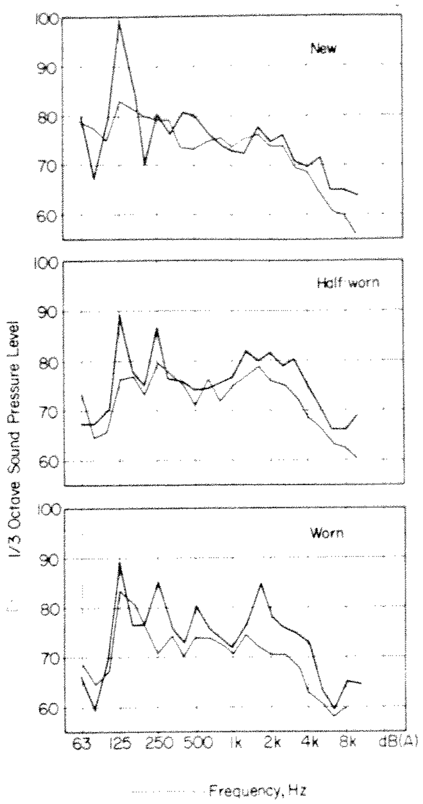


Figure 5—Comparison of exhaust spectra for new, half-worn, and worn exhaust systems. Microphone position according to ISO/DIS 5130. —— static spectrum, engine speed 3S/4; —— instantaneous spectrum taken at the moment of maximum A-weighted SL during a deceleration as from 3S/4.

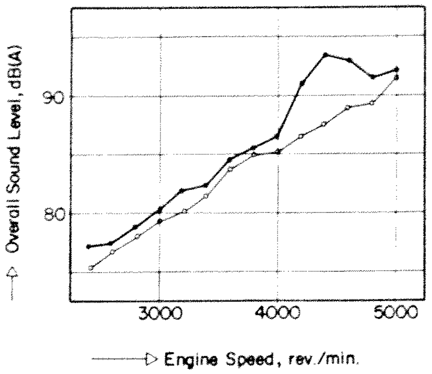


Figure 6—Exhaust noise level versus engine speed functions. ○——○ SL for constant engine speeds; •——• maximum A-weighted SL during decelerations as from the engine speed indicated. Worn exhaust system microphone position according to ISO/DIS 5130.

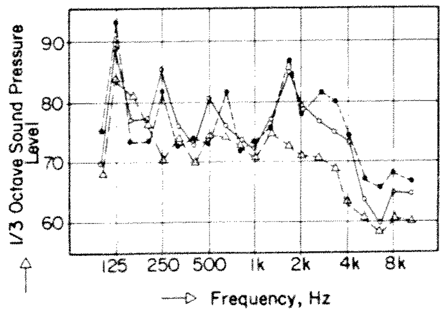


Figure 7—Instantaneous spectra for a worn exhaust system measured under different operating conditions. Δ-•-Δ constant engine speed of 3S/4 = 4200 rpm; •---• free acceleration, measurement taken at approximately 4200 rpm; ○——○ spectrum corresponding to the highest A-weighted SL of a standard deceleration process as from 4200 rpm.

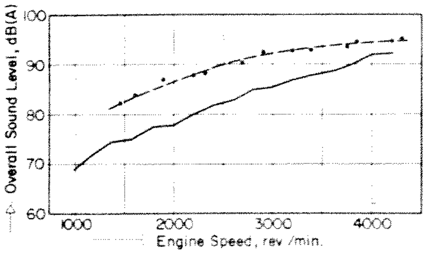


Figure 8—Engine noise level versus engine speed functions. —— constant engine speeds; ---- free acceleration.

the A-filter, resulting in a significant increase in the overall level. (This is in accordance with the subjective impression that such an exhaust system sounds characteristic and striking; its noise is sometimes referred to as *grunting* or *rattling*.)

This is but one possible explanation, and only a thorough analysis of the exhaust system dynamics will give the correct answer. Nevertheless, the transient measurement methods seem to be useful for monitoring and diagnostic purposes. It is additionally worth noting that the general use of the close proximity survey method requires that exhaust system design methods are also able to handle these oscillation effects.

The draft standard prescribes that measurements near the engine should be carried out during free acceleration under wide-open-throttle conditions. The obvious reason for this is what is called signal-to-noise ratio improvement. Nevertheless, it has been shown that free acceleration results not only in level increase but also in remarkable spectrum deviation.

Details of the effect of free acceleration are given in Figs. 8 and 9. The highest level increase can be found at lower engine speeds. Fig. 9 reveals that the highest level increase of up to 20 dB takes place at the firing frequency component. This means that the measurement near the engine is governed mainly by the firing frequency component, which is not the case for operating conditions corresponding to normal traffic situations or to the type approval test; Fig. 10 proves that the results of the pass-by test according to ISO/R 362 are controlled by medium frequencies, and the contribution of the firing frequency is negligible. The free acceleration spectrum taken for the same engine speed (5000 rpm) is similar, with the only exception being that the firing frequency component becomes commensurable with the medium frequency components. This effect is even more pronounced if a free acceleration is evaluated with the prescribed engine speed (2800 rpm); that is, the less stationary the operating conditions, the higher the contribution of the firing components. This means that the measurement near the engine is an appropriate approach for engine-noisy automobiles working under heavily transient operating conditions. As discussed earlier, the majority of automobiles are engine-noisy, and this stresses the importance of monitoring the engine noise. However, engine noise measurements raise some instrumentation and repeatability problems. Considering that, due to deterioration or alteration of the components, the exhaust noise level usually increases more than the engine noise level, the close proximity noise test at the engine point seems to be inferior to that of the exhaust noise.

The information content of the one-number results obtained from the close proximity methods have been discussed mainly theoretically. However, extensive use of the methods requires some study of the practical aspects, too. The most important question concerning everyday applications involves the factors which influence measurement accuracy.

What are the Most Important Factors Influencing the Accuracy of Measurements?

As can be seen from Fig. 1, the effect of *microphone position* is not too strong. An error of 10 cm causes a random error of some 1 dB(A) (expected value) in the measured overall level, which can be minimized by means of appropriate microphone stands that enable quick and reliable microphone positioning.

There are a number of problems arising from the adjustment and measurement of the *engine speed.* Fig. 6 shows that—at least for certain types or individual vehicles—the exhaust level may depend to a great extent on the initial engine speed of the deceleration. This means that for a 1 dB(A) error in level, a 1.4 percent error limit in the engine speed measurement should be observed. This is unattainable in everyday practice. An expected value of 3 dB(A) seems to be a reasonable estimate, especially when the engine speed is adjusted by untrained personnel.

In the case of measurements near the engine on vehicles with controlled ignition engines, another serious problem arises concerning the *rpm meter*. Most rpm meters work by the

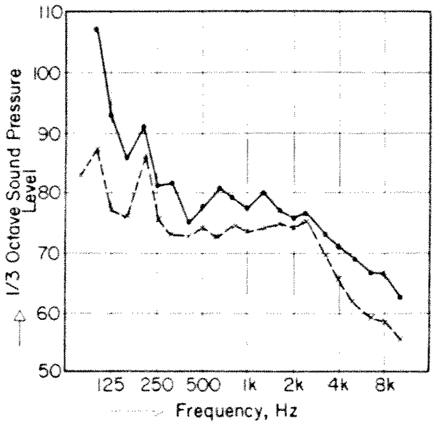


Figure 9—Comparison of free acceleration and constant engine speed engine noise spectra at an engine speed of S/2 = 2800 rpm. —— free acceleration; ---- constant engine speed.

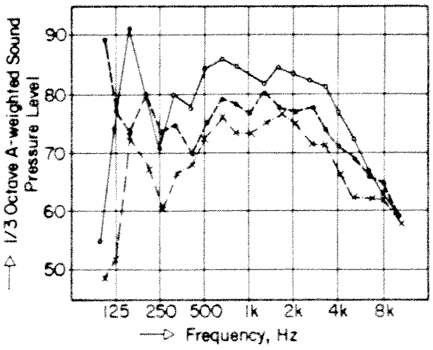


Figure 10—Comparison of pass-by (type approval) and near-the-engine (surveying) methods in terms of A-weighted instantaneous spectra. ×-•-× spectrum taken at the moment of maximum A-weighted SL in a pass-by test according to ISO/R 362; •---• engine noise spectrum at an engine speed of S/2 = 2800 rpm; o——o engine noise spectrum at an engine speed of 5000 rpm, the engine speed at the moment of the highest SL measured in the pass-by test.

integration of the ignition pulses. To enable rpm measurements in the lower range, the integration constant is relatively high; that is, the meter is too lazy for the correct rpm measurement in a fast, free acceleration.

For the sake of a more detailed analysis, let us consider the highly simplified model of an integrating electronic rpm meter depicted in Fig. 11. The model consists of a simple RC integrating network driven by an ideal voltage source representing the ignition pulses. The output voltage of the network is measured by means of an ideal dc voltmeter. The time function of the input voltage can be resolved to a slowly varying dc component as well as an infinite number of ac components being neglected by the voltmeter. Hence, we can assume that the input voltage V_{in} varies as

$$V_{in}(t) = \epsilon t + V_o, \quad (1)$$

which represents a uniformly increasing engine speed. The output voltage $V_{out}(t)$ can be computed by means of the Laplace theory:

$$V_{out}(t) = \epsilon t - \epsilon \tau + \epsilon \tau e^{-t/\tau} + V_o, \quad (2)$$

where τ = RC, the time constant of the network.

The input and output voltages represent the correct and the erroneously measured engine speeds as depicted in the example shown in Fig. 12. (The correct engine speed varies from 500 to 4000 rpm within 1.2 s, and it is measured by an rpm meter with a time constant of 0.3 s.) As can be seen, the measured engine speed lags behind the true value at the beginning, and a steady-state difference survives during the whole acceleration period. This difference results, for instance, in an erroneous readout of 2800 rather than 3650 rpm. Practical measurements, carried out with a similar rpm meter, gave the same values under both simulated and realistic conditions.

It can be seen from Fig. 8 that such an error in the engine speed results in a 2 dB(A) error in the measured noise level. The noise level error depends on the transient characteristics of the engine and the rpm meter as well, so no correction can be made.

In order to minimize the error of measurement in the proximity of a gas engine caused by incorrect engine condition adjustment and measurement, special apparatus with extra fast rpm readout and an automatic protection system preventing the engine from running too fast is required. Special care must also be taken to ensure that the acceleration will really be as rapid as possible. Experience shows that this meets difficulties if the measurement is carried out by untrained personnel, or especially by owners anxious about their automobiles.

Ignition timing is one of the most important engine alignment parameters. Tests were carried out to study the effect of the initial ignition angle on the near-field noise levels. Results are given in Fig. 13; values from pass-by measurements are also shown for comparison. The highest dependence can be found for the microphone position near the engine. The levels are, however, within a range of 3 dB(A). There is a positive minimum in all curves between 6 and 14 degrees. The rated initial ignition angle is 5 to 7 degrees, which shows that the correct ignition timing is advantageous for noise emission also. Note that there is a distinct similarity between the near-the-engine and right-side pass-by measurements, except for a shift in the abscissa, which is thought to be the consequence of the centrifugal advance. This also stresses the relation of the near-field and far-field measurements.

The *operating temperature* of the engine and exhaust system influences the near-field measurements to a small degree only. After a short

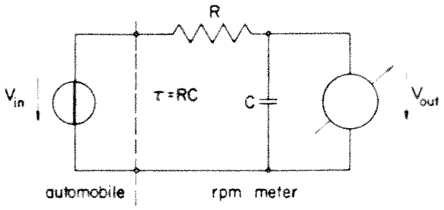


Figure 11—A simple electronic model of the engine speed measurement for assessment of the error caused by integrating-type rpm meters under transient engine conditions

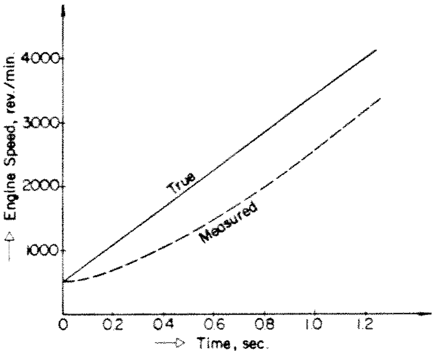


Figure 12—Computed engine speed time functions of an idealized free acceleration test. —— assumption of linearly increasing, true engine speed (see Eq. 1); ---- erroneous readout of the rpm meter of Fig. 11, with a time constant of τ = 0.3 s computed from Eq. 2.

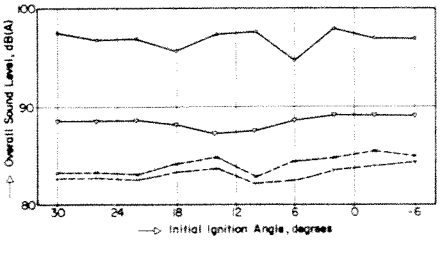


Figure 13—Noise levels versus initial ignition timing for different measurements. o——o ISO/DIS 5130 near-the-engine procedure; ∇——∇ ISO/DIS 5130 near-the-exhaust procedure; ×---× ISO/R 362 pass-by test, right side; +---+ ISO/R 362 pass-by test, left side.

warm-up time, the measurement error is probably less than 1.5 dB(A). Similar values were found for the exhaust measurements.

The effect of the influencing factors for the automobile type and the rpm meter under discussion is summarized in Table I. The most important parameter is undoubtedly the engine speed. This implies that if the close proximity measurements are established for wide-range monitoring purposes, the problem of correct, fast, and simple measurement of the engine speed as well as the engine protection must be solved.

TABLE I
THE EFFECT OF INFLUENCING FACTORS FOR AUTOMOBILE TYPE AND RPM METER

Source of Error	Estimated Value and Type of Error*	
	Exhaust	Engine
Engine speed	±3.5 expected	+2.0 systematic
Temperature	+1.5 maximum	+1.5 maximum
Sound level meter readout, calibration	±1.5 expected	±1.5 expected
Ignition timing	±0.5 expected	±1.5 expected
Background noise, reflections	±0.5 expected	±0.5 expected

*Values are given in dB(A)

Summary

It has been proved that in the close proximity noise test of a front-engine automobile, the microphone is actually in the sound field of one particular noise source of the automobile. This implies that monitoring one single noise source is generally unsatisfactory for controlling the noise emission of the automobile as a whole. Consequently, the close proximity methods are essentially of a supplementary nature and are unable to substitute for the standard pass-by measurements; this is why no close connections between the results of ISO pass-by and close proximity measurements can be found if data for different vehicle types are gathered and evaluated. However, the one-number noise level, measured in proximity to the engine and exhaust, contains valuable information concerning the variation of the acoustical behavior of individual vehicles of one certain type as a function of time or wear. The transient operating conditions rather than constant engine speeds result in a noticeable overall SPL increase as well as significant variations in spectral characteristics. This is advantageous because measurements can be made more easily in areas of high ambient noise levels, and a better approximation of peak emission, arising from frequent accelerations and decelerations in dense traffic situations, can be attained. Accuracy and repeatability of the close proximity measurements seem to be reasonable, but special care should be taken to measure and control the engine speed correctly.

Acknowledgments

The authors wish to express their thanks to Dr. M. J. Crocker for his encouragement in writing this paper. Thanks are also due to Mr. J. Toth and Mr. G. Ecsedy for their valuable help and remarks on the project.

References

1. ISO/DIS 5130, "Acoustics—Measurement of Noise Emitted by Stationary Road Vehicles—Survey Method" (1977).
2. G. Frietzsche, "Geräuschkontroll-Messmethode für Kraftfahrzeuge," *Automobiltechnische Zeitschrift*, **76**, 6, 175-182 (1974), in German.
3. W. Betzl, "Messung der Geräuschentwicklung in Form einer Nahfeldmessung," *Deutsche Kraftforschung und Strassenverkehrstechnik*, Heft 235 (VDI Verlag, Düsseldorf, 1974), in German.
4. W. Betzl, "Möglichkeiten und Grenzen einer Geräuschkontrolle von Kraftfahrzeugen durch Nahfeldmessung," VDI-Berichte No. 234 (1975), in German.
5. J. S. Simandonidis et al., "A Study of Some Elements of Traffic Noise with Special Emphasis on Motorcycles," paper V/9, 9th AICB Congress (Budapest, 1976).
6. Regulation No. 9 E/ECE/TRANS/505 Add. 8/Rev. 1, "Uniform Provisions Concerning the Approval of Vehicles with Regard to Noise," Economic Commission for Europe, Inland Transport Committee.
7. TRANS/SC 1/WP 29/R. 97, "Draft Amendments to Regulation No. 9."
8. E. J. Rathé et al., "Survey of the Exterior Noise of Some Passenger Cars," *J. Sound Vib.*, **29**, 4, 483-499 (1973).
9. F. Augusztinovicz, L. Veréb, and B. Buna, "Relation Between Passby and Stationary Near-Field Noise Measurement of a Passenger Car," XVIIth International FISITA Congress, Vol. II (Budapest, 1978), pp. 865-876.
10. P. E. Waters, "Commercial Road Vehicle Noise," *J. Sound Vib.*, **35**, 2, 155-222 (1974).
11. T. Abe and M. Shimizu, "A Study of the Reduction of Pass-by Noise Emitted by Light Duty Trucks," XVIIth International FISITA Congress, Vol. II (Budapest, 1978), pp. 1257-1276.