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Measurement of noise emitted by accelerating road vehicles — Engineering method

Part 1: M and N categories

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National foreword

This British Standard is the UK implementation of ISO 362-1:2015. It supersedes BS ISO 362-1:2007 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EH/1/2, Transport noise.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Part 1: M and N categories

Mesurage du bruit émis par les véhicules routiers en accélération — Méthode d'expertise —

Partie 1: Catégories M et N

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This second edition cancels and replaces the first edition (ISO 362-1:2007), which has been technically revised.

It also incorporates the Corrigendum ISO 362-1:2007/Cor.1:2009.

ISO 362 consists of the following parts, under the general title *Measurement of noise emitted by accelerating road vehicles — Engineering method*:

— *Part 1: M and N categories*

— *Part 2: L category*

— *Part 3: Indoor testing M and N categories*

Introduction

An extensive review was conducted of actual in-use vehicle operations, beginning with data from the TUV Automotive study in the early 1990s and continuing with data developed through other committee members from 1996 through 2000. It includes nearly 100 vehicles operated on a variety of urban roads in Europe and Asia. The primary focus of the in-use measurements was to determine how vehicles are driven with a variety of vehicles, driving behaviours, and traffic situations. The in-use behaviour determined from these studies was successfully correlated to urban traffic use in the United States by evaluation of the fuel economy test cycles used by the United States Environmental Protection Agency (USEPA). The resulting test specifications are therefore valid for all global urban use conditions.

The procedure defined here provides a measure of the sound pressure level from vehicles under controlled and repeatable conditions. The definitions have been made according to the requirements of vehicle categories. In cases of vehicles other than very heavy trucks and buses, the working group found that attempts to conduct a partial load test as in actual use resulted in considerable run-to-run variability that significantly interfered with the repeatability and reproducibility of the test cycle. Therefore, two primary operating conditions (i.e. a wide-open-throttle acceleration phase and a constant speed phase) were used to guarantee simplicity. The combination was found to be equivalent to the partial throttle and partial power (engine load) actually used.

As a further consequence of the investigation of the requirements for an efficient test, it was decided to design a test which was independent of vehicle design and therefore safe and adaptable for future technologies, as well as for future traffic conditions. The test guarantees an excitation of all relevant noise sources, and the final test result reflects a combination of these sources as a compromise between normal urban use and "worst case".

In 2004, the given test for M and N category vehicles was evaluated for technical accuracy and practical considerations by test programmes carried out by the Japan Automobile Standards Internationalization Center (JASIC), the European Automotive Manufacturers Association (ACEA), and the Society of Automotive Engineers, Inc. (SAE) in the United States. Over 180 vehicles were included in these tests. The reports of these test programmes were considered prior to preparation of this part of ISO 362.

This part of ISO 362 was developed following demands for a new test procedure considering the following:

— "The test procedure (ISO 362) doesn't reflect realistic driving conditions" (1996 EU Green Paper);

— "In the case of motor vehicles, other factors are also important such as the dominance of tyre noise above quite low speeds (50 km/h)" (1996 EU Green Paper).

— "A new measurement procedure should require that the major noise sources of a vehicle be measured" (2001 Noise Emission of Road Vehicles – I-INCE).

This edition of ISO 362-1 while maintaining the same technical procedures as the previous edition, has been revised based on practical experience to provide additional clarification, to provide additional equivalent test modes for heavy commercial vehicles, and to incorporate provisions for addressing hybrid propulsion systems for M1 and N1 category vehicles.

Measurement of noise emitted by accelerating road vehicles — Engineering method —

Part 1:
M and N categories

IMPORTANT — The electronic file of this International Standard contains colours which are considered to be useful for the correct understanding of the International Standard. Users should therefore consider printing this International Standard using a colour printer.

1 Scope

This part of ISO 362 specifies an engineering method for measuring the noise emitted by road vehicles of categories M and N under typical urban traffic conditions. It excludes vehicles of category L1 and L2, which are covered by ISO 9645, and vehicles of category L3, L4, and L5, which are covered by ISO 362-2.

The specifications are intended to reproduce the level of noise generated by the principal noise sources during normal driving in urban traffic (see Annex A).

The method is designed to meet the requirements of simplicity as far as they are consistent with reproducibility of results under the operating conditions of the vehicle.

The test method requires an acoustical environment that is obtained only in an extensive open space. Such conditions are usually provided for

— type approval measurements of a vehicle,

— measurements at the manufacturing stage, and

— measurements at official testing stations.

NOTE 1 The results obtained by this method give an objective measure of the noise emitted under the specified conditions of test. It is necessary to consider the fact that the subjective appraisal of the noise annoyance of different classes of motor vehicles is not simply related to the indications of a sound measurement system. As annoyance is strongly related to personal human perception, physiological human conditions, culture, and environmental conditions, there is a large variation and it is, therefore, not useful as a parameter to describe a specific vehicle condition.

NOTE 2 Spot checks of vehicles chosen at random are rarely made in an ideal acoustical environment. If measurements are carried out on the road in an acoustical environment that does not fulfil the requirements stated in this part of ISO 362, the results obtained can deviate appreciably from the results obtained using the specified conditions.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1176, *Road vehicles — Masses — Vocabulary and codes*

ISO 2416, *Passenger cars — Mass distribution*

ISO 5725 (all parts), *Accuracy (trueness and precision) of measurement methods and results*

ISO 10844:2014, *Acoustics — Specification of test tracks for measuring noise emitted by road vehicles and their tyres*

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

IEC 60942, *Electroacoustics — Sound calibrators*

IEC 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1176 and ISO 2416 and the following apply.

3.1 Vehicle mass

3.1.1
kerb mass
complete shipping mass of a vehicle fitted with all equipment necessary for normal operation plus the mass of the following elements for M1, N1, and M2 having a maximum authorized mass not exceeding 3 500 kg:

— lubricants, coolant (if needed), washer fluid;

— fuel (tank filled to at least 90 % of the capacity specified by the manufacturer);

— other equipment if included as basic parts for the vehicle, such as spare wheel(s), wheel chocks, fire extinguisher(s), spare parts, and tool kit

Note 1 to entry: The definition of kerb mass can vary from country to country, but in this part of ISO 362, it refers to the definition contained in ISO 1176.

3.1.2
maximum authorized mass
kerb mass plus the maximum allowable payload

3.1.3
unladen vehicle mass
nominal mass of a complete N2, N3, or M2 vehicle having a maximum authorized mass greater than 3 500 kg or an M3 vehicle as determined by the following conditions:

a) mass of the vehicle includes the bodywork and all factory-fitted equipment and electrical and auxiliary equipment for normal operation of the vehicle, including liquids, tools, fire extinguisher, standard spare parts, chocks, and spare wheel, if fitted;

b) the fuel tank is filled to at least 90 % of rated capacity and the other liquid-containing systems (except those for used water) are filled to 100 % of the capacity specified by the manufacturer

3.1.4
driver mass
nominal mass of a driver

3.1.5
mass in running order
nominal mass of an N2, N3, or M2 vehicle having a maximum authorized mass greater than 3 500 kg or an M3 vehicle as determined by the following conditions:

a) the mass is taken as the sum of the unladen vehicle mass and the driver's mass;

b) in the case of category M2 and M3 vehicles that include seating positions for additional crewmembers, their mass is incorporated in the same way and equal to that of the driver

Note 1 to entry: The driver's mass is calculated in accordance with ISO 2416.

3.1.6
maximum axle (group of axles) capacity
permissible mass corresponding to the maximum mass that can be carried by the axle (group of axles) as defined by the vehicle manufacturer, not exceeding the axle manufacturer's specifications

3.1.7
unladen axle (group of axles) load
actual mass carried by the axle (group of axles) in an unladen condition

Note 1 to entry: The unladen vehicle mass is equal to the sum of the unladen axles (group of axles) load.

3.1.8
extra loading
mass which is added to the unladen vehicle mass

3.1.9
laden axle (group of axles) load
actual mass carried by the axle (group of axles) in a laden condition

3.2
power-to-mass ratio index
PMR
dimensionless quantity used for the calculation of acceleration according to the following formula:

$$\text{PMR} = \frac{P_\text{n}}{m_\text{t}} \times 1\,000$$

where

P_n is the numerical value of total engine power, expressed in kilowatts;

m_t is the numerical value of the test mass, expressed in kilograms

3.2.1
total engine power
sum of all power from available propulsion sources

3.3
rated engine speed
S
engine speed at which the combustion engine develops its rated maximum net power as stated by the manufacturer

Note 1 to entry: If the rated maximum net power is reached at several engine speeds, *S* used in this part of ISO 362 is the highest engine speed at which the rated maximum net power is reached.

Note 2 to entry: ISO 80000-3 defines this term as "rated engine rotational frequency". The term "rated engine speed" was retained due to its common understanding by practitioners and its use in government regulations.

3.4 Vehicle categories

3.4.1
category L
motor vehicles with fewer than four wheels

Note 1 to entry: United Nations Economic Commission for Europe (UNECE) document TRANS/WP.29/78/Rev.1/Amend.4 (26 April 2005) extended the L category to four-wheeled vehicles as defined by L6 and L7.

3.4.1.1
category L1 and L2
mopeds

Note 1 to entry: See ISO 9645 for further details.

3.4.1.2
category L3
two-wheeled motor vehicles with an engine cylinder capacity greater than 50 cm^3 or maximum speed greater than 50 km/h

3.4.1.3
category L4
three-wheeled motor vehicles with an engine cylinder capacity greater than 50 cm^3 or maximum speed greater than 50 km/h, the wheels being attached asymmetrically along the longitudinal vehicle axis

3.4.1.4
category L5
three-wheeled motor vehicles with an engine cylinder capacity greater than 50 cm^3 or maximum speed greater than 50 km/h, having a gross vehicle mass rating not exceeding 1 000 kg and wheels attached symmetrically along the longitudinal vehicle axis

3.4.1.5
category L6
four-wheeled vehicles whose unladen mass is not more than 350 kg, not including the mass of the batteries in the case of electric vehicles, whose maximum design speed is not more than 45 km/h and whose engine cylinder capacity does not exceed 50 cm^3 for spark (positive) ignition engines, or whose maximum net power output does not exceed 4 kW in the case of other internal combustion engines, or whose maximum continuous rated power does not exceed 4 kW in the case of electric engines

3.4.1.6
category L7
four-wheeled vehicles, other than those classified as category L6, whose unladen mass is not more than 400 kg (550 kg for vehicles intended for carrying goods), not including the mass of the batteries in the case of electric vehicles, and whose maximum continuous rated power does not exceed 15 kW

3.4.2
category M
power-driven vehicles having at least four wheels and used for the carriage of passengers

3.4.2.1
category M1
vehicles used for the carriage of passengers and comprising no more than eight seats in addition to the driver’s seat

3.4.2.2
category M2
vehicles used for the carriage of passengers and comprising more than eight seats in addition to the driver’s seat and having a maximum mass not exceeding 5 000 kg

Note 1 to entry: In this definition, “maximum mass” is equivalent to “maximum authorized mass” used elsewhere in this part of ISO 362.

3.4.2.3
category M3
vehicles used for the carriage of passengers and comprising more than eight seats in addition to the driver’s seat and having a maximum mass exceeding 5 000 kg

Note 1 to entry: In this definition, “maximum mass” is equivalent to “maximum authorized mass” used elsewhere in this part of ISO 362.

3.4.2.4
incomplete vehicle of category M2 or M3:
incomplete vehicle with just chassis rails or tube assembly, power train, and axles, which is intended to be completed with bodywork, customized to the needs of the transport operator

3.4.3
category N
power-driven vehicles having at least four wheels and used for the carriage of goods

3.4.3.1
category N1
vehicles used for the carriage of goods and having a maximum authorized mass not exceeding 3 500 kg

3.4.3.2
category N2
vehicles used for the carriage of goods and having a maximum authorized mass exceeding 3 500 kg but not exceeding 12 000 kg

3.4.3.3
category N3
vehicles used for the carriage of goods and having a maximum authorized mass exceeding 12 000 kg

3.5
reference point
point depending on the design and category of the vehicle

3.5.1
reference point for category M1 and N1 vehicles and M2 having a maximum authorized mass not exceeding 3 500 kg
point on the vehicle as follows:

— for front-engine vehicles, the front end of the vehicle;

— for mid-engine vehicles, the centre of the vehicle;

— for rear-engine vehicles, the rear end of the vehicle

3.5.2
reference point for category M2 having a maximum authorized mass exceeding 3 500 kg, M3, N2, and N3 vehicles
point on the vehicle as follows:

— for front-engine vehicles, the front end of the vehicle;

— for all other vehicles, the border of the engine closest to the front of the vehicle

3.6
target acceleration
acceleration at a partial throttle condition in urban traffic, derived from statistical investigations

Note 1 to entry: Refer to Annex A for more detailed explanations.

3.7
reference acceleration
required acceleration during the acceleration test on the test track

Note 1 to entry: Refer to Annex A for more detailed explanations.

3.8
gear ratio weighting factor
k
dimensionless quantity used to combine the test results of two gear ratios for the acceleration test and the constant-speed test

3.9
partial power factor
k_P
dimensionless quantity used for the weighted combination of the test results of the acceleration test and the constant-speed test for vehicles of categories M1, N1, and M2 having a maximum authorized mass not exceeding 3 500 kg

Note 1 to entry: Refer to Annex A for more detailed explanations.

3.10
pre-acceleration
application of acceleration control device prior to the position AA' for the purpose of achieving stable acceleration between AA' and BB'

Note 1 to entry: See Figure 1 for additional details.

3.11
locked gear ratio
control of transmission such that the transmission gear cannot change during a test

3.12
engine
power source without detachable accessories

Note 1 to entry: Power source includes in this context all sources of motive power; for example, electric or hydraulic power sources used alone or in combination with other power sources.

3.13
test track length
l_{10}
length of test track used in the calculation of acceleration from points PP' to BB'

3.14
test track length
l_{20}
length of test track used in the calculation of acceleration from points AA' to BB'

3.15
target engine rotational speed
$n_{\text{target BB'}}$
interval between 70 % and 74 % of the speed *S* for vehicles of category M2 having a maximum authorized mass exceeding 3 500 kg and N2 and an interval between 85 % and 89 % of the speed *S* for vehicles of category M3 and N3

3.16
target vehicle speed
$v_{\text{target BB'}}$
vehicle speed of 35 km/h ± 5 km/h

4 Symbols terms and abbreviated terms

Table 1 lists the symbols, terms, and abbreviated terms used in this part of ISO 362 and the subclause where they are used for the first time.

Table 1 — Symbols and abbreviated terms used and corresponding clauses

Symbol	Unit	Subclause	Explanation
AA’	—	3.10	Line perpendicular to vehicle travel which indicates beginning of zone in which to record sound pressure level during test
a_i	m/s^2	A.2.6	Partial throttle acceleration in gear *i*
a_{max}	m/s^2	A.2.2.3	Maximum acceleration during an acceleration phase measured in in-use studies
$a_{max\ 90}$	m/s^2	A.2.3.1	90th percentile of maximum acceleration during an acceleration phase measured in in-use studies
a_{wot}	m/s^2	A.2.2.1	In-use acceleration measured in urban traffic for a specific vehicle
$a_{wot\ 50}$	m/s^2	A.2.8.1	Acceleration at 90th percentile of noise emission and 50 km/h vehicle velocity for a specific vehicle
$a_{wot\,i}$	m/s^2	5.1	Acceleration at wide-open-throttle in gear *i*
$a_{wot\ (i+1)}$	m/s^2	5.1	Acceleration at wide-open-throttle in gear (i + 1)
$a_{wot\ test}$	m/s^2	5.1	Acceleration at wide-open throttle in single gear test cases
$a_{wot\ ref}$	m/s^2	5.4	Reference acceleration for the wide-open-throttle test
a_{urban}	m/s^2	5.3	Target acceleration representing urban traffic acceleration
BB’	—	3.10	Line perpendicular to vehicle travel which indicates end of zone in which to record sound pressure level during test
CC’	—	8.1	Centre line of vehicle travel through test surface as defined in ISO 10844
$\delta_1 - \delta_7$	dB	B.2	Input quantities to allow for any uncertainty
gear *i*	—	8.3.1.3.2	First of two gear ratios for use in the vehicle test
gear (i + 1)	—	8.3.1.3.2	Second of two gear ratios, with an engine speed lower than gear ratio *i*
gear *x*	—	8.3.2.3.2	First of two gear ratios used for testing of M2 having a maximum authorized mass of more than 3 500kg, M3, N2, and N3 where certain criteria on test conditions are met
gear *y*	—	8.3.2.3.2	Second of two gear ratios used for testing of M2 having a maximum authorized mass of more than 3 500kg, M3, N2, and N3 where certain criteria on test conditions are met
j	—		Index for single test run within overall acceleration or constant speed test series *i* or (i + 1)
k_P	—	3.9	Partial power factor
k	—	3.8	Gear ratio weighting factor
$\mathrm{k_n}$	—	A.2.8.1	Interpolation factor between gears
l_{ref}	m	5.1	Reference length
l_{veh}	m	5.1	Length of vehicle
l_{10}	m	3.13	Length of test section for calculation of acceleration from PP’ to BB’
l_{20}	m	3.14	Length of test section for calculation of acceleration from AA’ to BB’
$L_{crs\,i}$	dB	8.4.3.2	Vehicle sound pressure level at constant speed test for gear *i*
$L_{crs\ (i+1)}$	dB	8.4.3.2	Vehicle sound pressure level at constant speed test for gear (i + 1)
$L_{crs\ rep}$	dB	8.4.3.2	Reported vehicle sound pressure level at constant speed test
$L_{wot\,i}$	dB	8.4.3.2	Vehicle sound pressure level at wide-open-throttle test for gear *i*
$L_{wot\ (i+1)}$	dB	8.4.3.2	Vehicle sound pressure level at wide-open-throttle test for gear (i + 1)
$L_{wot\ rep}$	dB	8.4.3.2	Reported vehicle sound pressure level at wide-open-throttle

Table 1 *(continued)*

Symbol	Unit	Subclause	Explanation
L_{urban}	dB	8.4.3.2	Reported vehicle sound pressure level representing urban operation
$m_{fa\ load\ unladen}$	kg	8.2.2.1	Unladen front axle load
$m_{ac\ ra\ max}$	kg	8.2.2.1	Maximum rear axle capacity
$m_{ra\ load\ unladen}$	kg	8.2.2.1	Unladen rear axle load
m_d	kg	8.2.2.1	Mass of driver
m_{kerb}	kg	8.2.2.1	Kerb mass of the vehicle
$\mathrm{m_{chassisM2M3}}$	kg	8.2.2.1	Mass of the incomplete vehicle (M2 or M3)
$\mathrm{m_{xloadM2M3}}$	kg	8.2.2.1	Extra load to be added to the incomplete vehicle (M2 or M3) to reach the mass of the vehicle in running order as chosen by the manufacturer
$M_{fa\ load\ laden}$	kg	8.2.2.2.2	Laden front axle load
$M_{ra\ load\ laden}$	kg	8.2.2.2.2	Laden rear axle load
m_{ref}	kg	8.2.2.1	Kerb mass + 75 kg for the driver (75 kg ± 5 kg in the case of category L)
m_{ro}	kg	8.2.2.1	Mass in running order
m_t	kg	3.2	Test mass of the vehicle
m_{target}	kg	8.2.2.1	Target mass of the vehicle
$m_{unladen}$	kg	8.2.2.1	Unladen vehicle mass
m_{xload}	kg	8.2.2.1	Extra loading
n	1/min	A.2.4	Engine rotational speed of the vehicle
$n_{PP'}$	1/min	9	Engine rotational speed of the vehicle when the reference point passes PP’
$n_{BB'}$	1/min	8.3.2.2.1	Engine rotational speed of the vehicle when the reference point passes BB’
$n_{targetBB'}$	1/min	8.3.2.2	Target engine rotational speed of the vehicle when the reference point has to pass line BB’ (see 5.1 for definition of reference point)
$(n/S)_{a90}$	—	A.2.8.1	Dimensionless engine rotational speed ratio at 90th percentile acceleration
$(n/S)_{L90}$	—	A.2.6	Dimensionless engine rotational speed ratio at 90th percentile noise emission
$(n/S)_i$	—	A.2.8.1	Dimensionless engine rotational speed ratio at maximum acceleration of i gear
$(n/S)_{(i+1)}$	—	A.2.8.1	Dimensionless engine rotational speed ratio at maximum acceleration of $(i + 1)$ gear
PMR	—	3.2	Power-to-mass ratio index to be used for calculations (abbreviation)
P_n	kW	3.2	Rated total engine power (see ISO 1585 for combustion engines)
PP’	—	3.13	Line perpendicular to vehicle travel that indicates location of microphones
S	1/min	3.3	Rated engine rotational speed in revolutions per minute, synonymous with the engine rotational speed at maximum power
$v_{AA'}$	km/h	5.2.1	Vehicle velocity when reference point passes line AA’ (see 5.1 for definition of reference point)

Table 1 *(continued)*

Symbol	Unit	Subclause	Explanation
$v_{BB'}$	km/h	5.2.1	Vehicle velocity when reference point or reference length passes line BB' (see 5.1 for definition of reference length and see 3.5 for definition of reference point)
$v_{BB'1}$	km/h	8.3.2.3.3	Target vehicle velocity when certain conditions are met
$v_{BB'2}$	km/h	8.3.2.3.3	Target vehicle velocity when certain conditions are met
$v_{PP'}$	km/h	5.2.2	Vehicle velocity when reference point passes line PP' (see 5.1 for definition of reference point)
$v_{target\ BB'}$	km/h	8.3.2.2	Target vehicle velocity when it is necessary that the reference point pass line BB' (see 5.1 for definition of reference point)
v_{test}	km/h	8.3.1.2	Target vehicle test velocity
$v_{a\ max\ 50}$	km/h	A.2.3.1	50th percentile vehicle velocity at maximum acceleration during an acceleration phase measured in in-use studies
$v_{a\ max\ 90}$	km/h	A.2.3.1	90th percentile vehicle velocity at maximum acceleration during an acceleration phase measured in in-use studies

5 Specification of the acceleration for vehicles of categories M1 and M2 having a maximum authorized mass not exceeding 3 500 kg and of category N1

5.1 General

5.1.1 Applicability and conditions

All accelerations are calculated using different speeds of the vehicle on the test track. The formulae given in 5.2 are used for the calculation of $a_{wot\ i}$, $a_{wot\ (i+1)}$, and $a_{wot\ test}$. The speed either at AA' ($v_{AA'}$) or PP' ($v_{PP'}$) is defined by the vehicle speed when the reference point passes AA' or PP'. The speed at BB' ($v_{BB'}$) is defined when the rear of the vehicle passes BB' or the front of the vehicle passes BB' + 5 m if l_{ref} is chosen as 5 m. The method used for determination of the acceleration shall be indicated in the test report

Due to the definition of the reference point for the vehicle, the length of the vehicle is considered to be different in Formulae (2) and (3). If the reference point is the front of the vehicle, $l_{ref} = l_{veh}$, i.e. the length of vehicle; if the reference point is the midpoint of the vehicle, l_{ref} = 0,5 l_{veh} (i.e. 0,5 times the length of vehicle); if the reference point is the rear of the vehicle, l_{ref} = 0.

At the choice of the vehicle manufacturer, front engine vehicles may use l_{ref} = 5 m, and mid engine vehicles may use l_{ref} = 2,5 m

The dimensions of the test track are used in the calculation of acceleration. These dimensions are defined as follows: l_{20} = 20 m, l_{10} = 10 m.

Due to the large variety of technologies, it is necessary to consider different modes of calculation. New technologies (such as continuously variable transmission) and older technologies (such as automatic transmission) that have no electronic control require a more specific treatment for a proper determination of the acceleration. The given possibilities for calculation of the acceleration shall cover these requirements.

5.1.2 Calculation of total engine power

If two or more sources of propulsive power operate at the conditions of test specified in this part of ISO 362, the total engine power, P_n, shall be the arithmetic sum of parallel propulsive engines on the vehicle. Applicable parallel propulsive engines are those power sources which provide forward motion to the vehicle in combination at the conditions of test specified in this part of ISO 362. Specified power for non-combustion engines shall be the power stated by the manufacturer.

NOTE 1 The intent of this provision is to insure that vehicles with two or more sources of propulsive power that can operate at the same time in a parallel fashion, i.e. hybrid vehicles, use the sum of available electric and combustion power to determine the vehicle power used for subsequent calculations of the power to mass ratio.

NOTE 2 For certification or other regulation purposes, it can be necessary to require the combustion engine to operate for all testing conditions.

5.1.3 Battery state of charge

If so equipped, propulsion batteries shall have a state-of-charge sufficiently high to enable all key functionalities as per the manufacturer's specifications. Propulsion batteries shall be within their component-temperature window to enable all key functionalities. Any other type of rechargeable energy storage system shall be ready to operate during the test

5.2 Calculation of acceleration

5.2.1 Calculation procedure for vehicles with manual transmission, automatic transmission, adaptive transmission, and continuously variable transmission (CVT) tested with locked gear ratios

The value of $a_{\text{wot test}}$ used in the determination of gear selection shall be the average of the four $a_{\text{wot test}, j}$ values during each valid measurement run.

Calculate $a_{\text{wot test}, j}$ using Formula (1):

$$a_{\text{wot test}, j} = \frac{\left(v_{\text{BB}', j} / 3{,}6\right)^2 - \left(v_{\text{AA}', j} / 3{,}6\right)^2}{2\left(l_{20} + l_{\text{ref}}\right)} \quad (1)$$

where

$a_{\text{wot test}, j}$	is the numerical value of the acceleration, expressed in metres per second squared;
$v_{\text{BB}', j}$, $v_{\text{AA}', j}$	are numerical values of the velocity, expressed in kilometres per hour;
l_{20}, l_{ref}	are numerical values of the length, expressed in metres.

Pre-acceleration can be used.

Each $a_{\text{wot test}, j}$ shall be reported to two significant digits after the decimal place (x,xx). Calculation of $a_{\text{wot test}}$ shall use each $a_{\text{wot test}, j}$ and the final reported $a_{\text{wot test}}$ shall be reported to two significant digits after the decimal place (x,xx). The final reported $a_{\text{wot test}}$ shall be used in all subsequent calculations.

5.2.2 Calculation procedure for vehicles with automatic transmission, adaptive transmission, and CVT tested with non-locked gear ratios

The value of $a_{\text{wot test}}$ used in the determination of gear selection shall be the average of the four $a_{\text{wot test}, j}$ values during each valid measurement run.

If the devices or measures described in 8.3.1.3.3 are used to control transmission operation for the purpose of achieving test requirements, calculate $a_{\text{wot test}, j}$ using Formula (1).

Pre-acceleration can be used.

If the devices or measures described in 8.3.1.3.3 are not used, calculate $a_{\text{wot test}, j}$ using Formula (2):

$$a_{\text{wot test}, j} = \frac{\left(v_{\text{BB'}}/3{,}6\right)^2 - \left(v_{\text{PP'}}/3{,}6\right)^2}{2\left(l_{10} + l_{\text{ref}}\right)} \tag{2}$$

where

$a_{\text{wot test},j}$	is the numerical value of the acceleration, expressed in metres per second squared;
$v_{\text{PP'}}$, $v_{\text{BB'}}$	are numerical values of the velocity, expressed in kilometres per hour;
l_{10}, l_{ref}	are numerical values of the length, expressed in metres.

Pre-acceleration shall not be used.

Each $a_{\text{wot test}, j}$ shall be reported to two significant digits after the decimal place (x,xx). Calculation of $a_{\text{wot test}}$ shall use each $a_{\text{wot test}, j}$ and the final reported $a_{\text{wot test}}$ shall be reported to two significant digits after the decimal place (x,xx). The final reported $a_{\text{wot test}}$ shall be used in all subsequent calculations.

NOTE It would be useful for these types of vehicles to record the vehicle speeds at AA', PP', and BB' to provide information for a future revision of this part of ISO 362.

5.3 Calculation of the target acceleration

Calculate a_{urban} using Formula (3):

$$a_{\text{urban}} = 0{,}63 \lg\left(\text{PMR}\right) - 0{,}09 \tag{3}$$

where

a_{urban}	is the numerical value of the acceleration, expressed in metres per second squared;
PMR	is the dimensionless value of the power-to-mass index.

The calculated a_{urban} value shall be reported to two significant digits (x,xx) after the decimal place. The reported a_{urban} shall be used in all subsequent calculations.

5.4 Calculation of the reference acceleration

Calculate $a_{\text{wot ref}}$ using Formula (4) and Formula (5):

$$a_{\text{wot ref}} = 1{,}59 \lg\left(\text{PMR}\right) - 1{,}41 \text{ for } 25 < \text{PMR} \tag{4}$$

or

$$a_{\text{wot ref}} = a_{\text{urban}} = 0{,}63 \lg\left(\text{PMR}\right) - 0{,}09 \text{ for } 25 > \text{PMR} \tag{5}$$

where

$a_{\text{wot ref}}$	is the numerical value of the reference acceleration, expressed in metres per second squared;
a_{urban}	is the numerical value of the acceleration relative to urban traffic, expressed in metres per second squared;
PMR	is the dimensionless value of the power-to-mass index.

The calculated $a_{wot\ ref}$ value shall be reported to two significant digits (x,xx) after the decimal place. The reported $a_{wot\ ref}$ shall be used in all subsequent calculations.

NOTE Calculations of $a_{wot\ ref}$ and a_{urban} for a specific vehicle are based on statistical analyses of in-use vehicle data. As such, this is not strictly a calculation of acceleration based on the independent non-dimensional variable PMR since this is used as a function to identify the appropriate target acceleration.

5.5 Partial power factor k_P

Partial power factor k_P is

$$k_p = 1 - \left(a_{urban} / a_{wot\ test}\right) \tag{6}$$

In cases other than a single gear test, $a_{wot\ ref}$ shall be used instead of $a_{wot\ test}$, as defined in 8.4.3.2.

The final reported k_P value shall be mathematically rounded to two significant digits (x,xx) after the decimal place. The final reported k_P shall be used in all subsequent calculations.

6 Instrumentation

6.1 Instruments for acoustical measurement

6.1.1 General

The apparatus used for measuring the sound pressure level shall be a sound level meter or equivalent measurement system meeting the requirements of class 1 instruments (inclusive of the recommended windscreen, if used). These requirements are described in IEC 61672-1.

The entire measurement system shall be checked by means of a sound calibrator that fulfils the requirements of class 1 sound calibrators in accordance with IEC 60942.

Measurements shall be carried out using the time weighting “F” of the acoustic measurement instrument and the “A” frequency weighting curve also described in IEC 61672-1. When using a system that includes periodic monitoring of the A-weighted sound pressure level, a reading should be made at a time interval not greater than 30 ms.

The instruments shall be maintained and calibrated in accordance with the instructions of the instrument manufacturer.

6.1.2 Calibration

At the beginning and at the end of every measurement session, the entire acoustic measurement system shall be checked by means of a sound calibrator as described in 6.1.1. Without any further adjustment, the difference between the readings shall be less than or equal to 0,5 dB. If this value is exceeded, the results of the measurements obtained after the previous satisfactory check shall be discarded.

6.1.3 Compliance with requirements

Compliance of the sound calibrator with the requirements of IEC 60942 shall be verified once a year. Compliance of the instrumentation system with the requirements of IEC 61672-1 shall be verified at least every 2 years. All compliance testing shall be conducted by a laboratory that is authorized to perform calibrations traceable to the appropriate standards.

6.2 Instrumentation for speed measurements

The rotational speed of the engine shall be measured with an instrument meeting specification limits of at least ±2 % at the engine speeds required for the measurements being performed.

The road speed of the vehicle shall be measured with instruments meeting specification limits of at least ±0,5 km/h when using continuous measuring devices.

If testing uses independent measurements of speed, this instrumentation shall meet specification limits of at least ±0,2 km/h.

NOTE Independent measurements of speed are when two or more separate devices determine the $v_{AA'}$, $v_{BB'}$, and $v_{PP'}$ values. A continuous measuring device determines all required speed information with one device.

6.3 Meteorological instrumentation

The meteorological instrumentation used to monitor the environmental conditions during the test shall meet the following specifications:

— at least ±1 °C for a temperature measuring device;

— at least ±1,0 m/s for a wind speed measuring device;

— at least ±5 hPa for a barometric pressure measuring device;

— at least ±5 % for a relative humidity measuring device.

7 Acoustical environment, meteorological conditions, and background noise

7.1 Test site

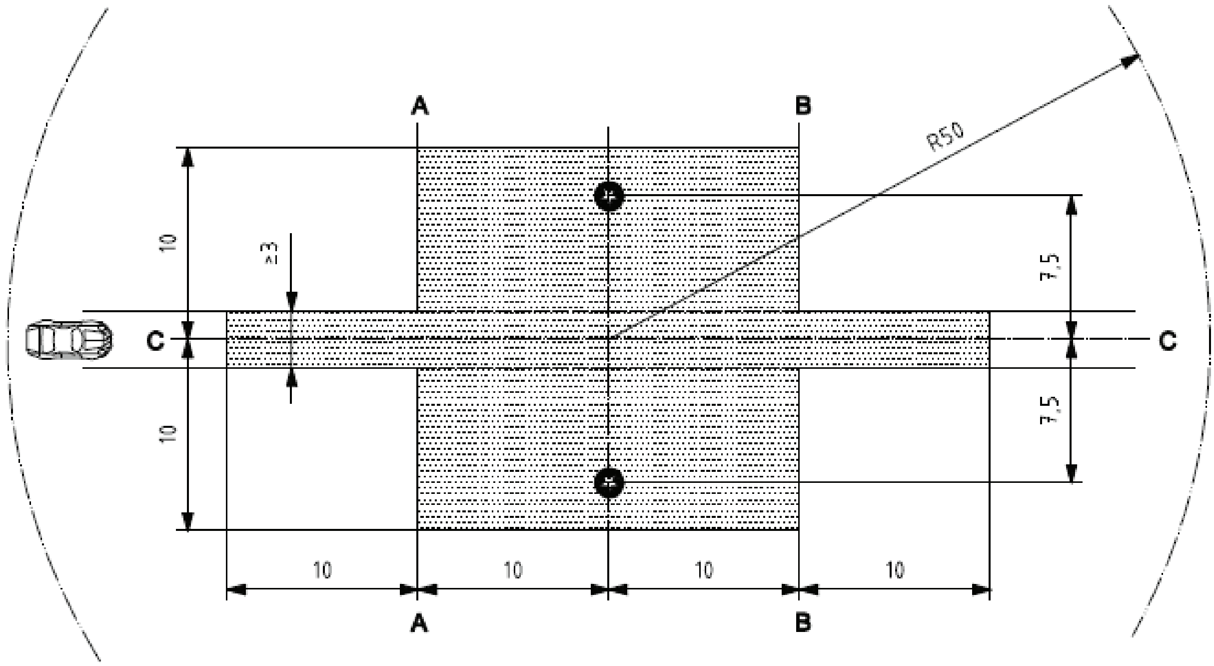
The test site shall be substantially level. The test track construction and surface shall meet the requirements of ISO 10844:2014. The test site dimensions reflecting ISO 10844:1994 are shown in Figure 1.

NOTE 1 The symbols in Figure 1 are directly copied from ISO 10844:1994 and are not necessarily consistent with the symbols in this part of ISO 362.

Within a radius of 50 m around the centre of the track, the space shall be free of large reflecting objects such as fences, rocks, bridges, or buildings. The test track and the surface of the site shall be dry and free from absorbing materials such as powdery snow or loose debris.

In the vicinity of the microphone, there shall be no obstacle that can influence the acoustical field and no person shall remain between the microphone and the noise source. The meter observer shall be positioned so as not to influence the meter reading.

NOTE 2 Buildings outside the 50 m radius can have significant influence if their reflection focuses on the test track.



Key

(empty box)	minimum area covered with test road surface, i.e. test area
(filled circle)	microphone positions (height 1,2 m)

NOTE Shaded area ("test area") is the minimum area that it is required to cover with a surface complying with ISO 10844.

Figure 1 — Test site dimensions

7.2 Meteorological conditions

The meteorological instrumentation shall deliver data representative of the test site and shall be positioned adjacent to the test area at a height representative of the height of the measuring microphone.

The measurements shall be made when the ambient air temperature is within the range from 5 °C to 40 °C. The tests shall not be carried out if the wind speed, including gusts, at microphone height exceeds 5 m/s during the sound measurement interval.

A value representative of temperature, wind speed and direction, relative humidity, and barometric pressure shall be recorded during the sound measurement interval.

NOTE Refer to Annex B for the effects of temperature and other factors.

7.3 Background noise

Any sound peak that appears unrelated to the characteristics of the general sound level of the vehicle shall be ignored when taking the readings.

The background noise shall be measured for a duration of 10 s immediately before and after a series of vehicle tests. The measurements shall be made with the same microphones and microphone locations used during the test. The maximum A-weighted sound pressure level shall be reported.

The background noise (including any wind noise) shall be at least 10 dB below the A-weighted sound pressure level produced by the vehicle under test. If the difference between the ambient sound pressure level and the measured sound pressure level is between 10 dB and 15 dB, in order to calculate the *j*th test result, the appropriate correction shall be subtracted from the readings on the sound level meter, as given in Table 2.

Table 2 — Correction applied to an individual measured test value

Background sound pressure level difference to measured sound pressure level, in dB	10	11	12	13	14	≥15
Correction, in dB	0,5	0,4	0,3	0,2	0,1	0,0

8 Test procedures

8.1 Microphone positions

The distance from the microphone positions on the microphone line PP' to the perpendicular reference line CC' (see Figure 1) on the test track shall be 7,5 m ± 0,05 m.

The microphone shall be located 1,2 m ± 0,02 m above the ground level. The reference direction for free-field conditions (see IEC 61672-1) shall be horizontal and directed perpendicularly towards the path of the vehicle line CC'.

8.2 Conditions of the vehicle

8.2.1 General conditions

The vehicle shall be supplied as specified by the vehicle manufacturer.

Before the measurements are started, the vehicle shall be brought to its normal operating conditions.

The variation of results between runs can be reduced if there is a 1-min wait, at idle in neutral, between runs.

8.2.2 Test mass of the vehicle

8.2.2.1 General

Measurements shall be made on vehicles at the test mass m_t specified in Table 3.

Target mass, m_{target}, is used to denote the mass that N2 and N3 vehicles should be tested at. The actual test mass can be less due to limitations on vehicle and axle loading.

Table 3 — Test mass, m_t

Vehicle category	**Vehicle test mass** kg
M1	$m_t = m_{ref} = m_{kerb}$ + 75 kg. The 75 kg added mass accounts for the mass of the driver according to ISO 2416. The test mass shall be achieved with a tolerance of ±5 %.
N1 [a, b]	$m_t = m_{ref} = m_{kerb}$ + 75 kg. The 75 kg added mass accounts for the mass of the driver according to ISO 2416. The test mass shall be achieved with a tolerance of ±5 %.

[a] N1 category vehicles may be loaded, at the discretion of the vehicle manufacturer, for practical reasons during the test. This practice is acceptable; however, it can lead to a higher level of vehicle noise (typically 1 dB).

[b] If load is added to these vehicles during testing, the added payload shall be noted in the test report.

Table 3 *(continued)*

Vehicle category	Vehicle test mass kg
N2, N3	m_{target} = 50 [kg/kW] × P_n [kW]. Extra loading, m_{xload}, to reach the target mass, m_{target}, of the vehicle shall be placed above the rear axle. The sum of the extra loading and the unladen rear axle load, $m_{ra\ load\ unladen}$, is limited to 75 % of the maximum axle capacity, $m_{ac\ ra\ max}$, allowed for the rear axle. The target mass shall be achieved with a tolerance of ±5 %. If the centre of gravity of the extra loading cannot be aligned with the centre of the rear axle, the test mass, m_t, of the vehicle shall not exceed the sum of the unladen front axle load, $m_{fa\ load\ unladen}$, and the unladen rear axle load plus the extra loading and the mass of driver, m_d. The test mass for vehicles with more than two axles shall be the same as for a two-axle vehicle. If the unladen vehicle mass, $m_{unladen}$, of a vehicle with more than two axles is greater than the test mass for the two-axle vehicle, then this vehicle shall be tested without extra loading. If the unladen vehicle mass, $m_{unladen}$, of a vehicle with two axles is greater than the target mass, then this vehicle shall be tested without extra loading.
M2, M3	$m_t = m_{ro}$ The mass in running order shall be achieved with a tolerance of ±5 %.
Incomplete M2, M3	m_{target} calculated according to the procedure for N2, N3 (see above) Or $m_t = m_{chassisM2M3} + m_{xloadM2M3} = m_{ro}$ The mass in running order shall be achieved with a tolerance of ±5 %.

[a] N1 category vehicles may be loaded, at the discretion of the vehicle manufacturer, for practical reasons during the test. This practice is acceptable; however, it can lead to a higher level of vehicle noise (typically 1 dB).

[b] If load is added to these vehicles during testing, the added payload shall be noted in the test report.

8.2.2.2 Calculation procedure to determine extra loading of N2 and N3 vehicles only

8.2.2.2.1 Calculation of extra loading

The target mass, m_{target}, (per kW rated power) for two-axle vehicles of category N_2 and N3 is specified in Table 3:

$$m_{target} = 50(\text{kg}/\text{kW}) \times P_n(\text{kW}) \qquad (7)$$

To reach the required target mass, m_{target}, for a vehicle being tested, the unladen vehicle, including the mass of the driver, m_d, shall be loaded with an extra mass, m_{xload}, which shall be placed above the rear axle as given in Formula (8):

$$m_{target} = m_{unladen} + m_d + m_{xload} \qquad (8)$$

The target mass, m_{target}, shall be achieved with a tolerance of ±5 %.

The vehicle mass of the test vehicle in the unladen condition, $m_{unladen}$, is calculated by measuring on a scale the unladen front axle load, $m_{fa\ load\ unladen}$, and the unladen rear axle load, $m_{ra\ load\ unladen}$, as given in Formula (9):

$$m_{unladen} = m_{fa\ load\ unladen} + m_{ra\ load\ unladen} \qquad (9)$$

By using Formulae (8) and (9), the extra loading, m_{xload}, is calculated as given in Formulae (10) and (11):

$$m_{xload} = m_{target} - (m_d + m_{unladen}) \qquad (10)$$

$$m_{\text{xload}} = m_{\text{target}} - \left(m_{\text{d}} + m_{\text{fa load unladen}} + m_{\text{ra load unladen}}\right) \tag{11}$$

The sum of the extra loading, m_{xload}, and the unladen rear axle load, $m_{\text{ra load unladen}}$, is limited to 75 % of the maximum axle capacity for the rear axle, $m_{\text{ac ra max}}$, as given in Formula (12):

$$0{,}75\ m_{\text{ac ra max}} \geq m_{\text{xload}} + m_{\text{ra load unladen}} \tag{12}$$

The m_{xload} is limited according to Formula (13):

$$m_{\text{xload}} \leq 0{,}75\ m_{\text{ac ra max}} - m_{\text{ra load unladen}} \tag{13}$$

If the calculated extra loading, m_{xload}, in Formula (11) fulfils Formula (13), then the extra loading is equal to Formula (11). The test mass, m_{t}, of the vehicle is as calculated from Formula (14):

$$m_{\text{t}} = m_{\text{xload}} + m_{\text{d}} + m_{\text{fa load unladen}} + m_{\text{ra load unladen}} \tag{14}$$

In this case, the test mass of the vehicle is equal to the target mass

$$m_{\text{t}} = m_{\text{target}} \tag{15}$$

If the calculated extra loading, m_{xload}, in Formula (11) does not fulfil Formula (13), but rather fulfils Formula (16)

$$m_{\text{xload}} > 0{,}75\ m_{\text{ac ra max}} - m_{\text{ra load unladen}} \tag{16}$$

then, the extra loading, m_{xload}, shall be as given by Formula (17):

$$m_{\text{xload}} = 0{,}75\ m_{\text{ac ra max}} - m_{\text{ra load unladen}} \tag{17}$$

and the test mass, m_{t}, of the vehicle shall be as given by Formula (18):

$$m_{\text{t}} = 0{,}75\ m_{\text{ac ra max}} + m_{\text{d}} + m_{\text{fa load unladen}} \tag{18}$$

In this case, the test mass of the vehicle is lower than the target mass

$$m_{\text{t}} < m_{\text{target}} \tag{19}$$

8.2.2.2.2 Loading considerations if load cannot be aligned with the centre of rear axle

If the centre of gravity of the extra loading, m_{xload}, cannot be aligned with the centre of the rear axle, the test mass of the vehicle, m_{t}, shall not exceed the sum of the unladen front axle load, $m_{\text{fa load unladen}}$, and the unladen rear axle load, $m_{\text{ra load unladen}}$, plus the extra loading, m_{xload}, and the mass of the driver, m_{d}.

This means that if the actual front and rear axle loads are measured on a scale when the extra loading, m_{xload}, is placed onto the vehicle and it is aligned with the centre of the rear axle, the test mass of the vehicle minus the mass of the driver is as given by Formula (20):

$$m_t - m_d = m_{fa\ load\ laden} + m_{ra\ load\ laden} \tag{20}$$

where

$$m_{fa\ load\ laden} = m_{fa\ load\ unladen} \tag{21}$$

If the centre of gravity of the extra loading cannot be aligned with the centre of the rear axle, Formula (20) is still fulfilled, but

$$m_{fa\ load\ laden} > m_{fa\ load\ unladen} \tag{22}$$

because the extra loading has partly distributed its mass to the front axle. In that case, it is not allowed to add more mass onto the rear axle to compensate for the mass moved to the front axle.

8.2.2.2.3 Test mass for vehicles with more than two axles

If a vehicle with more than two axles is tested, then the test mass of this vehicle shall be the same as the test mass for the two-axle vehicle.

If the unladen vehicle mass of a vehicle with more than two axles is greater than the test mass for the two-axle vehicle, then this vehicle shall be tested without extra loading.

8.2.3 Tyre selection and condition

The tyres shall be appropriate for the vehicle and shall be inflated to the pressure recommended by the tyre manufacturer for the test mass of the vehicle. The tyre inflation pressure shall be recommended by the vehicle manufacturer for M1 and N1.

For certification and related purposes, additional requirements for the tyres, defined by regulation, are necessary. The tyres for such a test shall be selected by the vehicle manufacturer and shall correspond to one of the tyre sizes and types designated for the vehicle by the vehicle manufacturer. The tyre shall be commercially available on the market at the same time as the vehicle.

NOTE The tread depth can have a significant influence on the test result.

8.3 Operating conditions

8.3.1 Vehicles of categories M1 and M2 having a maximum authorized mass not exceeding 3 500 kg and category N1

8.3.1.1 General conditions

The path of the centreline of the vehicle shall follow line CC' as closely as possible throughout the entire test, from the approach to line AA' until the rear of the vehicle passes line BB' (see Figure 1). Any trailer that is not readily separable from the towing vehicle shall be ignored when considering the crossing of the line BB'. If the vehicle is fitted with more than two-wheel drive, test it in the drive selection that is intended for normal road use. If the vehicle is fitted with an auxiliary manual transmission or a multi-gear axle, the position used for normal urban driving shall be used. In all cases, the gear ratios for slow movements, parking, or braking, shall be excluded.

8.3.1.2 Test speed

The test speed, v_{test}, shall be 50 km/h ± 1 km/h. The test speed shall be reached when the reference point according to 3.5 is at line PP'. If the test speed is modified according to 8.3.1.3.2, the modified test speed shall be used for both the acceleration and constant speed test.

8.3.1.3 Gear ratio selection

8.3.1.3.1 General

It is the responsibility of the manufacturer to determine the correct manner of testing to achieve the required accelerations.

The vehicle transmission, gear, or gear ratio shall be chosen to provide acceleration nearest to a_{wot_ref} according to 8.3.1.3.2 and 8.3.1.3.3. The vehicle transmission, gear, or gear ratio may be controlled by electronic or mechanical measures including exclusion of kick-down function.

Annex C gives gear selection criteria and test run criteria for categories M1 and M2 having a maximum authorized mass not exceeding 3 500 kg and for category N1, in a flowchart form as an aid to test operation.

8.3.1.3.2 Manual transmission, automatic transmissions, adaptive transmissions, or transmissions with continuously variable gear ratios (CVTs) tested with locked gear ratios

The selection of gear ratios for the test depends on the specific acceleration achieved $a_{wot,\ i}$ under full-throttle condition according to the specification in 5.2.1 in relation to the reference acceleration, $a_{wot\ ref}$, required for the full-throttle acceleration test according to Formula (4).

The following conditions for the selection of gear ratios are possible.

NOTE 1 The selection of gear ratio is determined by the average of the four $a_{wot\ test,\ j}$ runs.

a) If one specific gear ratio gives acceleration in a tolerance band of ±5 % of the reference acceleration, $a_{wot\ ref}$, not exceeding 2,0 m/s^2, test with that gear ratio.

   NOTE 2 Individual $a_{wot\ test,j}$ runs may be in excess of 5 % of the reference acceleration.

b) If none of the gear ratios gives the required acceleration, then choose a gear ratio i, with an acceleration higher and a gear ratio $(i + 1)$, with an acceleration lower than the reference acceleration $a_{wot\ ref}$. If the acceleration value in gear ratio i does not exceed 2,0 m/s^2, use both gear ratios for the test. The gear ratio weighting factor k in relation to the reference acceleration $a_{wot\ ref}$ is calculated by Formula (23):

$$k = \left[a_{wot\ ref} - a_{wot(i+1)} \right] / \left[a_{wot\ i} - a_{wot(i+1)} \right] \quad (23)$$

   The value of k shall be calculated to two significant places after the decimal (x,xx). The final reported k shall be used in all subsequent calculations.

c) If the acceleration value of gear ratio i or $(i + 1)$ exceeds 2,0 m/s^2, the first gear ratio shall be used that gives an acceleration below 2,0 m/s^2 unless gear ratio $(i + 1)$ provides acceleration less than a_{urban}. The achieved acceleration $a_{wot\ test}$ during the test shall be used for the calculation of the partial power factor k_P instead of $a_{wot\ ref}$ for tests using one gear.

d) In the case where gear ratio $(i + 1)$ provides acceleration less than a_{urban}, two gears, i and $(i + 1)$, shall be used, including the gear i with acceleration exceeding 2,0 m/s^2. The gear ratio weighting factor k in relation to the reference acceleration $a_{wot\ ref}$ is calculated by Formula (23).

If the vehicle has a transmission in which there is only one selection for the gear ratio, the full-throttle test is carried out in this vehicle gear selection. The achieved acceleration $a_{wot\ test}$ is then used for the calculation of the partial power factor k_P (see 3.9) instead of $a_{wot\ ref}$.

If rated engine speed is exceeded in a gear ratio before the vehicle passes BB', the next higher gear shall be used. If the next higher gear results in an acceleration below a_{urban}, the vehicle test speed, v_{test}, shall be reduced by 2,5 km/h and the gear ratio selection shall proceed as specified by the options given in this paragraph. In no case shall the vehicle test speed be reduced below 40 km/h. In this case, a gear ratio is allowed even if a_{wot} test does not exceed a_{urban}.

8.3.1.3.3 Automatic transmission, adaptive transmissions, and transmissions with variable gear ratios tested with non-locked gear ratios

The gear selector position for full automatic operation shall be used.

The acceleration $a_{wot\ test}$ shall be calculated by Formula (1) or Formula (2) as specified in 5.2.

The test can then include a gear change to a lower range and a higher acceleration. A gear change to a higher range and a lower acceleration is not allowed. In any case, a gear shifting to a gear ratio that is typically not used at the specified condition as defined by the manufacturer in urban traffic shall be avoided.

Therefore, it is permitted to establish and use electronic or mechanical devices, including alternative gear selector positions, to prevent a downshift to a gear ratio which is typically not used at the specified test condition as defined by the manufacturer in urban traffic.

The achieved acceleration, $a_{wot\ test}$, shall be greater than or equal to a_{urban}.

If possible, the manufacturer shall take measures to avoid an acceleration value $a_{wot\ test}$ greater than $a_{wot\ ref}$ or 2,0 m/s^2, whichever is lower. Electronic or mechanical measures are permitted for all vehicle technologies to control vehicle operation to achieve the acceleration conditions.

The achieved acceleration, $a_{wot\ test}$, is then used for the calculation of the partial power factor k_P (see 3.9) instead of $a_{wot\ ref}$.

8.3.1.4 Acceleration test

The acceleration test shall be carried out in all gear ratios specified for the vehicle according to 8.3.1.3 with the test speed specified in 8.3.1.2.

When the front of the vehicle reaches the AA', the acceleration control unit shall be fully engaged and held fully engaged until the rear of the vehicle reaches BB'. The acceleration control unit shall then be released. Pre-acceleration can be used if acceleration is delayed beyond AA'. The location of the start of the acceleration shall be reported.

The vehicle speeds measured $v_{AA'}$, $v_{BB'}$, or $v_{PP'}$ shall be reported to the first digit after the decimal place (xx,x). The resulting vehicle speeds shall be used in all subsequent calculations.

The calculated acceleration $a_{wot\ test}$ shall be reported as specified in 5.2.1 or 5.2.2, as applicable.

8.3.1.5 Constant-speed test

The constant-speed test is not required for vehicles with a PMR < 25.

For vehicles with transmissions specified in 8.3.1.3.2, the constant-speed test shall be carried out with the same gears specified for the acceleration test. For vehicles with transmissions specified in 8.3.1.3.3, the gear selector position for full automatic operation shall be used. If the gear is locked for the acceleration test, the same gear shall be locked for the constant-speed test.

During the constant-speed test, the acceleration control unit shall be positioned to maintain a constant speed between AA' and BB' as specified in 8.3.1.2.

8.3.2 Vehicles of category M2 having a maximum authorized mass exceeding 3 500 kg, and categories M3, N_2 and N3

8.3.2.1 General conditions

The path of the centreline of the vehicle shall follow line CC' as closely as possible throughout the entire test, from the approach to line AA' until the rear of the vehicle passes line BB' (see Figure 1) or the reference point is 5 m behind line BB', whichever occurs first. The test shall be conducted without a trailer or semi-trailer. If a trailer is not readily separable from the towing vehicle, it shall be ignored when considering the crossing of line BB'. If the vehicle incorporates equipment such as a concrete mixer, a compressor, etc., this equipment shall not be in operation during the test. The test mass of the vehicle including the test payload shall be according to Table 3.

The value of $n_{BB'}$ and $v_{BB'}$ used in the determination of gear and vehicle speed selection shall be the average of the four $n_{BB', j}$ and $v_{BB', j}$ values during each valid measurement run.

The value of $n_{BB'}$ shall be reported to a precision of 10 r/min. The reported $n_{BB'}$ shall be used in all subsequent calculation.

The value of $v_{BB'}$ shall be reported to the first digit after the decimal (xx,x). The reported $v_{BB''}$ shall be used in all subsequent calculation.

8.3.2.2 Target conditions

8.3.2.2.1 Vehicles of category M2 having a maximum authorized mass exceeding 3 500 kg, and category N_2

When the reference point passes BB', the engine rotational speed, $n_{BB'}$, shall fulfil the target engine rotational speed, $n_{target\ BB'}$. The target engine rotational speed, $n_{target\ BB'}$, is defined as an interval from 70 % to 74 % of the speed, S.

When the reference point passes BB', the vehicle speed, $v_{BB'}$, shall fulfil the target vehicle speed, $v_{target\ BB'}$. The target vehicle speed, $v_{target\ BB'}$, is defined as 35 km/h ± 5 km/h.

8.3.2.2.2 Categories M3 and N3

When the reference point passes BB', the engine rotational speed, $n_{BB'}$, shall fulfil the target engine rotational speed, $n_{target\ BB'}$. The target engine rotational speed, $n_{target\ BB'}$, is defined as an interval from 85 % to 89 % of the speed, S.

When the reference point passes BB', the vehicle speed, $v_{BB'}$, shall fulfil the target vehicle speed, $v_{target\ BB'}$. The target vehicle speed, $v_{target\ BB'}$, is defined as 35 km/h ± 5 km/h.

8.3.2.3 Gear selection

8.3.2.3.1 General

It is the responsibility of the manufacturer to determine the correct manner of testing to achieve the required conditions.

Stable acceleration conditions shall be insured.

The vehicle transmission, gear, or gear ratio, shall be chosen to be able to fulfil the target conditions according to 8.3.2.2. The vehicle transmission, gear, or gear ratio can be controlled by electronic or mechanical measures including exclusion of kick-down function.

Annex D, Annex E, and Annex F give gear selection criteria and test run criteria for categories M2 having a maximum authorized mass exceeding 3 500 kg, and for category N_2, M3 and N3, in a flowchart as an aid to test operation.

8.3.2.3.2 Manual transmission, automatic transmissions, adaptive transmissions or transmissions with continuously variable gear ratios (CVTs) tested with locked gear ratios

The gear choice is determined by the target conditions.

The following conditions for fulfilling the target conditions in 8.3.2.2 are possible.

a) If one gear choice fulfils both target conditions for the rotational engine speed $n_{\text{target BB'}}$ and for the vehicle speed $v_{\text{target BB'}}$, test with that gear.

b) If more than one gear choice fulfils both target conditions for the rotational engine speed $n_{\text{ target BB'}}$ and for the vehicle speed $v_{\text{ target BB'}}$, test in gear i that gives velocity $v_{\text{BB' gear I}}$ closest to 35 km/h

c) If two gear choices fulfil both target conditions for the rotational engine speed $n_{\text{ target BB'}}$ and for the vehicle speed $v_{\text{ target BB'}}$, and fulfil the following condition

$(v_{\text{target BB'}} - v_{\text{BB' gear i}}) = (v_{\text{BB' gear i+1}} - v_{\text{target BB'}})$

then both gears are taken for further calculation of L_{urban}.

d) If one gear choice fulfils the target condition for the rotational engine speed $n_{\text{target BB'}}$ but not the target condition for the vehicle speed $v_{\text{target BB'}}$, use two gears, gear_x and gear_y. The target conditions for the vehicle speed for these two gears are as follows:

gear $_x$

$25 \text{ km/h} \leq v_{\text{BB'x}} \leq 30 \text{ km/h}$

and

gear $_y$

$40 \text{ km/h} \leq v_{\text{BB'y}} \leq 45 \text{ km/h}$

Both gears, gear_x and gear_y shall fulfil the target rotational engine speed $n_{\text{ target BB'}}$.

Both gears shall be used for further calculation of L_{urban}.

If only one of the gears fulfils the target rotational engine speed, $n_{\text{target BB'}}$, test with that gear. This gear shall be used for further calculation of L_{urban}.

e) If none of the two gears fulfils the target rotational engine speed $n_{\text{target BB'}}$ under condition d) then condition f) shall be chosen.

f) If no gear choice fulfils the target rotational engine speed choose the gear that fulfils the target vehicle velocity $v_{\text{target BB'}}$ and is closest to the target rotational engine speed $n_{\text{target BB'}}$, but not higher than $n_{\text{target BB'}}$.

$v_{\text{BB' gear i}} = v_{\text{target BB'}}$

$n_{\text{BB' gear i}} \leq n_{\text{target BB'}}$

A stable acceleration condition shall be insured. If a stable acceleration cannot be insured in a gear, this gear shall be disregarded. In all conditions, the rated engine speed shall not be exceeded while the reference point of the vehicle is in the measurement zone. If the rated engine speed is exceeded within the measurement zone, this gear shall be disregarded.

8.3.2.3.3 Automatic transmission, adaptive transmissions, and transmissions with variable gear ratio tested with non-locked gear ratios

The gear selector position for full automatic operation shall be used.

The test can then include a gear change to a lower range and a higher acceleration. A gear change to a higher range and a lower acceleration is not allowed. In any case, a gear change to a gear ratio that is typically not used at the specified condition as defined by the manufacturer in urban traffic shall be avoided.

Therefore, it is permitted to establish and use electronic or mechanical devices, including alternative gear selector positions, to prevent a downshift to a gear ratio that is typically not used at the specified test condition as defined by the manufacturer in urban traffic.

The following conditions for fulfilling the target conditions in 8.3.2.2 are possible.

a) If the choice of the gear selector position fulfils both target conditions for the rotational engine speed $n_{\text{target BB'}}$ and for the vehicle speed $v_{\text{target BB'}}$, test with the gear selector in that position.

b) If the choice of the gear selector position fulfils the target condition for the rotational engine speed $n_{\text{target BB'}}$ but not the target condition for the vehicle speed $v_{\text{target BB'}}$, change the target condition for the vehicle speed to two vehicle target speeds as follows:

   Define $v_{\text{BB'1}}$ as

   $25\ \text{km/h} \leq v_{\text{BB'1}} \leq 35\ \text{km/h}$

   and

   Define $v_{\text{BB'2}}$ as

   $35\ \text{km/h} \leq v_{\text{BB'2}} \leq 45\ \text{km/h}$.

   Conduct two tests, one with $v_{\text{BB'1}}$ and one with $v_{\text{BB'2}}$.

   Both test conditions are used for further calculation of L_{urban}.

c) If under condition b) the target rotational engine speed $n_{\text{target BB'}}$ cannot be fulfilled, condition d) shall be chosen.

d) If the choice of the gear selector position cannot fulfil the target condition for the rotational engine speed $n_{\text{target BB'}}$ but the target condition for the vehicle speed $v_{\text{target BB'}}$, change the target condition for the vehicle speed to two vehicle target speeds as follows:

   Define $v_{\text{BB'1}}$ as

   $25\ \text{km/h} \leq v_{\text{BB'1}} \leq 30\ \text{km/h}$

   and

   Define $v_{\text{BB'2}}$ as

   $40\ \text{km/h} \leq v_{\text{BB'2}} \leq 45\ \text{km/h}$.

   Conduct two tests, one with $v_{\text{BB'1}}$ and one with $v_{\text{BB'2}}$.

   Use the test where $n_{\text{BB'}}$ is closest to the target rotational engine speed $n_{\text{target BB'}}$ but not higher than $n_{\text{target BB'}}$.

   $n_{\text{BB' i}} \leq n_{\text{target BB'}}$ for i = 1, 2

   If the vehicle cannot fulfil the condition:

   $n_{\text{BB' i}} \leq n_{\text{target BB'}}$ for i = 1, 2

   condition e) shall be used.

e) If the choice of the gear selector position cannot fulfil the target conditions for the rotational engine speed $n_{target\,BB'}$ and the target condition for the vehicle speed $v_{target\,BB'}$, change the target condition for the vehicle speed to the following:

$v_{BB'} = v_{target\,BB'} + 5$ km/h

Conduct the test with that vehicle speed $v_{BB'}$. where $n_{BB'}$ is closest to the target rotational engine speed $n_{target\,BB'}$.

A gear change to a higher range and a lower acceleration is allowed after the vehicle passes line PP'.

f) If the vehicle includes a transmission design that provides only a single gear selection (D) that limits engine speed during the test, the vehicle shall be tested using only the target vehicle speed $v_{target\,BB'}$,.

8.3.2.3.4 Powertrains with no rotational engine speed available

Vehicles with a powertrain where no rotational engine speed is available shall fulfill only the target condition for the vehicle speed $v_{target\,BB'}$

The following conditions for fulfilling the target condition $v_{target\,BB'}$ in 8.3.2.2 are possible.

a) If no rotational engine speed is available, it is necessary to fulfil only the target vehicle speed $v_{target\,BB'}$.

b) If no rotational engine speed is available and the target vehicle speed $v_{target\,BB'}$ cannot be fulfilled, two test conditions shall be conducted as follows:

$v_{BB'1}$ for the first test condition is defined as

25 km/h ≤ $v_{BB'1}$ ≤ 35 km/h

and

$v_{BB'2}$ for the second test condition is defined as

35 km/h ≤ $v_{BB'2}$ ≤ 45 km/h

Both test conditions are used for further calculation of L_{urban}.

c) If no rotational engine speed is available and the target vehicle speed $v_{target\,BB'}$ and

$v_{BB'1}$ defined as

25 km/h ≤ $v_{BB'1}$ ≤ 35 km/h

cannot be fulfilled, it is necessary to conduct, only one test with $v_{BB'2}$ where

$v_{BB'2}$ is defined as

35 km/h ≤ $v_{BB'2}$ ≤ 45 km/h

The test condition for $v_{BB'2}$ is taken for further calculation of L_{urban}

NOTE What is the interpretation of broaden the window for the target vehicle velocity? The target vehicle velocity $v_{target\,BB'}$ is defined as $v_{target\,BB'}$ = 35 km/h ± 5 km/h which results in a window for the velocity $v_{BB'}$, when the reference point passes line BB', from 30 km/h to 40 km/h If the target vehicle velocity $v_{target\,BB'}$ is changed into two target vehicle velocities, a lower and a higher one, the following is meant: The lower target vehicle velocity is defined as the target vehicle velocity $v_{target\,BB'}$ reduced by 5 km/h ($v_{target\,BB'}$ - 5 km/h) which results in a window for the velocity $v_{BB'1}$, when the reference point passes line BB', from 25 km/h to 35 km/h

25 km/h ≤ $v_{BB'1}$ ≤ 35 km/h

The higher target vehicle velocity is defined as the target vehicle velocity $v_{target\,BB'}$ increased by 5 km/h ($v_{target\,BB'}$ + 5 km/h) which results in a window for the velocity $v_{BB'2}$, when the reference point passes line BB', from 35 km/h to 45 km/h

35 km/h ≤ $v_{BB'2}$ ≤ 45 km/h

8.3.2.4 Wide-open-throttle test

When the reference point of the vehicle reaches AA', the acceleration control unit shall be fully engaged and held fully engaged until the reference point reaches BB' + 5 m. The acceleration control unit can then be released on request of the manufacturer.

8.4 Measurement readings and reported values

8.4.1 General

8.4.1.1 Measurement conditions and acceptance

At least four measurements for all test conditions shall be made on each side of the vehicle and for each gear ratio.

The first four *j*th valid consecutive measurement results for any test condition, within 2,0 dB, allowing for the deletion of non-valid results, shall be used for the calculation of the appropriate intermediate or final result.

8.4.1.2 Vehicles of categories M1 and M2 having a maximum authorized mass not exceeding 3500 kg, and category N1

The maximum recorded A-weighted sound pressure level shall be noted, to the first significant digit after the decimal place (e.g. xx,x), during each passage of the vehicle between AA' and BB' (see Figure 1). These values shall be used in all subsequent calculations. If a sound peak obviously out of character with the general sound pressure level is observed, that measurement shall be discarded.

8.4.1.3 Vehicles of category M2 having a maximum authorized mass exceeding 3 500 kg and categories M3, N2, and N3

The maximum recorded A-weighted sound pressure level shall be noted, to the first significant digit after the decimal place (e.g. xx,x), during each passage of the reference point of the vehicle between AA' and BB' + 5 m (see Figure 1). These values shall be used in all subsequent calculations. If a sound peak obviously out of character with the general sound pressure level is observed, that measurement shall be discarded.

8.4.2 Data compilation

For a given test condition, the results of each side of the vehicle shall be averaged separately. The intermediate result for each side shall be the average mathematically rounded to the first decimal place.

All further calculations to derive L_{urban} shall be done separately for the left and right vehicle side. The final value to be reported as the test result shall be the higher value of the two sides. The final result shall be reported mathematically rounded to the nearest integer.

NOTE 1 Calculations are carried out independently on the left and right side of the vehicle to provide data consistent with vehicle noise emission behaviour.

NOTE 2 Reporting results with one integer do not imply that the measurement is accurate to this precision. See 8.5 for full treatment.

8.4.3 Vehicles of categories M1 and M2 having a maximum authorized mass not exceeding 3 500 kg and category N1

8.4.3.1 Acceleration

The acceleration for further use is the average acceleration of the four runs, as given by Formula (24):

$$a_{\text{wot test}} = (1/4) \times \left[a_{\text{wot test}(1)} + a_{\text{wot test}(2)} + a_{\text{wot test}(3)} + a_{\text{wot test}(4)} \right] \quad (24)$$

where the numbers in round brackets symbolize the test runs *j*.

8.4.3.2 Reported value and final results

Calculate the reported value $L_{\text{wot rep}}$ for the wide-open-throttle test using Formula (25):

$$L_{\text{wot rep}} = L_{\text{wot}(i+1)} + k \left[L_{\text{wot } i} - L_{\text{wot}(i+1)} \right] \quad (25)$$

where *k* is the gear ratio weighting factor.

Calculate the reported value $L_{\text{crs rep}}$ for the constant speed test using Formula (26)

$$L_{\text{crs rep}} = L_{\text{crs}(i+1)} + k \left[L_{\text{crs } i} - L_{\text{crs}(i+1)} \right] \quad (26)$$

In the case of a single gear ratio test, the reported values are directly derived from the test result itself.

The formulae used to determine the partial power factor, k_{P}, are as follows:

a) In cases other than a single gear test, k_{P} is calculated by Formula (27):

$$k_{\text{p}} = 1 - \left(a_{\text{urban}} / a_{\text{wot ref}} \right) \quad (27)$$

b) If only one gear is specified for the test, k_{P} is given by Formula (28):

$$k_{\text{p}} = 1 - \left(a_{\text{urban}} / a_{\text{wot test}} \right) \quad (28)$$

c) In cases where $a_{\text{wot test}}$ is less than a_{urban}

$$k_{\text{p}} = 0 \quad (29)$$

The final result is calculated by combining Formula (25) for $L_{\text{wot rep}}$ and Formula (26) for $L_{\text{crs rep}}$ as given by Formula (30):

$$L_{\text{urban}} = L_{\text{wot rep}} - k_{\text{p}} \left(L_{\text{wot rep}} - L_{\text{crs rep}} \right) \quad (30)$$

The final result, L_{urban}, is mathematically rounded to the nearest integer. This value is reported as the final result.

8.4.4 Vehicles of category M2 having a maximum authorized mass exceeding 3 500 kg and categories M3, N2, and N3

When the result of one test condition is used, the final result, L_{urban}, is the maximum value as specified in 8.4.2.

When the result of two test conditions are used, the arithmetic mean of the two averages for each side of these two conditions shall be calculated. The final result, L_{urban}, is the maximum value of the two calculated averages.

The final result, L_{urban}, is mathematically rounded to the nearest integer. This value is reported as the final result.

8.5 Measurement uncertainty

The measurement procedure described in 8.4 is affected by several parameters (e.g. ISO 10844 surface texture variation, environmental conditions, measurement system uncertainty, etc.) that lead to variation in the resulting level observed for the same subject. The source and nature of these perturbations are not completely known and sometimes affect the end result in a non-predictable way. The uncertainty of results obtained from measurements according to this part of ISO 362 can be evaluated by the procedure given in ISO/IEC Guide 98-3 or by interlaboratory comparisons in accordance with ISO 5725 (all parts). Since extensive inter- and intra-laboratory data were not available, the procedure given in ISO/IEC Guide 98-3 was followed to estimate the uncertainty associated with this part of ISO 362. The uncertainties given below are based on existing statistical data, analysis of tolerances stated in this part of ISO 362, and engineering judgement. The uncertainties determined are grouped as follows:

a) variations expected within the same test laboratory and slight variations in ambient conditions found within a single test series (run-to-run);

b) variations expected within the same test laboratory but with variation in ambient conditions and equipment properties that can normally be expected during the year (day-to-day);

c) variations between test laboratories where, apart from ambient conditions, equipment, staff, and road surface conditions are also different (site-to-site).

If reported, the expanded uncertainty together with the corresponding coverage factor for the stated coverage probability of 80 % as defined in ISO/IEC Guide 98-3 shall be given. Information on the determination of the expanded uncertainty is given in Annex B.

NOTE Annex B gives a framework for analysis in accordance with ISO/IEC Guide 98-3, which can be used to conduct future research on measurement uncertainty for this part of ISO 362.

These data are given in Table 4 for two different vehicle categories. The variability is given for a coverage probability of 80 %. The data express the variability of results for a certain measurement object and do not cover product variation.

Table 4 — Variability of measurement results for a coverage probability of 80 %

Vehicle category	Run-to-run dB	Day-to-day dB	Site-to-site dB
M1, M2 having a maximum authorized mass not exceeding 3 500 kg and N1	0,5	0,9	1,4
M2 having a maximum authorized mass exceeding 3 500 kg and N2, M3, N3	0,5	0,9	1,4

Until more specific knowledge is available, the data for site-to-site variability can be used in test reports to state the expanded measurement uncertainty for a coverage probability of 80 %.

9 Test report

The test report shall include the following information:

a) a reference to this part of ISO 362 (i.e. ISO 362-1);

b) the details of the test site, site orientation, and weather conditions including wind speed and air temperature, wind direction, barometric pressure and humidity;

c) the type of measuring equipment, including the windscreen;

d) the maximum A-weighted sound pressure level typical of the background noise;

e) the identification of the vehicle, its engine, its transmission system, including available transmission ratios, size and type of tyres, tyre pressure, tyre production type, power, test mass, power-to-mass ratio, vehicle length, and location of the reference point;

f) the transmission gears or gear ratios used during the test;

g) the location of the beginning of the acceleration;

h) the vehicle speed ($v_{PP'}$, $v_{BB'}$) and engine rotational speed ($n_{BB'}$, $n_{PP'}$) at PP’ and at the end of the acceleration;

i) the method used for calculation of the acceleration;

j) the auxiliary equipment of the vehicle, where appropriate, and its operating conditions;

k) all valid A-weighted sound pressure level values measured for each test, listed according to the side of the vehicle and the direction of the vehicle movement on the test site.

Annex A
(informative)

Technical background for development of vehicle noise test procedure based on in-use operation in urban conditions

A.1 General

A.1.1 Explanation of technical background

This annex gives general technical background relating to the urban noise situation and the approach chosen to measure the noise contribution of a single vehicle in the overall urban noise situation. This annex is intended to provide information to evaluate the concepts used to guide the development of the procedures defined in this part of ISO 362. In support of the goal of providing background information, this annex uses examples drawn from the actual in-use studies but does not present the full in-use databases.

As vehicle noise emission is subject to regulation, an exterior noise measurement procedure for vehicles is used to evaluate the noise emission of the measured vehicle in typical urban traffic. The test procedures defined in this part of ISO 362 provide a measure of the noise emission of different vehicles in typical urban use. The noise emission so measured assumes a road surface with similar characteristics as defined in ISO 10844. ISO 10844 is representative of well-constructed and maintained asphalt road surfaces with small aggregate sizes. Reference [6] has shown the ISO 10844 surface to fall within the range of actual road surfaces in both the United States and Europe. Road surfaces that are specifically designed to be "silent" provided lower noise emission than the ISO 10844 surface. As a result, the procedures described in this part of ISO 362 represent a measure of the vehicle noise emission that is controllable by the vehicle manufacturer. Other contributors to the traffic noise situation are outside the control of vehicle manufacturers. These items include road surfaces, traffic regulations, aftermarket part control, in-use noise emission monitoring, and effective enforcement mechanisms.

A.1.2 Why a new procedure is necessary

The present procedure which supports regulation in all global markets is specified in ISO 362:1998. The measurement is performed on a specified test surface (see ISO 10844). The vehicle drives with wide-open-throttle, in second and/or third gear. The entry speed 10 m prior to the microphone position is 50 km/h. The resulting sound pressure level is the result of the single gear test for 2^{nd} or 3^{rd} gear only and the average of the measured sound pressure levels for the 2^{nd} and 3^{rd} gear test. With the support of this procedure, the regulated limit has been strongly reduced in most countries (from 82 dB to 74 dB in 20 years by ECE). However, the noise reduction observed in front of buildings measured in the same traffic conditions and during the same period has been weak.

A significant reason is the poor simulation of typical urban vehicle noise performed by the procedure (wide-open throttle, second and third gear). Many current regulatory implementations of ISO 362:1998 further impact the poor correlation between real traffic and the reported regulatory results by allowing the use of minimum tread depth tyres. A further reason for the poor simulation of typical urban vehicle noise is the technical development of vehicle engine technology and transmission technology that causes some of the original technical assumptions behind ISO 362:1998 to no longer be valid.

The result of these conditions is that ISO 362:1998, as implemented in regulations, measures vehicle noise in a condition dominated by powertrain noise. Since this condition is only rarely observed in urban traffic and tyre/road noise has been deliberately suppressed, the reported regulated levels do not provide a good measure of typical vehicle noise in urban traffic. Therefore, a new procedure that enables improved measurement of the actual level of noise due to vehicle emission in urban traffic and accounts for the technical developments in vehicle propulsion and transmission technology is a positive development for both directing government policy actions and for indicating to vehicle manufacturers an improved metric for optimizing the reduction of vehicle noise emission.

A.1.3 The contribution of an individual vehicle to overall traffic noise

Reference [9] showed that noise is an important concern for people living in large cities. The noise they endure is due to different sources: neighbours, city noises (street sweepers, sirens, etc.), aircraft, railways, and road traffic. The noise of these different sources can be subject to regulations with the goal of controlling the maximum noise in front of buildings.

The noise in front of buildings due to road traffic noise depends on different factors:

a) the way cities are built (primarily the distance between living houses and roads);

b) the actual traffic on the roads (number of vehicles);

c) the road surface as a contributing factor to tyre/road noise;

d) the sound path (noise transmission) control between the source and receiver (noise barriers, sound insulation, etc.);

e) the behaviour of drivers, which depends on

— speed limits (traffic laws),

— traffic density,

— road arrangement (traffic lights, corners, etc.),

— driving purpose (commuting, pleasure, commercial, etc.),

— enforcement of traffic laws, and

— the way the vehicle behaves as an acoustical source under these conditions.

A vehicle noise measurement procedure intended to describe the actual behaviour should take the actual driving conditions into account. Because there are many different driving conditions, the choice of a “representative” driving condition is difficult.

A.1.4 Information from previous traffic noise studies

Actual driving conditions do not all have the same influence on road traffic noise. As an example, some conditions occur on country roads, where nobody is annoyed by the noise.

Under what conditions is road traffic noise the most disturbing for dwellers?

A response to this question has been given by a study[10] (see Table A.1).

Table A.1 — Where are dwellers disturbed by vehicle traffic noise emission?

		Annoyed	Road	Annoyed	Road
Street-type	$V_{allowed}$	People	Length	People	Length
	in km/h		in m	in %	in %
Motorway	80 – 120	1 145	11 250	2,0	6,9
Residential streets	30	13 501	27 060	23,1	16,6
Main streets	50	42 704	109 233	73,0	67,1
Main streets	60	583	2 130	1,0	1,3
Arterials	70	139	3 390	0,2	2,1
Arterials	80	407	4 500	0,7	2,8
Arterials	100	21	5 300	0,0	3,3
Total number of inhabitants	220 000	58 500	162 863	100 %	100 %
	100 %	26,6 %			
Percentage of Various Road Catagories in Terms of Network Length and Noise-Affected Residents in a Medium-Sized City (FIGE Study from Dec. 98)					
+3 % of all people feel annoyed from noise emission during high acceleration.					

NOTE Table A.1 and all other figures in this Annex are directly copied from the literature; therefore, the notations of quantities and units do not always follow the use in this part of ISO 362.

Inquiries among dwellers along various streets show that noise disturbance happens mainly

— along urban main streets, and

— during vehicle acceleration transients.

The mean traffic speed is 50 km/h on these main streets (for the roads on which maximum allowed speed is 50 km/h) as shown in Figure A.1 based on research from Reference [9].

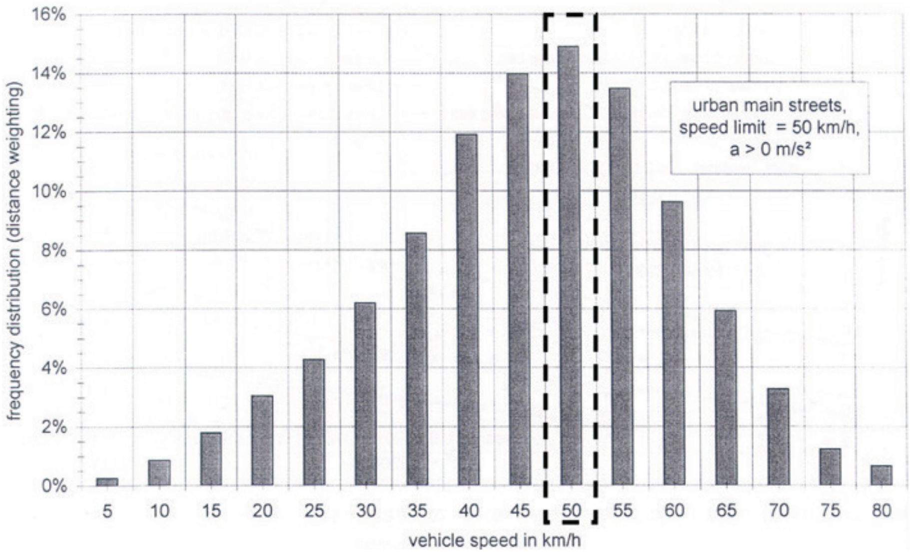


Figure A.1 — Measured vehicle speed in urban traffic and on the main roads

Based on these statistics, it was decided to perform the test at 50 km/h, in conditions representing the noisiest realistic case on main streets.

A.2 Concepts used in developing the new procedure for categories M1 and M2 having a maximum authorized mass not exceeding 3 500 kg and category N1

A.2.1 General

The first and main task of developing the new procedure was to describe the driving behaviour in urban traffic. Once this task was achieved, a new procedure was defined, which is a compromise between requirements.

— Measure the 90th percentile noise emission in typical urban driving (representative and reproducible).

— The test shall specify performance requirements only (no design-specific requirements).

— The test shall be applicable to all types of vehicles (technology neutral).

— The test shall be easy to run, consistent with the above requirements (practical).

A.2.2 Technical concepts for in-use vehicle measurement of urban driving behaviour

A.2.2.1 General

A.2.2.1.1 The vehicle noise depends mainly on three vehicle parameters:

— vehicle speed;

— vehicle acceleration (engine load);

— engine rotational speed (for internal combustion engines only).

A.2.2.1.2 Tyre/road noise is incorporated by its dependence on vehicle speed and vehicle acceleration. Two of the three parameters, vehicle speed and vehicle acceleration, describes driving behaviour. The vehicle parameters depend on the driver’s commands (input), but also on the vehicle performance and the traffic environment.

The third condition, engine rotational speed, is an additional parameter which is managed by the driver, or the transmission computer in the case of automatic transmissions, in order to achieve vehicle acceleration and vehicle speed. Thus, it is necessary that the urban traffic study identifies the independent parameters of

— vehicle speed, and

— vehicle acceleration.

A.2.2.1.3 In order to obtain this information, a study of the actual urban driving has been performed, including the following:

a) recording of vehicles in urban traffic;

b) extraction of acceleration phases;

c) identification of the highest acceleration (noisiest condition) as a function of vehicle speed;

d) identification of the highest acceleration (noisiest condition) at 50 km/h;

e) identification of the corresponding engine rotational speed;

f) for all vehicles, the urban behaviour is assumed to depend mainly on the vehicle performances, which can be described by the power-to-mass ratio (PMR). A regression analysis is, thus, performed between the PMR and the highest urban acceleration, and the corresponding engine rotational speed is recorded.

For manual transmission cars, the engine rotational speed is used by the driver to keep an “acceleration reserve”, i.e. a ratio between achieved and possible accelerations. Because the engine rotational speed is a “technological” or “design” parameter, it was decided to replace it by the acceleration ability, i.e. wide-open-throttle acceleration in urban driving conditions, a_{wot}. This way of describing the driver behaviour is, thus, applicable to very different kinds of engines (gasoline, diesel, wankel, hybrid, etc.).

An additional sample of vehicles was studied, and the correlation between a_{wot} and the PMR has been found. Since this information is required only to describe the way the driver manages the available power, it is necessary only for manual transmission cars. For automatic transmission vehicles, this parameter is controlled by the automatism.

The test procedure is then defined so as to reproduce the noisiest realistic urban driving conditions:

— 50 km/h;

— urban acceleration;

— for manual transmission cars: engine rotational speed conditions enabling a_{wot}.

Automatic transmission vehicles are covered as a subset of manual transmission vehicles. In actual in-use behaviour, automatic transmissions provide noise emissions equal to or lower than manual transmission vehicles.

A.2.2.2 Recording vehicle behaviour

In order to collect data about real urban use, 61 vehicles were driven in cities and their behaviour was recorded. This list includes European and Japanese vehicles of all types (M1, N1, N2, and one N3 up to 19 tons). The power ranged from 40 kW to 440 kW, whereas the power-to-mass ratio ranged from 12,7 to 380. The ratio between manual transmissions (52 manual transmission) and automatics (9 including 2 CVT) approximately represents the European market.

The vehicles were driven in eight different cities in Europe and Japan. The route selected to record the driving parameters (see Figure A.2) is representative of the different types of roadway, having different speed limits. The distance travelled on each type of roadway is proportional to the product of the roadway length and the traffic, which guarantees the same probability of occurrence as for a non-moving observer beside the road. During the recording, the driver was required to maintain normal driving behaviour in the traffic. Recording time was about 2 h of driving.

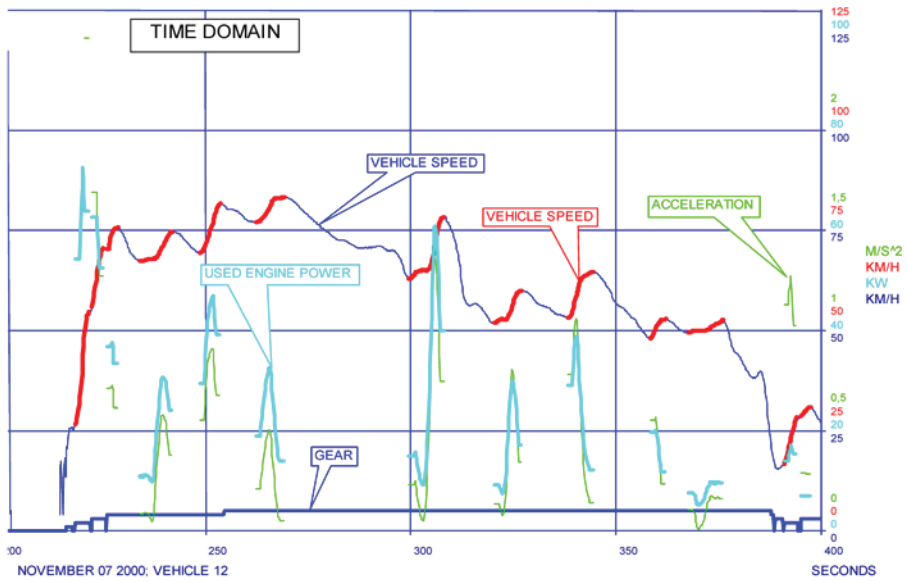


Figure A.2 — Time history of driving parameters

A.2.2.3 Identification of time events

First, the acceleration during driving was determined from the driving studies. To provide a figure for evaluation, the average value of the acceleration over a 2 s moving period was calculated. The maximum value for each 2 s acceleration phase was extracted (maximum acceleration a_{max}), together with the vehicle speed at which it occurred ($v_{a\ max}$). This was carried out according to the method shown in Figure A.3.

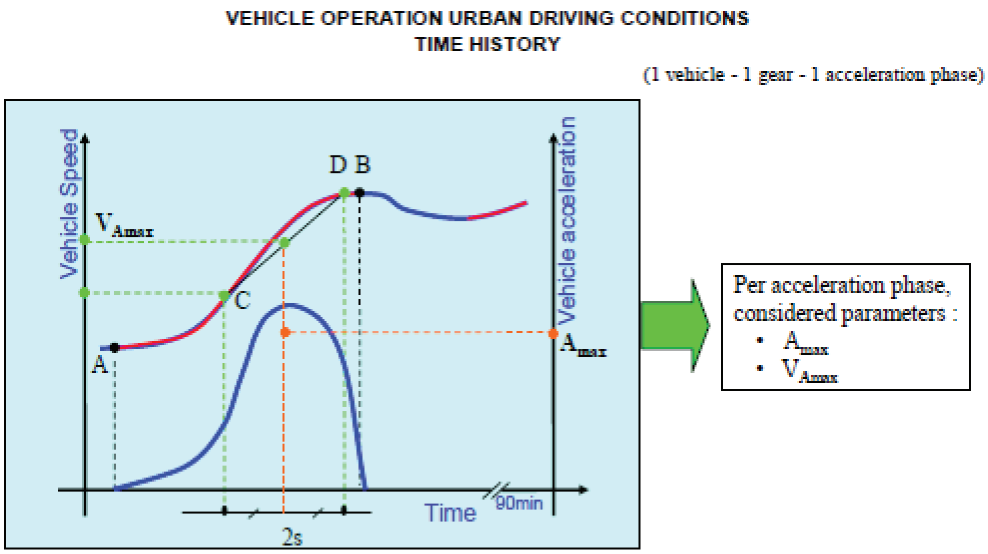


Figure A.3 — Maximum acceleration definition

Each acceleration peak a_{max} was stored together with the speed $v_{a\ max}$ and the gear ratio as a single event.

A.2.3 Statistical analysis of in-use data

A.2.3.1 One-dimensional analysis for a single vehicle

The maximum acceleration a_{max} and the vehicle speed $v_{a\ max}$ at which this maximum acceleration occurs, as shown in Figure A.3, are represented as a histogram and as a cumulative probability function for each gear. See Figure A.4 for peak acceleration and Figure A.5 for vehicle speed.

For each gear ratio and for all roads, the 90th percentile of peak acceleration $a_{max\ 90}$ at the most probable speed (50th percentile) $v_{a\ max\ 50}$ and the 90th percentile of peak acceleration $a_{max\ 90}$ at the maximum speed (90th percentile) $v_{a\ max\ 90}$ are considered.

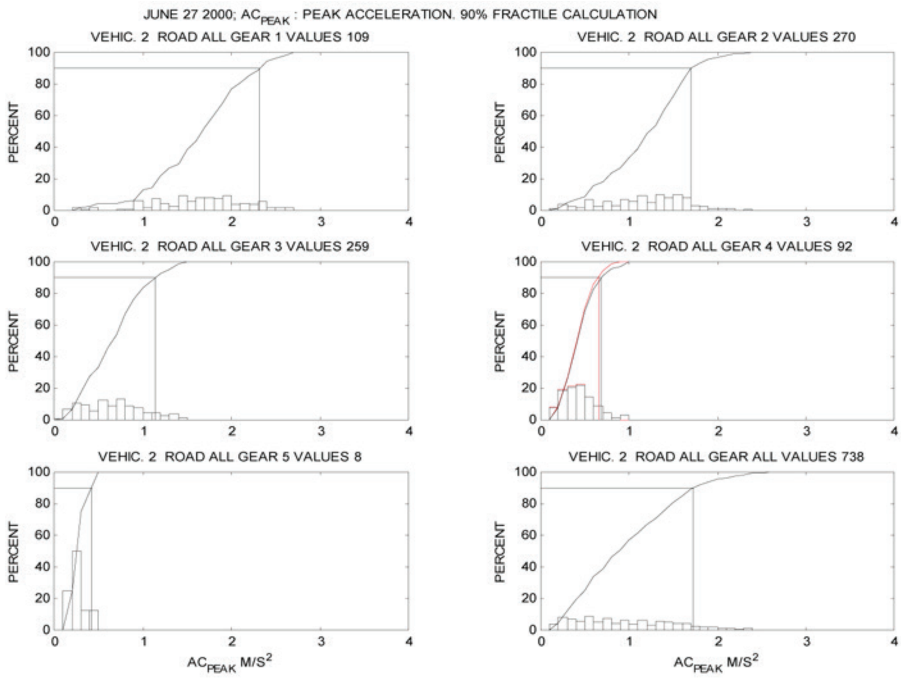


Figure A.4 — Histograms and cumulative probability functions of maximum acceleration

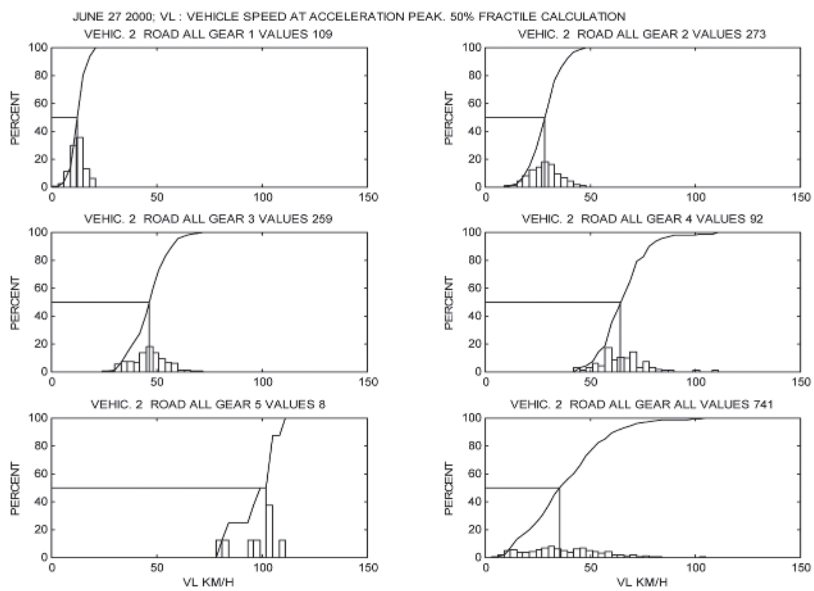


Figure A.5 — Histograms and cumulative probability functions of vehicle speed at maximum acceleration $v_{a\ max}$

This analysis, as shown above for one vehicle, has been done for each vehicle in the test.

A.2.3.2 Two-dimensional analysis

The results have also been combined in a two-dimensional diagram showing the density of probability of the individual events a_{max} and $v_{a\ max}$ (see Figure A.6). This figure shows the probability density for each gear ratio and for all gear ratios together.

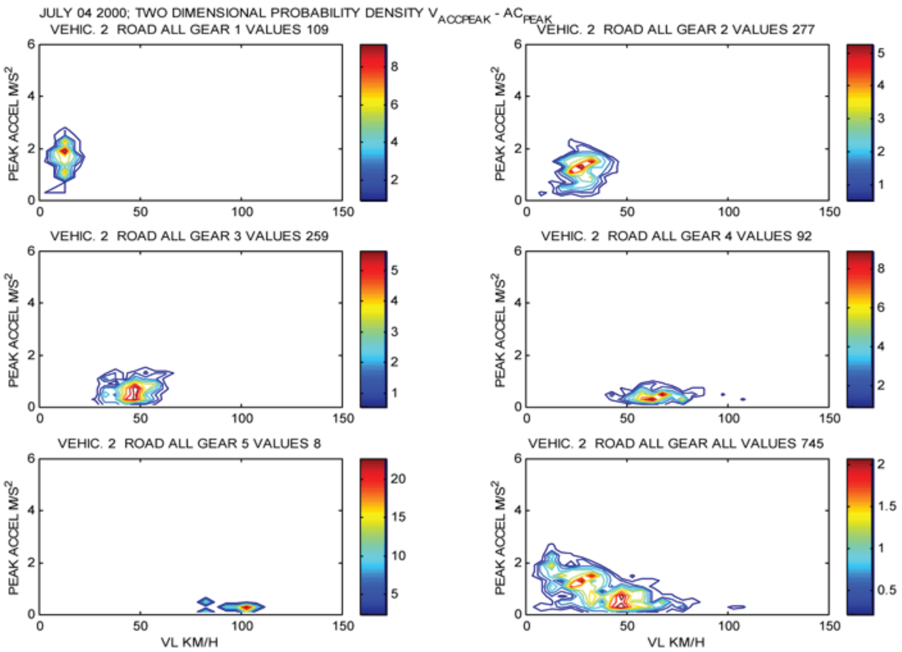


Figure A.6 — Two-dimensional probability density (a_{max}, $v_{a\ max}$) **for each gear for vehicle number 2**

Looking at this diagram, one can see the maximum value of the acceleration for each gear ratio. The last graph of all the gears and all the values shows that the maximum acceleration depends on the vehicle speed, with acceleration decreasing with increasing vehicle speed.

It is possible to place in the last graph the points [a_{max90}, $v_{a\ max\ 50}$] corresponding to each gear ratio using values from Figures A.4 and A.5. This has been done in Figure A.7, which includes a schematic representation of Figure A.6. The points [$a_{max\ 90}$, $v_{a\ max\ 90}$] are also drawn for each gear ratio.

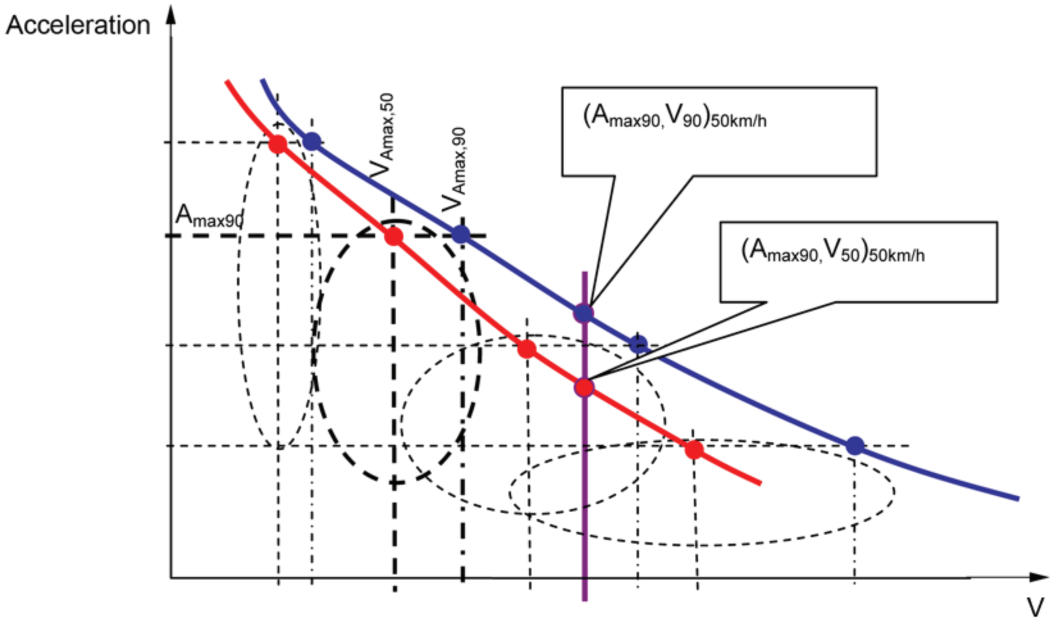


Figure A.7 — Interpolation at 50 km/h

The curve passing through the points [$a_{\text{max } 90}$, $v_{\text{a max } 50}$] corresponding to each gear ratio gives an estimate of the typical in-use limit of vehicle acceleration as a function of vehicle speed. But this lower curve is still below the maximum value observed for the acceleration in traffic. To estimate an acceleration curve representing a maximum, one can also consider the curve passing through the points [$a_{\text{max } 90}$, $v_{\text{a max } 90}$]. This curve is entirely above the maximum acceleration. Thus, the limit value is somewhere between the two curves.

Interpolating the two curves at 50 km/h enables one to estimate the 90$^{\text{th}}$ percentile of the acceleration for the 50th percentile of the velocity at 50 km/h, and the 90$^{\text{th}}$ percentile of the acceleration for the 90th percentile of the velocity at 50 km/h. The limit value of the acceleration at 50 km/h is somewhere between these two points.

A.2.4 Maximum acceleration and engine speed at 50 km/h

For each gear ratio, the vehicle speed corresponds to an engine rotational speed n. To be independent of rated engine rotational speed S, all engine speeds are expressed as a ratio between engine rotational speed and rated engine rotational speed, called n/S. Performing the same interpolation, one can obtain n/S at 50 km/h.

The way this interpolation is performed is described in Figure A.8, where

— accelerations come from Figure A.4,

— speeds come from Figure A.5 (50$^{\text{th}}$ percentile or 90$^{\text{th}}$ percentile), and

— engine rotational speeds are derived using gear ratios.

Figure A.8 uses the same scales as Figure A.7, vehicle speed and acceleration on the right scale, and adds engine rotational speed on the left scale.

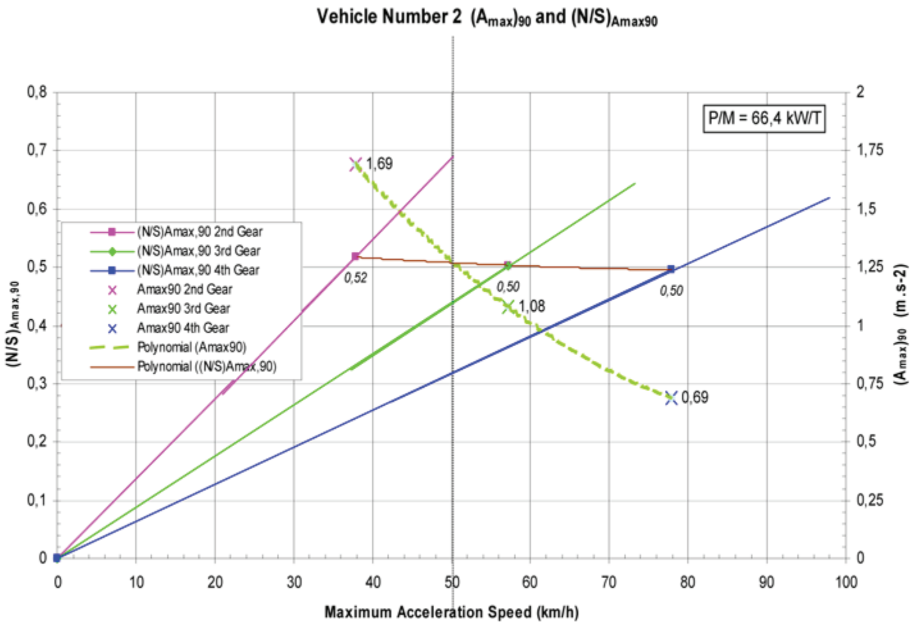


Figure A.8 — Interpolation ($a_{max\ 90}$ = f(v), n/S(a_{max})) **between gears, for vehicle number 2**

At this stage, it is not yet known how to describe precisely the noisiest behaviour in urban traffic.

A.2.5 Acceleration as a function of engine speed

Looking at the detailed results in Figure A.8, it can be seen that the engine speed is generally independent of the gear ratio at $a_{max\ 90}$. Of course, the vehicle speeds are different for each gear at the $a_{max\ 90}$ condition. This observation leads to the idea that it is possible to "merge" the results of all gear ratios in order to get an "average behaviour" at 50 km/h. This is carried out as follows:

— Peak accelerations are "compressed" using the ratio ($a_{max\ 90}$,50 km/h)/(a_{max90}, $v_{a\ max}$), one ratio for each gear;

— Engine speeds are calculated using $v_{a\ max}$ and the corresponding gear ratio.

This interpolation gives the acceleration that would have occurred at the same engine speed if the vehicle speed had been 50 km/h. This leads to the two-dimensional diagram of Figure A.9. The noisiest behaviour in urban traffic can be found from this diagram.

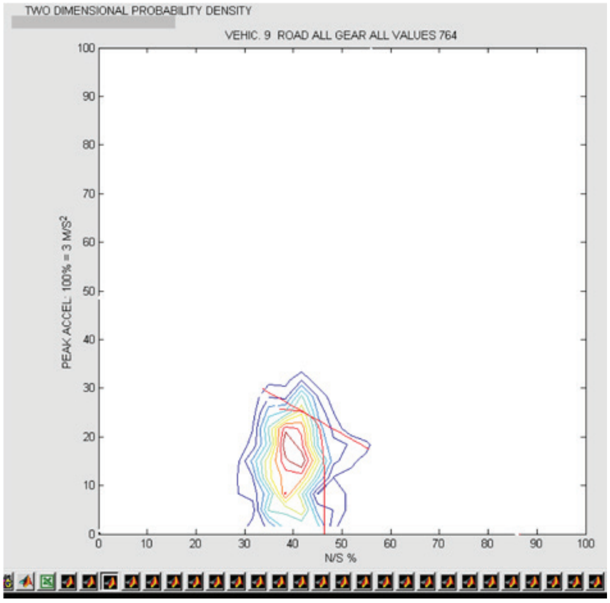


Figure A.9 — Bi-dimensional density of probability a = f(n/S) **at 50 km/h**

A.2.6 Noise behaviour on a test track

In order to study the partial load vehicle noise, it is necessary to make the assumption that the noise behaves in a linear way, at least as a function of the engine load and engine speed. Under this assumption, the noise is interpolated between a wide-open-throttle sound pressure level and a constant-speed sound pressure level.

Since only the acceleration is known, the acceleration ability (wide-open-throttle acceleration) of each vehicle is required. This value is measured on a test track at different speeds and with all gear ratios. The results are presented in Figure A.10.

The acceleration is evaluated during a stabilized acceleration starting before the measurement point. Different starting speeds lead to different vehicle speeds at the measurement point, which allows drawing a curve of the acceleration at the measurement point as a function of the speed at the measurement point.

From these curves, the 50 km/h value is extracted and is used to calculate the partial load factor defined by the quotient $a_i / a_{\text{wot}\ i}$.

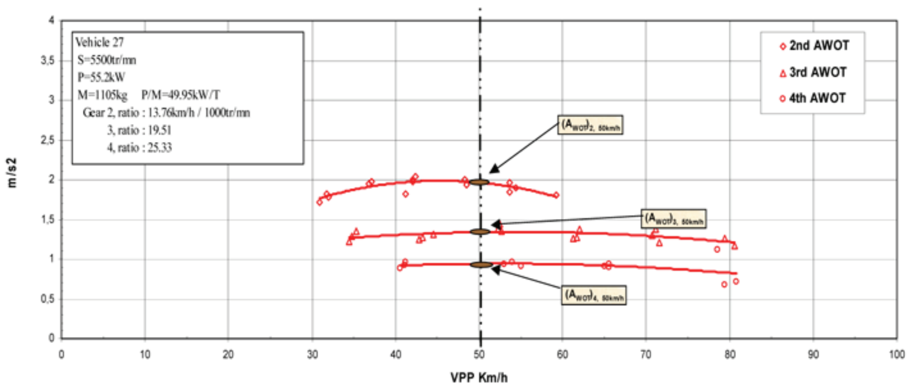


Figure A.10 — Wide-open-throttle vehicle acceleration (a_{wot}) = f(v)

The level of noise is also measured on an ISO 10844 test track. The measurement is presented as a function of the vehicle speed in front of the microphone, of the gear, and of the engine load by using constant speed and wide-open-throttle. A typical result is presented in Figure A.11.

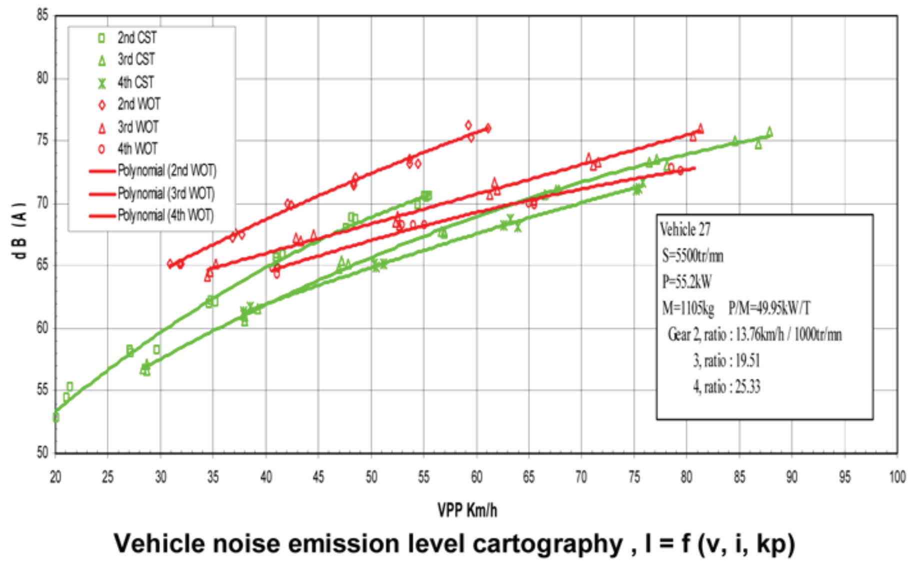


Figure A.11 — Vehicle noise emission levels as a function of gear, throttle, and vehicle speed

From the graph of Figure A.11, vehicle accelerations and the level of noise at 50 km/h are determined in each gear. This information can be used to find the iso-noise curve, using a bi-linear interpolation between the full-load and constant-speed measurements as shown in Figure A.12. This iso-noise curve can be approximated by a straight line, defined by the slope at the intersection between the wide-open-throttle test sound pressure level and the cruise-test sound pressure level.

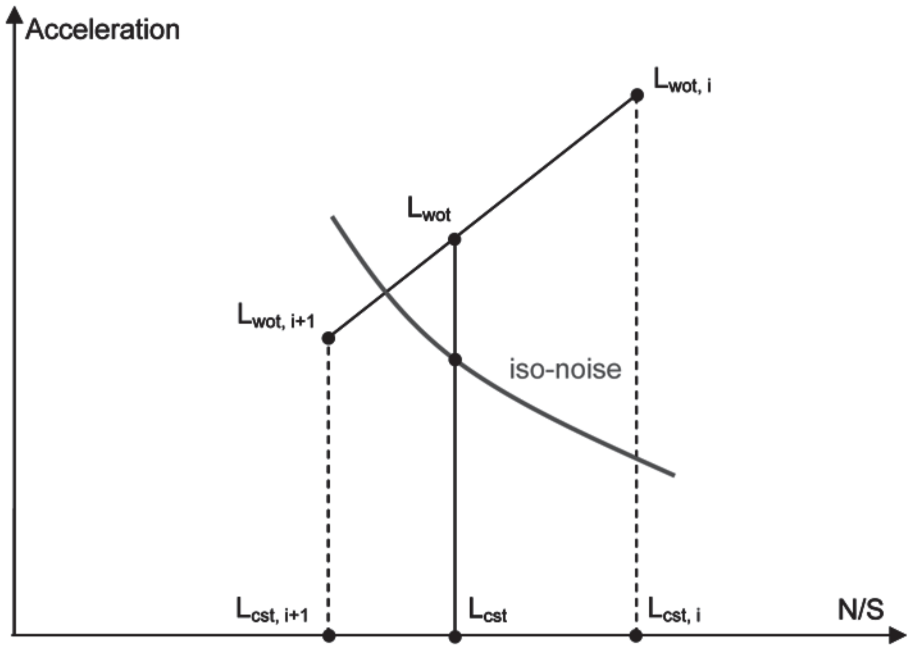


Figure A.12 — Constant-noise curve

This straight line is placed in Figure A.9 and moved parallel until 90 % of the acceleration events are below the line as shown in Figure A.13. All driving events below this line are less noisy and this position of the line defines the 90th percentile of the level of noise. The intersection of the tangent to the constant-noise line with 90th percentile acceleration gives the engine speed at the 90th percentile of noise emission.

NOTE Iso-noise as used in Figure A.12 is equivalent to "constant noise".

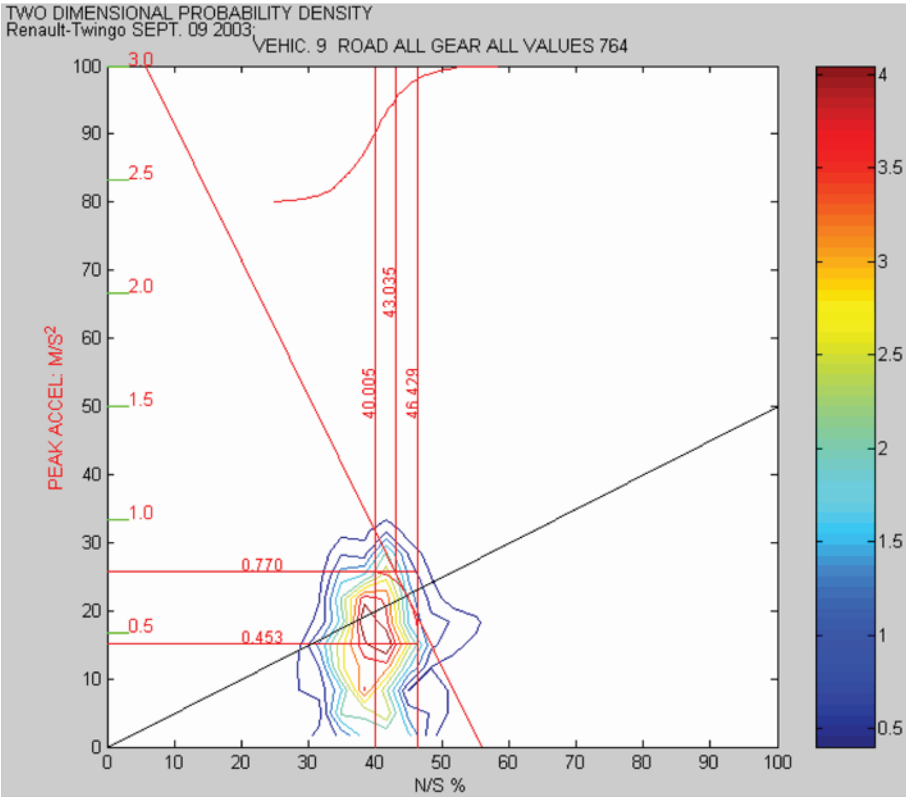


Figure A.13 — Definition of $(n/S)_{L90,a90}$ at 50 km/h

The point n/S at the 90th percentile of noise and 90th percentile of acceleration gives the "noisiest" case under the "highest" acceleration and was retained as the noisiest realistic urban case. This calculation was performed on each vehicle tested to develop a database of vehicle performance during urban driving.

A.2.7 Average behaviour during urban driving

Results from 52 vehicles with manual gearbox were analysed according to the above described procedure. The nine additional vehicles with automatic gearbox were analysed separately. For these vehicles, the 90th percentile peak acceleration at 50 km/h and the corresponding engine rotational speed n/S have been correlated to the power-to-mass ratio (PMR). A logarithmic regression has been performed for 12 < (PMR) < 400 and is shown in Figures A.14 and A.15.

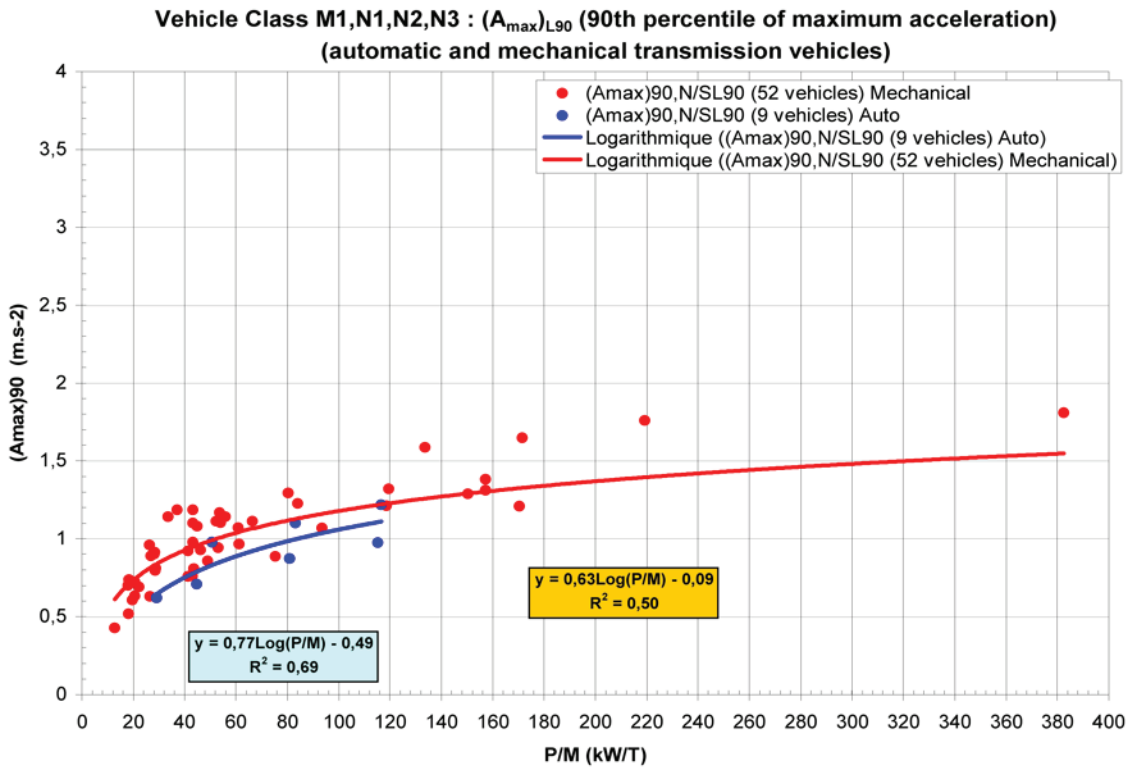


Figure A.14 — Regression curve $a_{\text{urban}} = f(I_{\text{PMR}})$ for 52 vehicles

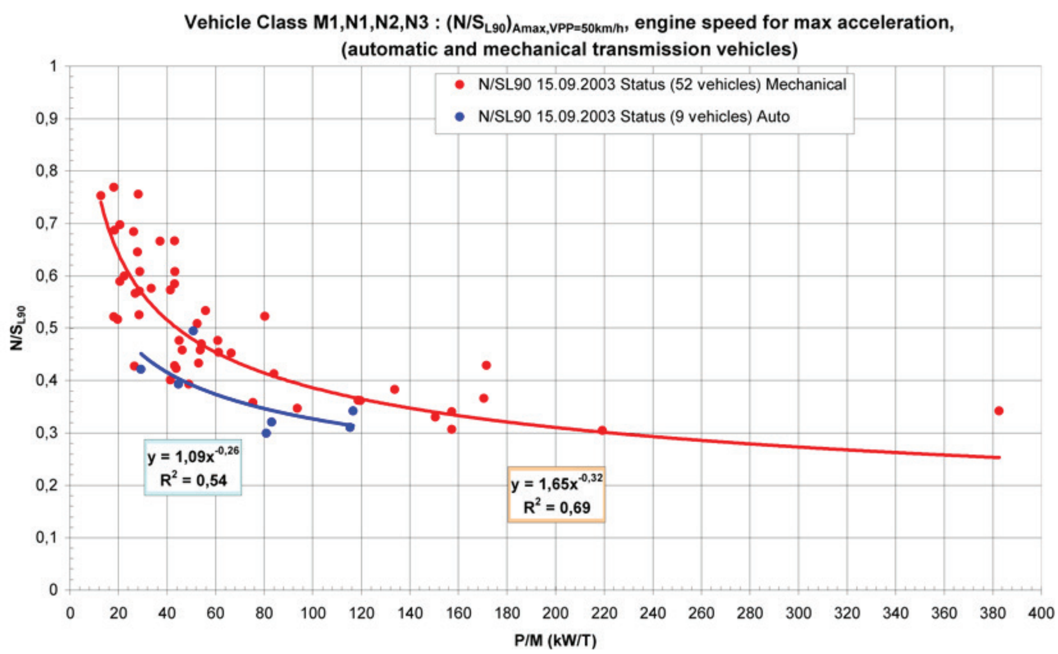


Figure A.15 — Engine speed at maximum acceleration and 50 km/h — Regression curve (n/S at 90th percentile sound pressure level, 90th percentile acceleration level, and 50 km/h) as a function of the power-to-mass ratio (PMR) for 52 vehicles

Examining these figures, it can be concluded that

— the urban traffic behaviour described by peak acceleration and engine rotational speed is well correlated with the power-to-mass ratio (PMR),

— the peak acceleration in urban traffic increases with the PMR, and

— the engine rotational speed at which this peak acceleration takes place decreases with the PMR and it is weakly dependent on the vehicle speed (for 30 km/h < v < 60 km/h).

These conclusions are consistent with intuitive expectations of vehicle behaviour in real traffic. A driver uses the acceleration capability of the vehicle to maintain position in the traffic flow. The percentage of the vehicle's acceleration capability used is higher for lower power-to-mass ratio vehicles and lower for higher power-to-mass ratio vehicles. The corollary result is that lower power vehicles use higher engine rotational speeds, and higher power vehicles use lower engine rotational speeds. The results for automatic transmission vehicles show that urban acceleration and engine rotational speeds are less. These vehicles have not been included in the statistical curves as the manual transmission results define the worst case (highest) sound pressure levels.

A.2.8 Wide-open-throttle acceleration

A.2.8.1 Individual vehicle analysis

For manual transmission vehicles, the engine speed is not known. It depends on the gear ratio, which is selected by the driver. A typical driver tries to keep an acceleration reserve which depends on the available power (PMR) of the car. The acceleration capability under typical urban driving conditions must be determined.

On a test track complying with ISO 10844, measurements were performed with wide-open throttle and on a distance of (20 m + vehicle length) for each gear i.

The values $a_{\text{wot}\ i}$ as a function of vehicle velocity were recorded and are shown in Figure A.10.

From these curves, the 50 km/h value was obtained.

The interpolation factor, k_n, between gears i and $(i + 1)$ was then calculated, using the statistical value of $(n/S)_{a90}$ as given by Formula (A.1):

$$k_n = \frac{(n/S)_{a90} - (n/S)_{(i+1)}}{(n/S)_i - (n/S)_{(i+1)}} \qquad \text{(A.1)}$$

Finally, the wide-open-throttle acceleration at 50 km/h with the corresponding non-dimensional engine rotational speed at the 90th percentile of noise was calculated by Formula (A.2):

$$a_{\text{wot 50}} = a_{\text{wot}\,(i+1)} + k_n\ [(a_{\text{wot}\ i} - a_{\text{wot}\,(i+1)}] \qquad \text{(A.2)}$$

as shown in Figure A.16.

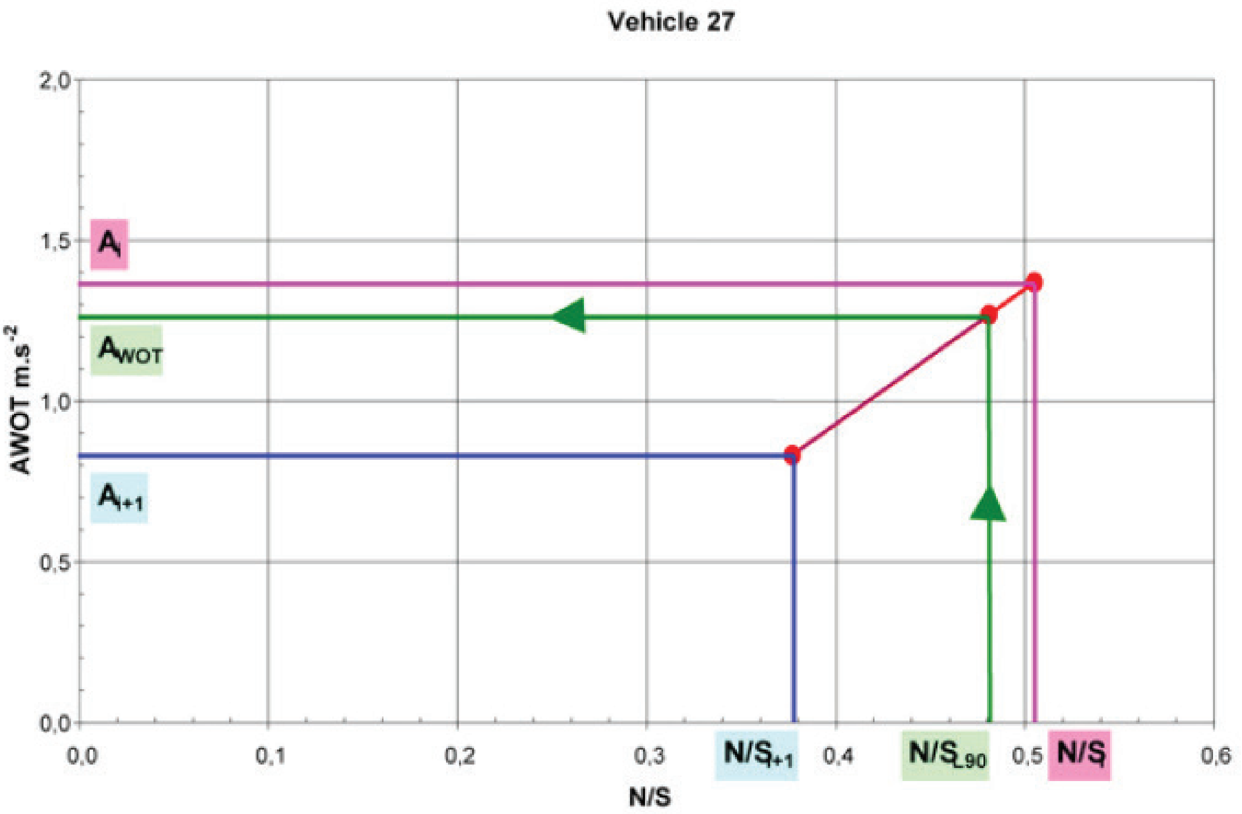


Figure A.16 — Determination of wide-open-throttle acceleration $a_{wot\ 50}$

A.2.8.2 Statistical analysis of wide-open-throttle acceleration

The measurements were performed for 127 vehicles. These were different from the vehicles used for the initial in-use driving behaviour studies. The logarithmic regression through the individual vehicle $a_{wot\ 50}$ points as a function of the power-to-mass ratio gives $a_{wot\ ref}$ and is represented in Figure A.17 for 20 < PMR < 220.

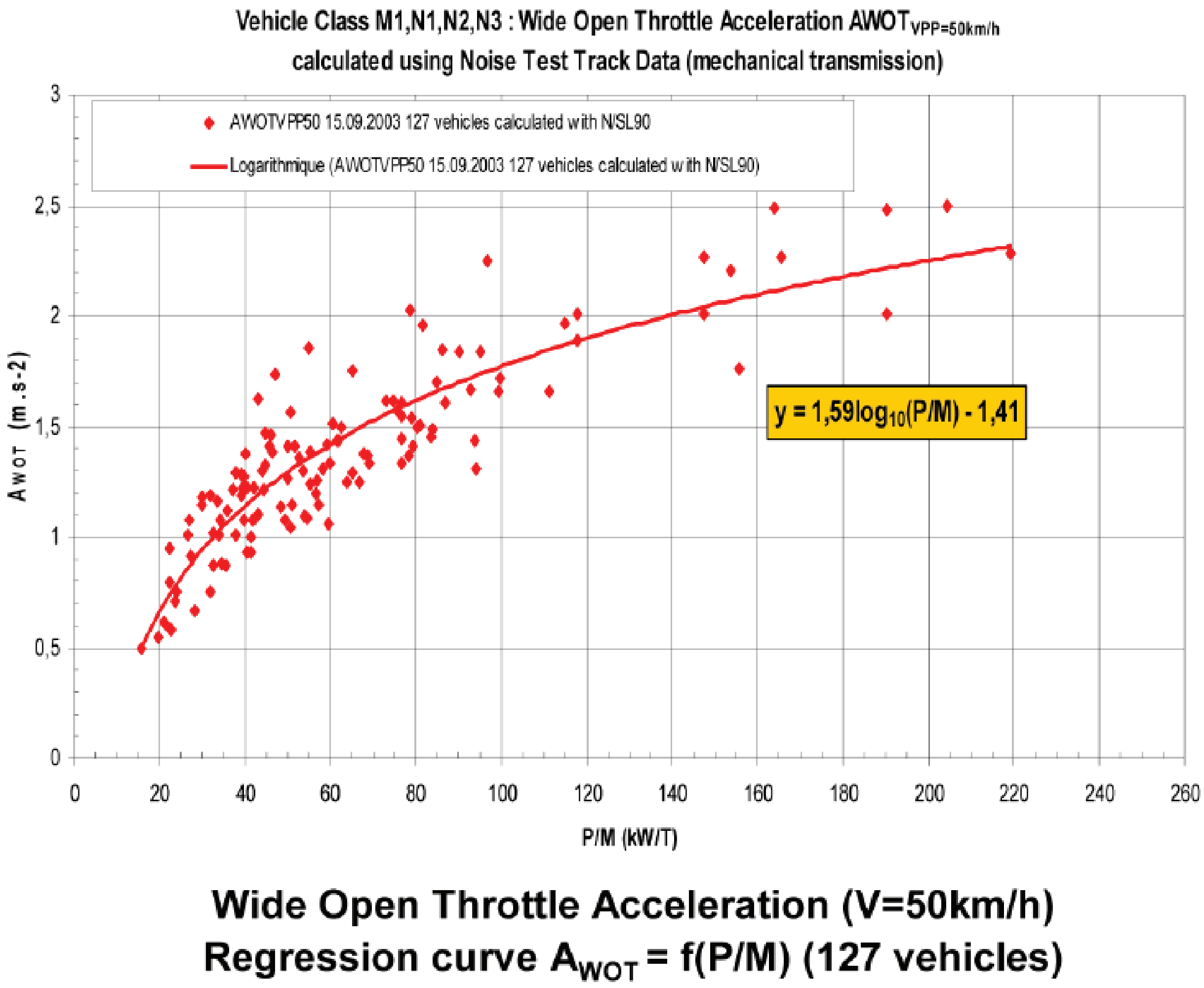


Figure A.17 — Regression curve of $a_{\text{wot ref}}$ as a function of the power-to-mass ratio (for 127 vehicles)

The wide-open-throttle acceleration, $a_{\text{wot ref}}$, at the same peak acceleration engine rotational speed, $(n/S)_{L90}$, which was measured in urban traffic, increases with the power-to-mass ratio. Also, the wide-open-throttle acceleration, $a_{\text{wot ref}}$, at the same engine rotational speed as the urban traffic peak acceleration $(n/S)_{L90}$ is almost always greater than the urban traffic peak acceleration, i.e. $a_{\text{wot ref}} > a_{\text{max 90}}$.

A.2.9 Partial power factor, k_P

A parameter $(1 - k_P)$ is defined as the ratio of the vehicle urban traffic peak acceleration $a_{max\ 90}$ to the vehicle wide-open-throttle acceleration $a_{wot\ ref}$ at the same engine rotational speed $(n/S)_{L90}$, as given by Formula (A.3) and at the same vehicle speed, as given by Formula (A.4) for a vehicle velocity of 50 km/h:

$$1 - k_P = \frac{a_{max\ 90}}{a_{wot\ ref}} \text{ for vehicle velocities at } (n/S)_{L90} \tag{A.3}$$

If vehicle velocities are 50 km/h

$$1 - k_p = \frac{a_{max 90}}{a_{wot\ ref}} \tag{A.4}$$

with $a_{max\ 90}$ measured at 50 km/h and a_{wot} measured at 50 km/h and a non-dimensional engine speed equal to 90th percentile noise emission. With this definition, $(1 - k_P)$ can be interpreted as the acceleration reserve that the driver maintains above the maximum acceleration used in urban traffic.

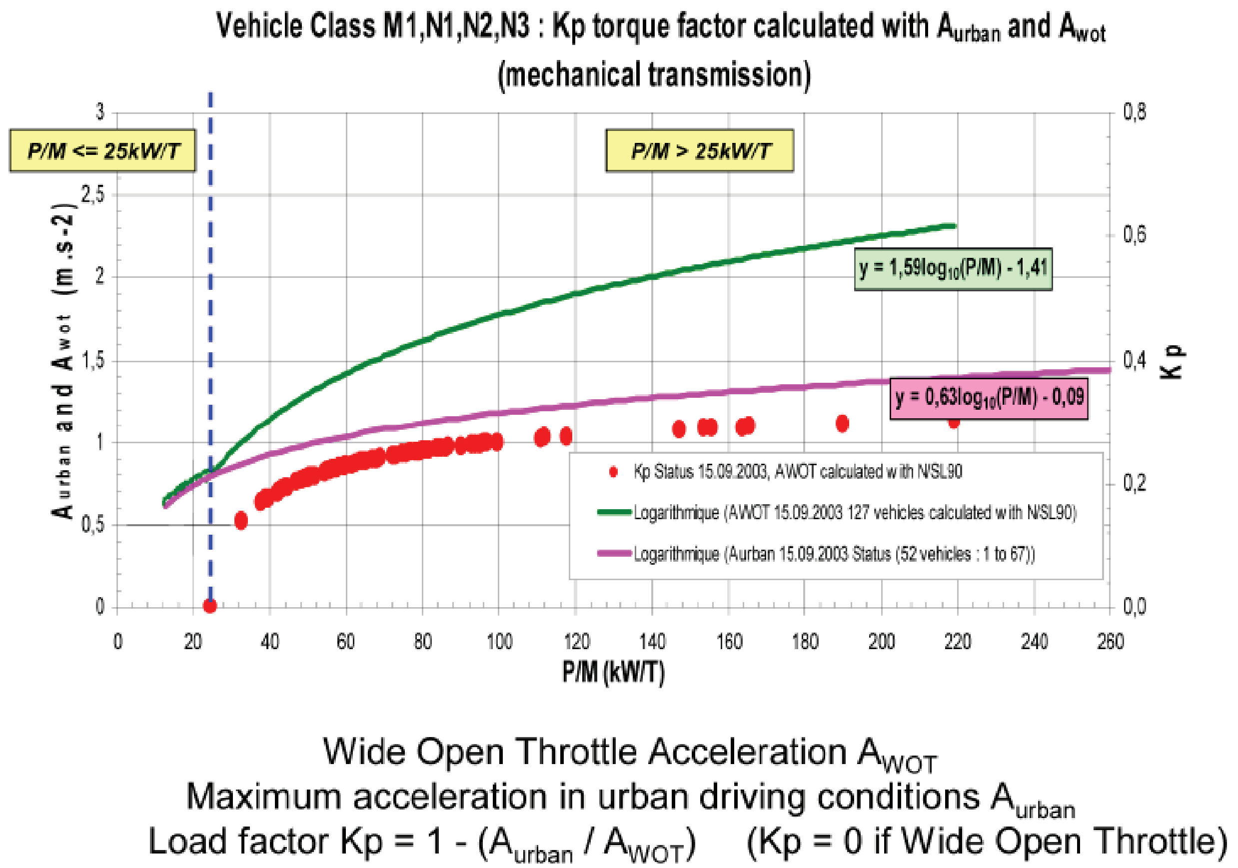


Figure A.18 — k_P factor

A.2.10 New method for measuring 90th percentile level of noise

The analysis of vehicle in-use driving behaviour and vehicle noise emission behaviour leads to the following procedure to measure a condition representing the noisiest realistic urban traffic condition using the following parameters:

— vehicle speed of 50 km/h;

— vehicle at peak acceleration, $a_{wot\ ref}$;

— partially open throttle (partial power factor).

This measurement is implemented as follows:

— The measurement is performed on the same test track complying with ISO 10844;

— For all measurements, the vehicle speed is measured in front of the microphones at PP';

— The vehicle acceleration is the average acceleration value between AA' and BB' according according to Formula (A.5):

$$a_{\text{wot test},\,j} = \left[\left(v_{\text{BB}'} / 3{,}6 \right)^2 - \left(v_{\text{AA}'} / 3{,}6 \right)^2 \right] \Big/ 2\left(l_{20} + l_{\text{ref}} \right) \qquad \text{(A.5)}$$

where

$a_{\text{wot test},j}$	is the numerical value of the acceleration, expressed in metres per second squared;
$v_{\text{BB}'}, v_{\text{AA}'}$	are the numerical values of the velocity, expressed in kilometres per hour;
l_{20}, l_{ref}	are the numerical values of the length, expressed in metres.

A.2.11 Vehicle noise emission for partial throttle

The vehicle noise emission L_{urban} for partial power is simulated by the combination of the following two test results using the hypothesis that for one vehicle speed and one engine rotational speed, the vehicle sound pressure level is proportional to the engine torque:

— the wide-open-throttle test in which the vehicle acceleration reaches the $a_{\text{wot ref}}$ acceleration and emits the measured level of noise $L_{\text{wot rep}}$;

— the constant-speed test (50 km/h) with the vehicle emitting the measured level of noise $L_{\text{crs rep}}$.

The final result is given by the weighted average of these two results as given by Formula (A.6):

$$L_{\text{urban}} = L_{\text{wot rep}} - k_{\text{p}} \left(L_{\text{wot rep}} - L_{\text{crs rep}} \right) \qquad \text{(A.6)}$$

A.2.12 Choice of the *i* and (*i* + 1) gears

The wide-open-throttle acceleration $a_{\text{wot ref}}$ is simulated by the combination of the $a_{\text{wot } i}$ and $a_{\text{wot } (i+1)}$ accelerations corresponding to the two *i* and (*i* + 1) gears for the conditions given in Formulae (A.7) and (A.8):

$$a_{\text{wot}(i+1)} < a_{\text{wot ref}} < a_{\text{wot } i} \qquad \text{(A.7)}$$

and

$$k = \left[a_{\text{wot ref}} - a_{\text{wot}(i+1)} \right] / \left[a_{\text{wot } i} - a_{\text{wot}(i+1)} \right] \qquad \text{(A.8)}$$

where *k* is defined as the interpolation factor between the *i* and (*i* + 1) gears.

A.2.13 Wide-open-throttle noise and constant-speed noise

The wide-open-throttle level of noise $L_{\text{wot rep}}$ or constant-speed level of noise $L_{\text{crs rep}}$ of a vehicle is a combination of the measured level of noise for the *i* and (*i* + 1) gears at wide-open throttle and at constant speed, using the hypothesis that noise is proportional to engine speed if vehicle speed and engine load are constant as given by Formula (A.9) and (A.10).

$$L_{\text{wot rep}} = L_{\text{wot}(i+1)} + k \left[L_{\text{wot } i} - L_{\text{wot}(i+1)} \right] \qquad \text{(A.9)}$$

$$L_{\text{crs rep}} = L_{\text{crs}(i+1)} + k\left[L_{\text{crs}\,i} - L_{\text{crs}(i+1)}\right] \tag{A.10}$$

The sound pressure level L_{urban} (which is obtained as a combination of the wide-open-throttle and constant-speed level of noise for two different gears) is the vehicle urban traffic level of noise during the 90$^{\text{th}}$ percentile acceleration phase at 50 km/h. As such, L_{urban} represents the 90$^{\text{th}}$ percentile of noise emission during typical urban conditions. Figure A.19 summarizes the procedure for cars and light vans.

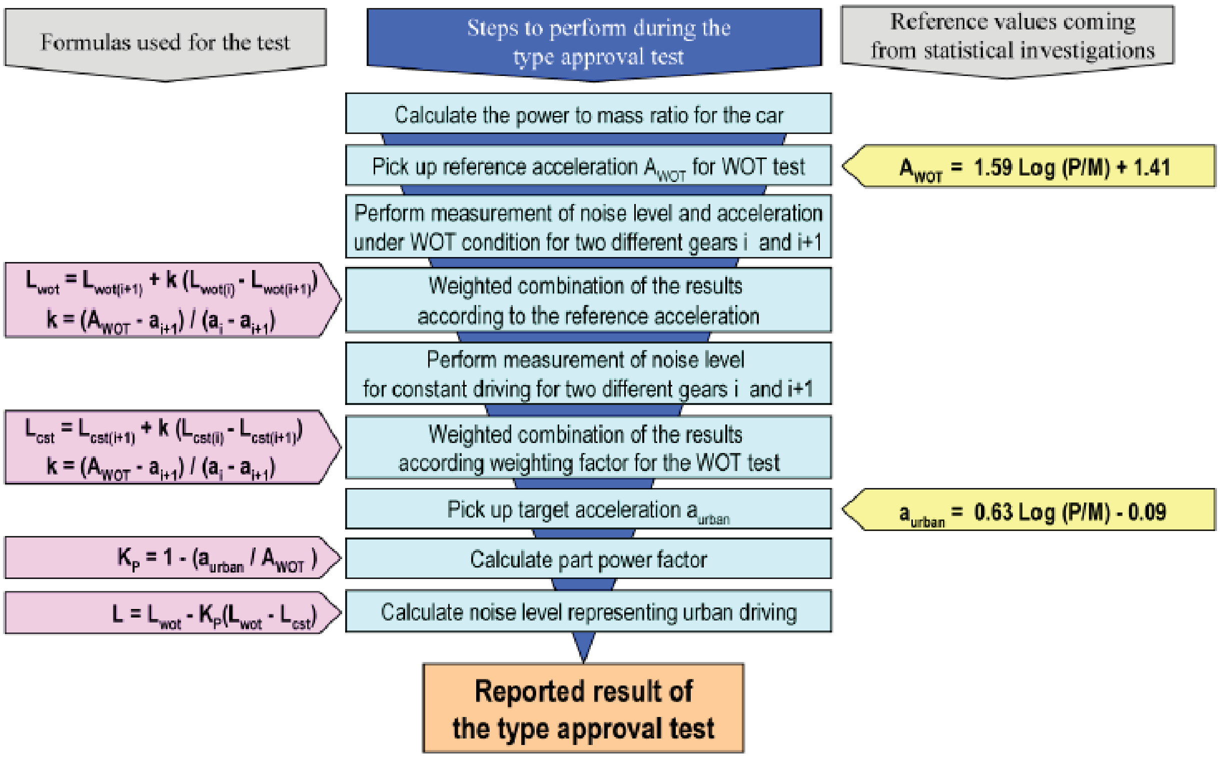


Figure A.19 — Pass-by noise measurement procedure

NOTE This is only a conceptual flow diagram. Refer to the actual procedure for specific requirements.

A.2.14 Period exceeding the measured level of noise

During urban driving, what is the time percentage during which the vehicle level of noise exceeds the one which is measured according to the suggested procedure? Figure A.20 describes a vehicle noise map, measured for all throttle conditions, all gear ratios, and all vehicle speeds.

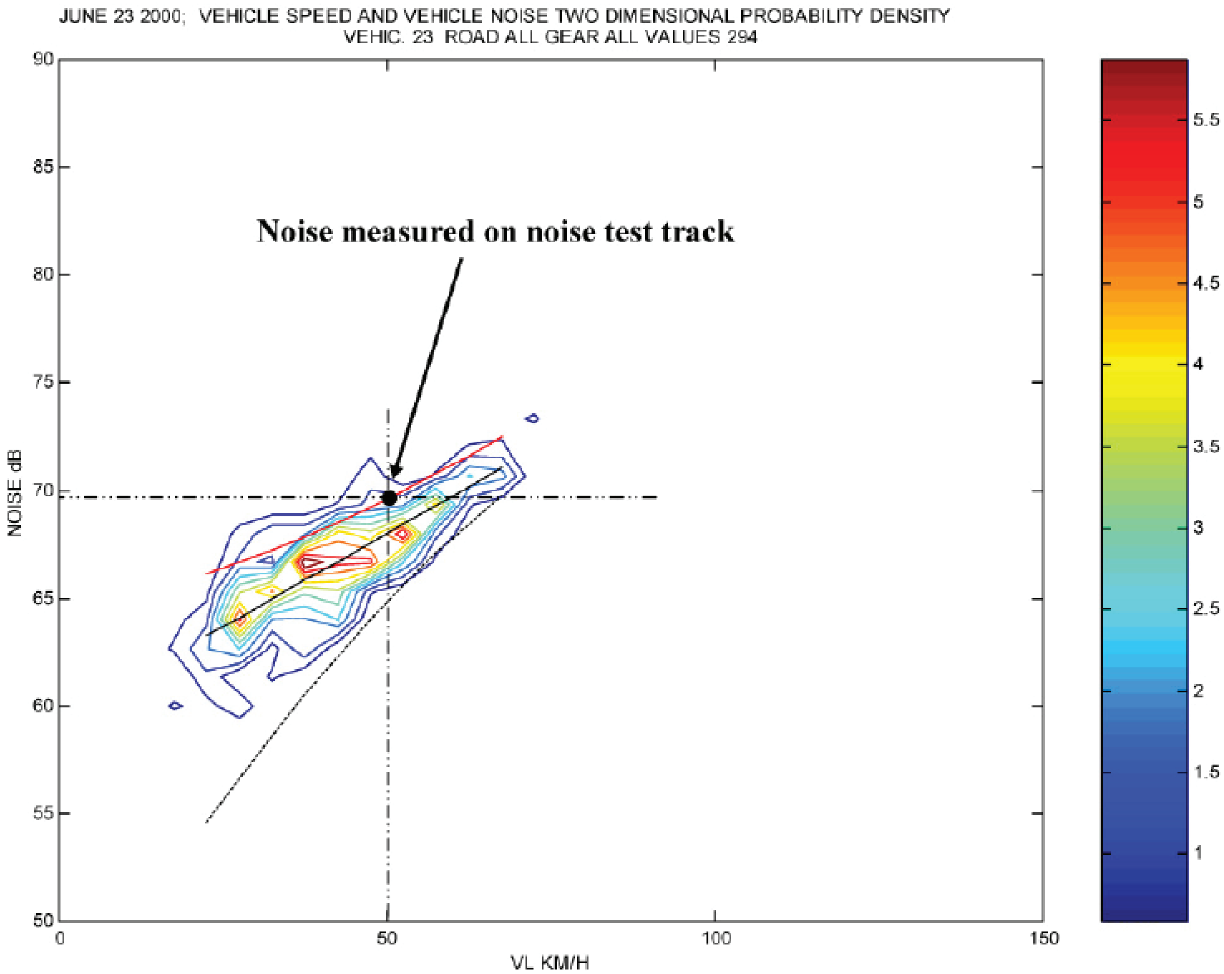


Figure A.20 — Maximum level of noise emitted by vehicle in urban driving conditions at the maximum acceleration — Density of probability along the trip

Knowing that the noise emission is a function of the partial power, gear ratio, and vehicle velocity, it is possible to compute an instantaneous urban traffic noise emission for a vehicle. The required information is vehicle speed, the gear ratio, and the vehicle acceleration during driving time. This results in noise emission as a function of time.

The maximum level of noise of the acceleration phases is statistically analysed. Figure A.20 is the two-dimensional probability density diagram of the maximum level of noise of a vehicle at the speed at which maximum noise takes place. As an example, this vehicle's measured sound pressure level is 70 dB according to this procedure.

It can be seen that on an urban route, the maximum noise emission for the acceleration phase does not exceed the on-track-edge-measured level of noise according to the procedure defined in this part of ISO 362, except for a small percent (2 % in the given example) of acceleration phases under 50 km/h and for vehicle speeds greater than 50 km/h.

A.2.15 Summary of procedure for categories M1 and M2 having maximum authorized mass not exceeding 3 500 kg, and category N1

The procedure defined in this part of ISO 362, outlined in Figure A.19, enables one to measure a vehicle's urban traffic sound pressure level during the driving phase causing most disturbance, i.e. acceleration phases at 50 km/h. The measured sound pressure level corresponds to the 90th percentile of the maximum noise emitted during the acceleration phases in urban traffic. The method provides excitation of all significant vehicle noise sources to provide the 90th percentile estimate of a vehicle's noise emission in an urban environment. This noise estimate should provide good correlation to actual vehicle noise emissions in the environment when the road surface is in good condition and approximates the noise characteristics specified in ISO 10844. Road surfaces of this type are presently in use, with road surfaces specifically designed to be "low noise", having lower noise emission levels than the ISO 10844 surface for typical M1 and N1 vehicles.

This method takes into account real driving behaviour, which depends on the acceleration potential and on the power-to-mass ratio of a vehicle. The method is based on the performance criteria of acceleration and is independent of the vehicle technology, transmission type, number of transmission gears, and the type of engine. These performance criteria make this method applicable to current and future vehicles, including adaptive automatic transmissions, hybrid vehicles, electric vehicles, and fuel cell vehicles.

Annex B
(informative)

Measurement uncertainty — Framework for analysis according to ISO/IEC Guide 98-3 (GUM)

B.1 General

The measurement procedure is affected by several factors causing disturbance that lead to variation in the resulting level observed for the same subject. The source and nature of these perturbations are not completely known and sometimes affect the end result in a non-predictable way. The accepted format for expression of uncertainties generally associated with methods of measurement is that given in ISO/IEC Guide 98-3. This format incorporates an uncertainty budget, in which all the various sources of uncertainty are identified and quantified and from which the combined standard uncertainty can be obtained. Uncertainties are due to the following factors:

— variations in measurement devices, such as sound level meters, calibrators, and speed-measuring devices;

— variations in local environmental conditions that affect sound propagation at the time of measurement of L_{urban};

— variations in vehicle speed and in vehicle position during the pass-by run;

— variations in local environmental conditions that affect the characteristics of the source;

— effect of environmental conditions (air pressure, air density, humidity, air temperature) that influence the mechanical characteristics of the source, mainly engine performance;

— effect of environmental conditions that influence the sound production of the propulsion system (air pressure, air density, humidity, air temperature) and the roiling noise (tyre and road surface temperature, humid surfaces);

— test site properties (test surface texture and absorption, surface gradient).

The uncertainty determined according to 8.5 represents the uncertainty associated with this part of ISO 362. It does not cover the uncertainty associated with the variation in the production processes of the manufacturer. The variations in the urban sound pressure level of identical units of a production process are outside the scope of this part of ISO 362.

The uncertainty effects can be grouped in the three areas composed of the following sources (see 8.5):

a) uncertainty due to changes in vehicle operation within consecutive runs, small changes in weather conditions, small changes in background noise levels, and measurement system uncertainty; these are referred to as run-to-run variations;

b) uncertainty due to changes in weather conditions throughout the year, changing properties of a test surface over time, changes in measurement system performance over longer periods, and changes in the vehicle operation; these are referred to as day-to-day variations;

c) uncertainty due to different test site locations, measurement systems, road surface characteristics, and vehicle operation; these are referred to as site-to-site variations.

The site-to-site variation comprises uncertainty sources from a), b), and c). The day-to-day variation comprises uncertainty sources from a) and b).

B.2 Expression for the calculation of sound pressure levels of vehicles in urban operation

The general expression for the calculation of the urban-operation sound pressure level, L_{urban}, is given by Formula (B.1):

$$L_{urban} = L_{wot\ rep} - k_P\ (L_{wot\ rep} - L_{crs\ rep}) + \delta_1 + \delta_2 + \delta_3 + \delta_4 + \delta_5 + \delta_6 + \delta_7 \qquad (B.1)$$

where

$L_{wot\ rep}$ is the A-weighted sound pressure level from wide-open-throttle tests;

$L_{crs\ rep}$ is the A-weighted sound pressure level from cruise tests, if applicable;

k_P is the partial power factor, if applicable;

δ_1 is an input quantity to allow for any uncertainty in the measurement system;

δ_2 is an input quantity to allow for any uncertainty in the environmental conditions that affect sound propagation from the source at the time of measurement;

δ_3 is an input quantity to allow for any uncertainty in the vehicle speed and position;

δ_4 is an input quantity to allow for any uncertainty in the local environmental conditions that affect characteristics of the source;

δ_5 is an input quantity to allow for any uncertainty in the effect of environmental conditions on the mechanical characteristics of the power unit;

δ_6 is an input quantity to allow for any uncertainty in the effect of environmental conditions on the sound production of the propulsion system and the tyre/road noise;

δ_7 is an input quantity to allow for any uncertainty in the effect of test site properties, primarily related to road surface characteristics.

NOTE 1 The inputs included in Formula (B.1) to allow for errors are those considered applicable according to the state of knowledge at the time when this part of ISO 362 was being prepared, but further research could reveal that there are others.

NOTE 2 For vehicles of category N2, N3, and M2 with authorized mass exceeding 3 500 kg and category M3, k_P is always zero.

NOTE 3 The estimated values of the delta functions can be principally positive or negative although they are considered to be zero for the given measurement (see Table B.1). Their uncertainties are not additive for the purpose of determining a measurement result.

B.3 Uncertainty budget

Table B.1 — Uncertainty budget for determination of urban sound pressure level

Quantity	**Estimate** dB	**Standard uncertainty**, u_i dB	**Probability distribution**	**Sensitivity coefficient**, c_i	**Uncertainty contribution**, $u_i c_i$ dB
$L_{\text{wot rep}}$	$L_{\text{wot rep}}$			1	
k_{P}	k_{P}			$L_{\text{wot rep}} - L_{\text{crs rep}}$	
$L_{\text{wot rep}} - L_{\text{crs rep}}$	$L_{\text{wot rep}} - L_{\text{crs rep}}$			k_{P}	
δ_1	0			1	
δ_2	0			1	
δ_3	0			1	
δ_4	0			1	
δ_5	0			1	
δ_6	0			1	
δ_7	0			1	

From the individual uncertainty contributions, $u_i c_i$, the combined standard uncertainty, u, can be calculated according to the rules of ISO/IEC Guide 98-3, taking into account potential correlations between various input quantities.

NOTE The uncertainty evaluation described represents a framework that provides useful information to users of this part of ISO 362. This information represents the state of technical information at this time. Further work is necessary to provide uncertainty information on all terms in Formula (B.1) and all interactions between such terms.

B.4 Expanded uncertainty of measurement

The expanded uncertainty, U, is calculated by multiplying the combined standard uncertainty, u, by the appropriate coverage factor for the chosen coverage probability as described in ISO/IEC Guide 98-3.

Annex C
(informative)

Flowchart of the procedure for categories M1 and M2 having a maximum authorized mass not exceeding 3 500 kg and category N1

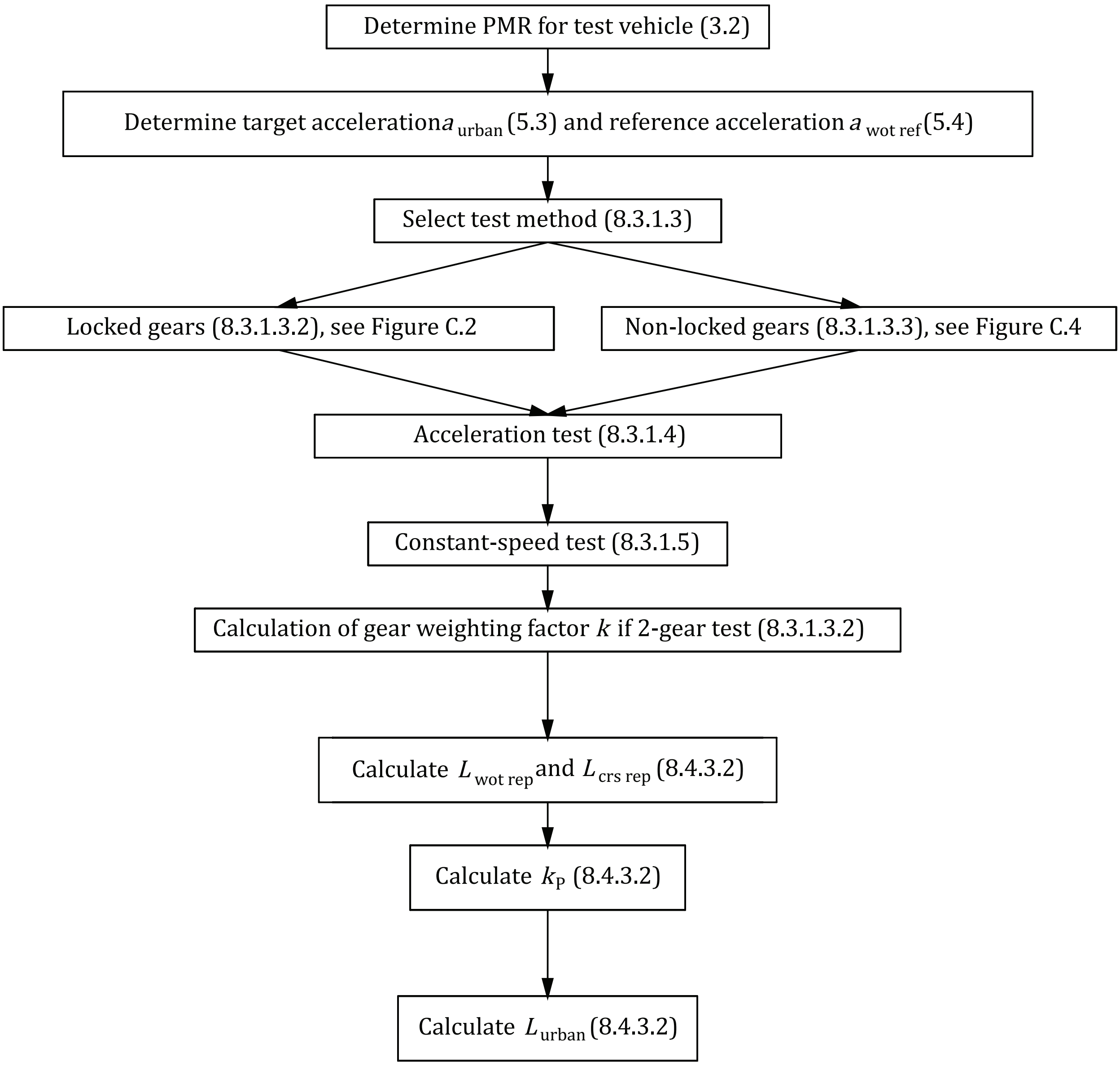


Figure C.1 — Flowchart for computation of L_{urban}

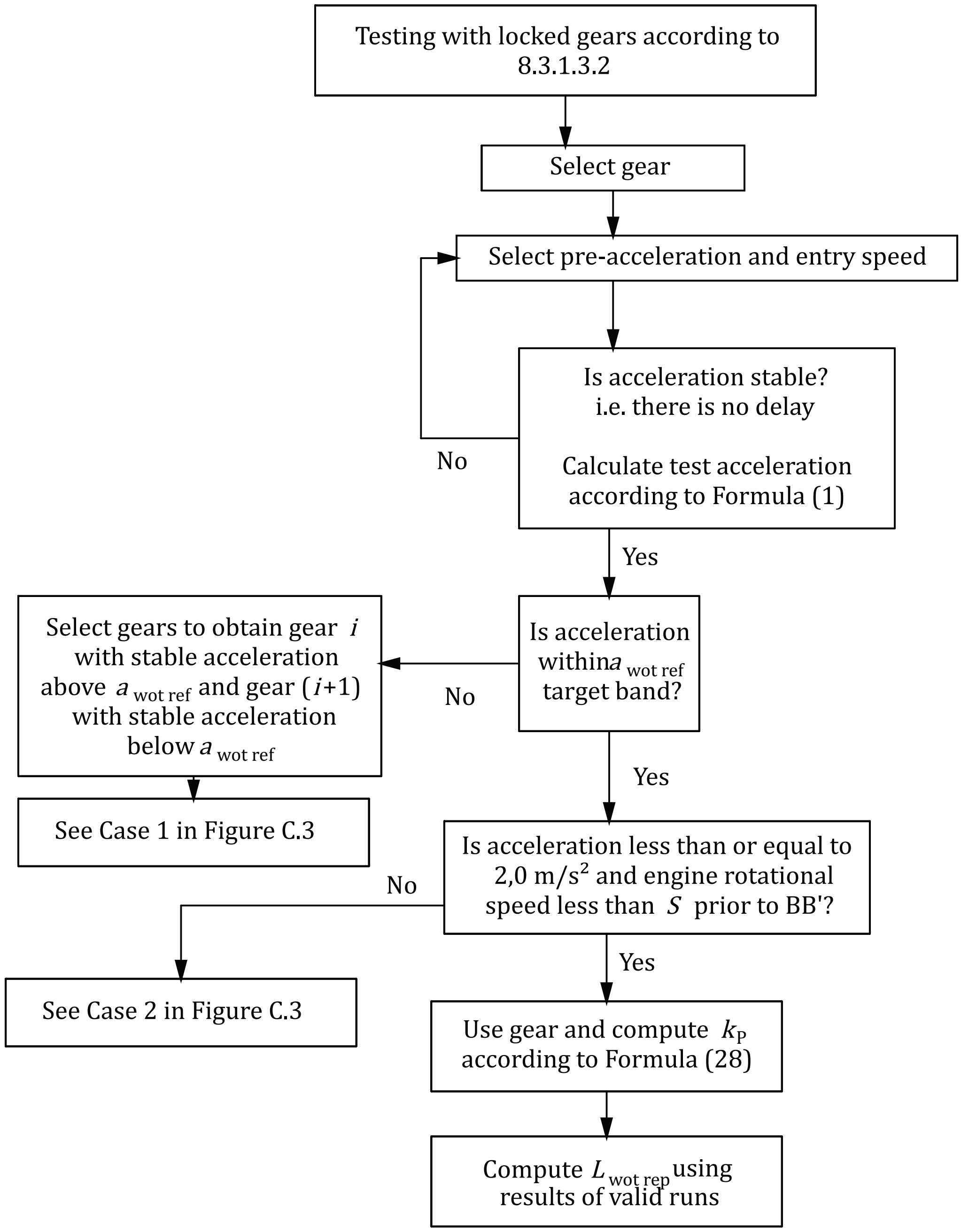


Figure C.2 — Flowchart 1 of 3 for gear selection using locked gears

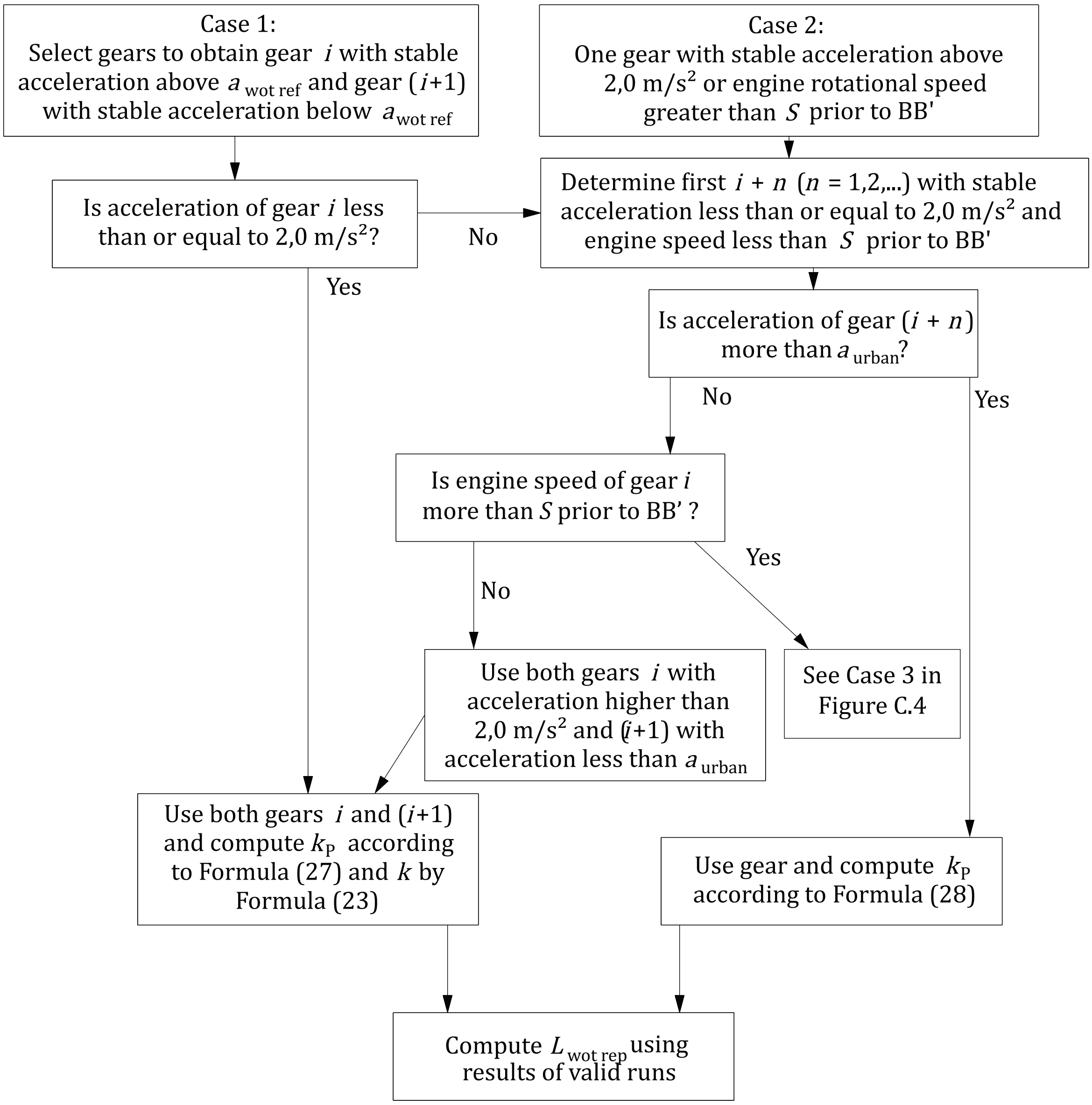


Figure C.3 — Flowchart 2 of 3 for gear selection using locked gears

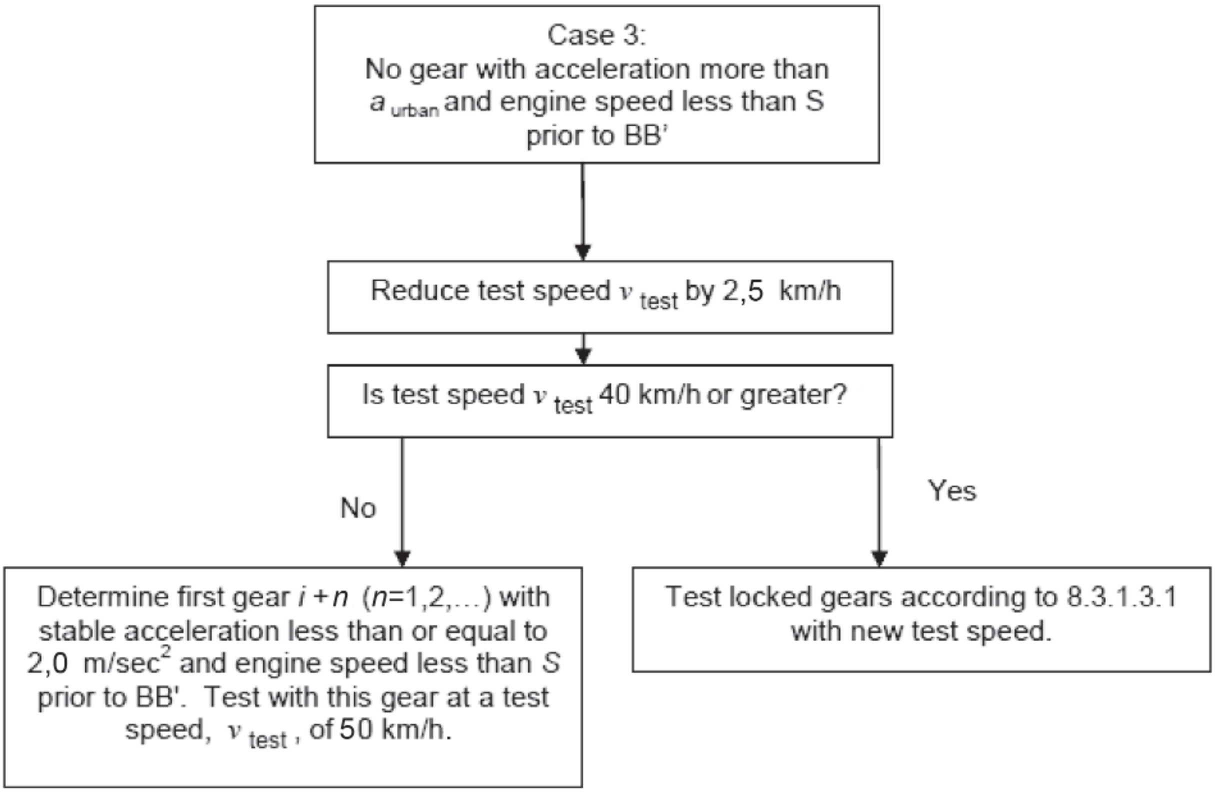


Figure C.4 — Flowchart 3 of 3 for gear selection using locked gears

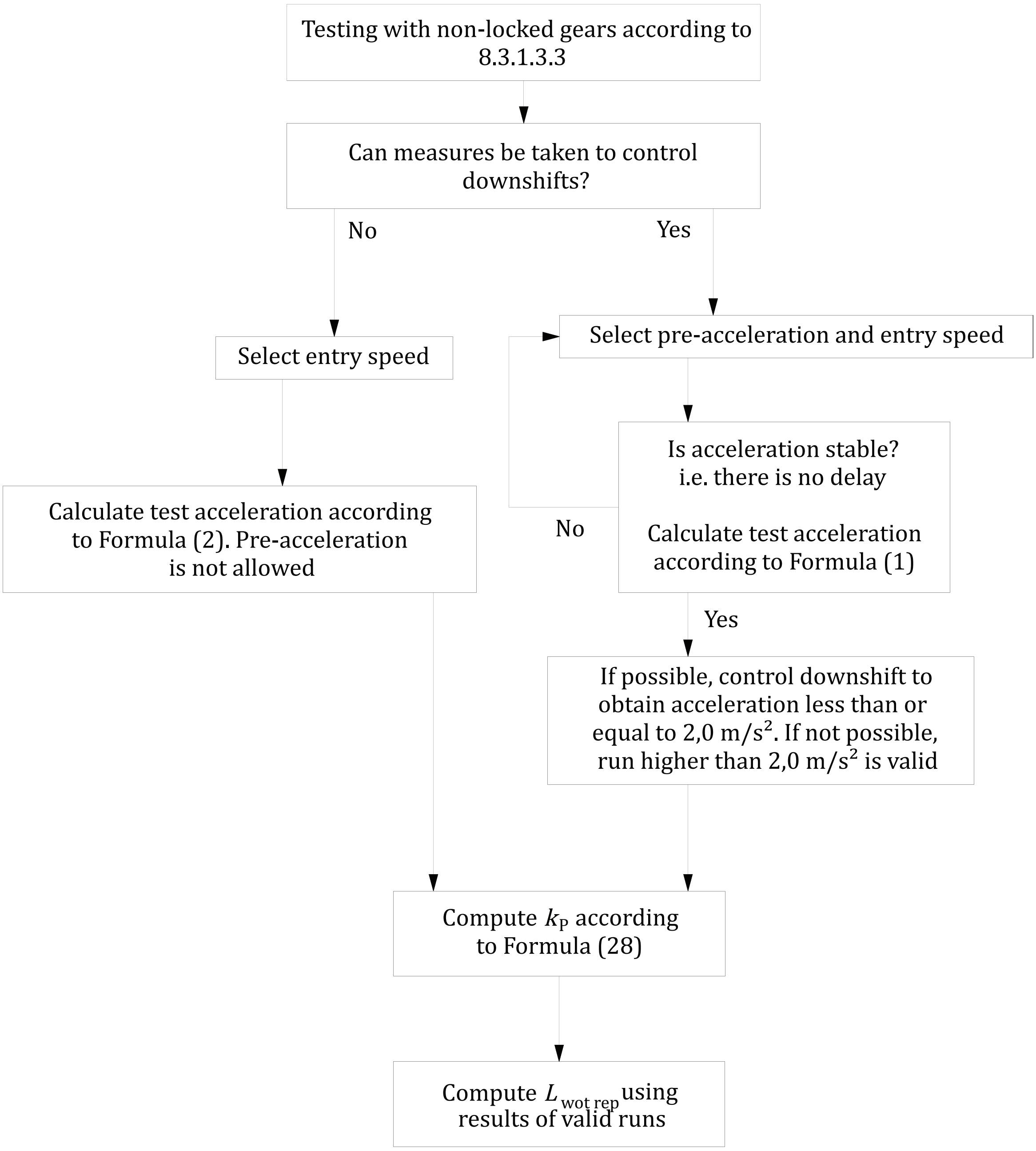


Figure C.5 — Flowchart for determining proper acceleration and $L_{\text{wot rep}}$ using non-locked gears

Annex D
(informative)

Flowchart for vehicles of category M2 having a maximum authorized mass exceeding 3 500 kg and categories M3, N2, and N3 with locked gears

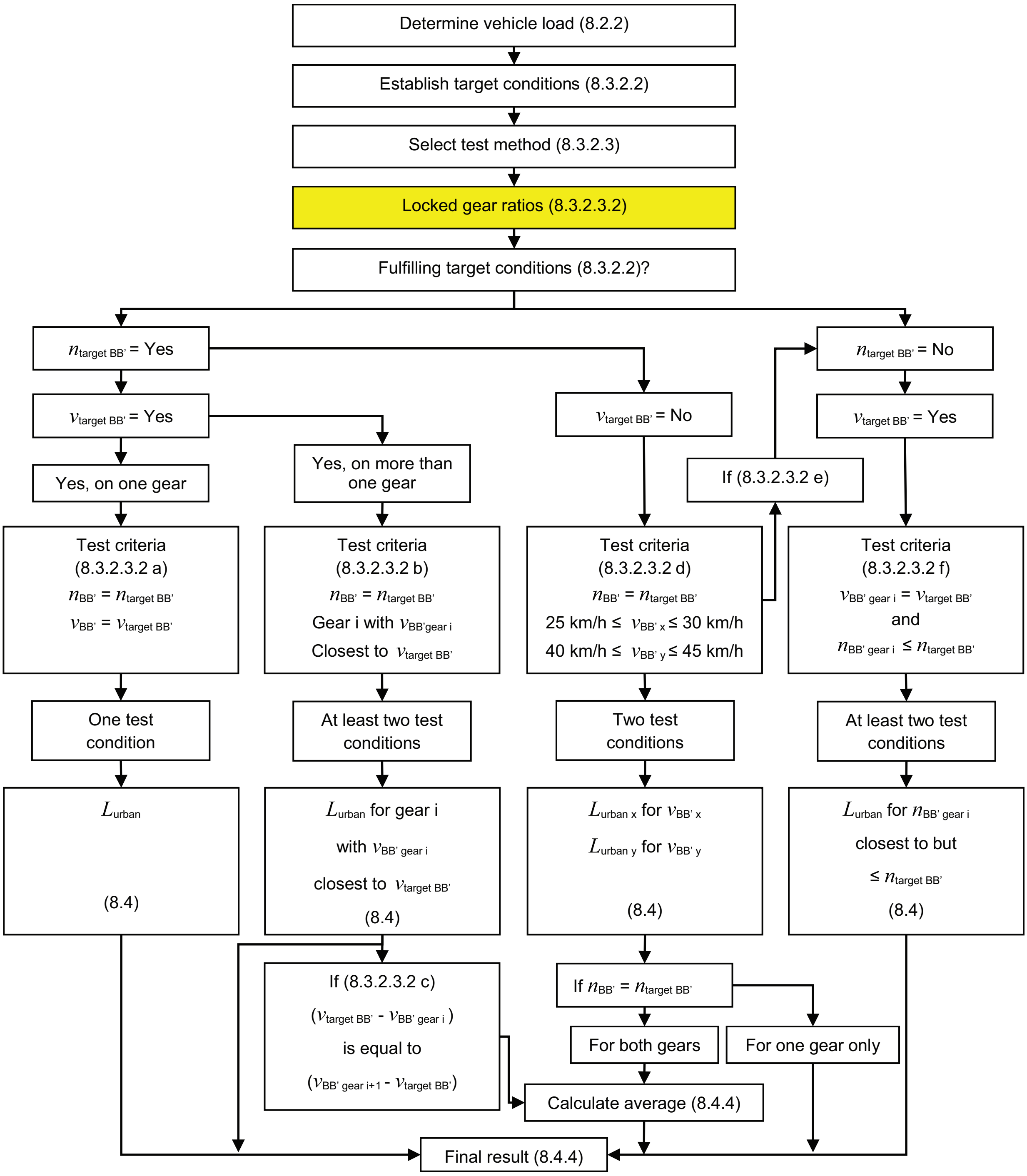


Figure D.1 — HCV flowchart using locked gears

Annex E
(informative)

Flowchart for vehicles of category M2 having a maximum authorized mass exceeding 3 500 kg and categories M3, N2, and N3 with non-locked gears

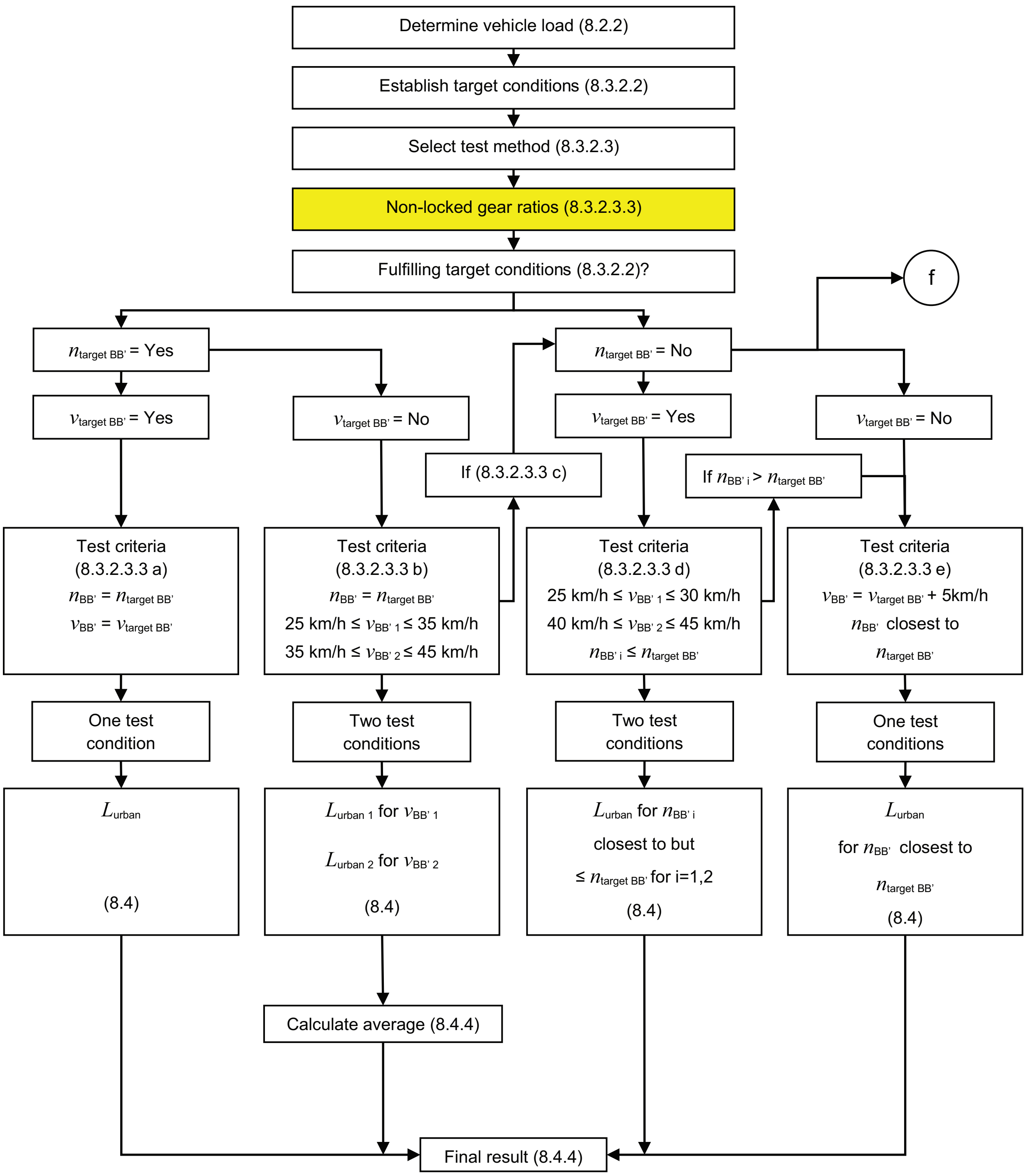


Figure E.1 — HCV flowchart using non-locked gears

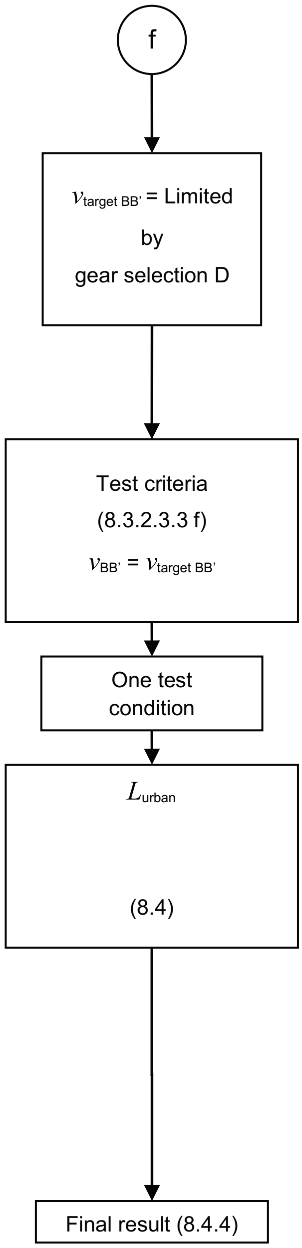


Figure E.2 — HCV flowchart using non-locked gears

Annex F
(informative)

Flowchart for vehicles of category M2 having a maximum authorized mass exceeding 3 500 kg and categories M3, N2, and N3 with no rotational engine speed available

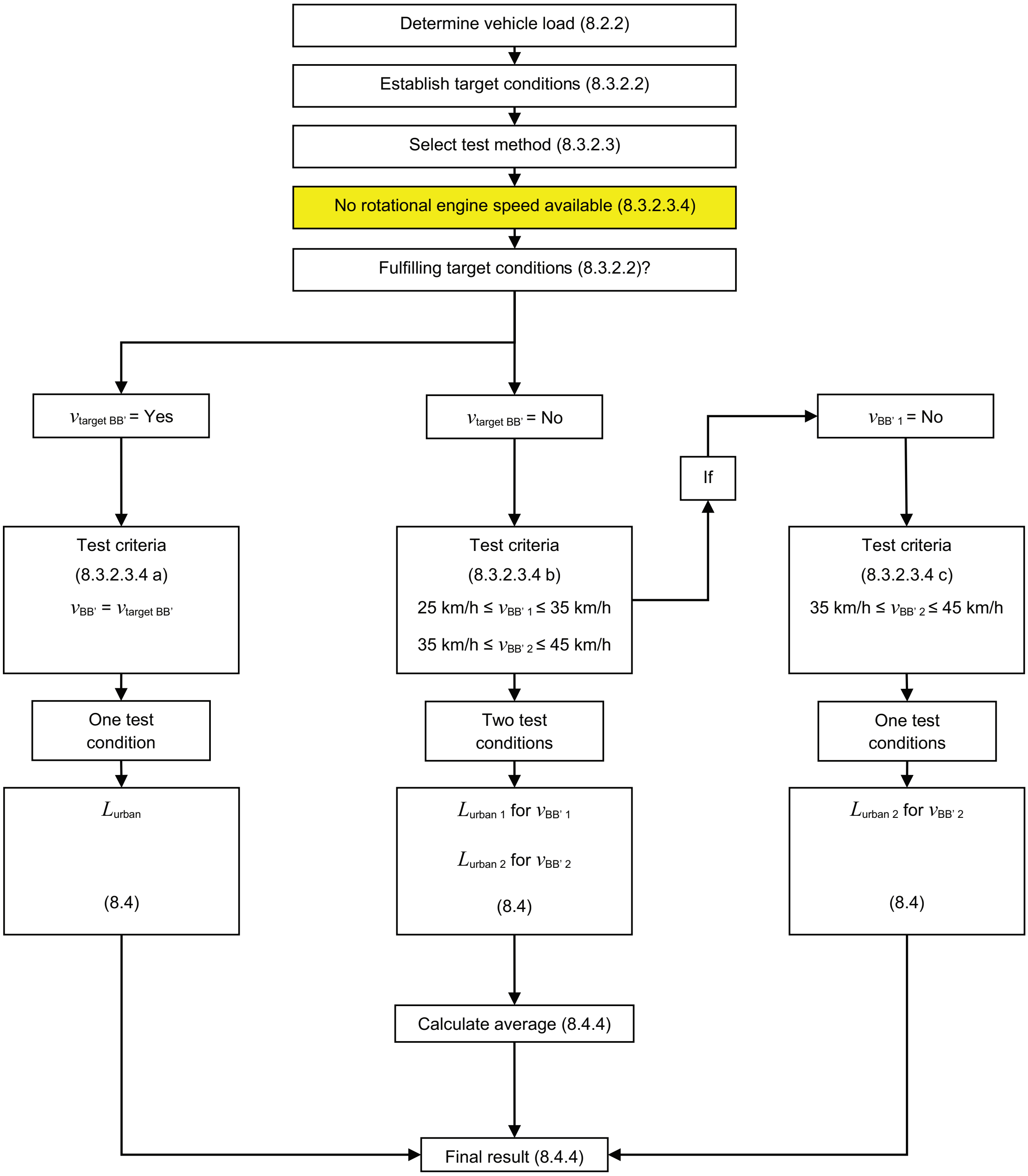


Figure F.1 — HCV flowchart with no combustion engine speed

Annex G
(informative)

Indoor test operation

G.1 General

With the technological advancements in room acoustics, vehicle dynamometer simulation, and digital signal processing typically available in today's market place, it is possible to conduct vehicle exterior noise measurements indoors with a high degree of accuracy. Testing conducted at various indoor facilities has shown good correlation to similar tests performed at a conventional open-air test site. Conducting testing, as described in this part of ISO 362, in an indoor environment eliminates constraints due to ambient conditions such as weather and background noise. In addition, indoor testing can provide significant time savings during vehicle development programmes in which many iterative tests are performed.

The information given in this annex outlines the basic requirements for such an indoor test facility, as well as information to improve correlation of indoor and open-air testing.

NOTE More information will be provided in ISO 362-3 (*Indoor testing M and N categories*).

G.2 Concept

The exterior noise test operation described in this part of ISO 362 is designed to measure the noise radiated from a vehicle to a stationary bystander on the street during an urban driving cycle. One of the principal criteria of this part of ISO 362 is that testing be performed in an acoustic-free field or, more precisely, a hemi-anechoic space. This acoustic criterion can be reproduced in a laboratory by installing sound-absorbing wedges in a sufficiently large dynamometer room to provide a hemi-anechoic space with the same effective propagation characteristics as an open-air space.

A dynamometer test bench is used to simulate the road operation of the vehicle. The vehicle's radiated noise is measured using a roving microphone or microphone array that collects time-based acoustic data. Movement of the vehicle past the stationary measurement point, as in open-air testing, is simulated using digital signal processing techniques and a synchronized sampling of the time-based acoustic data.

G.3 Room requirements

The determining factor in the room width is the desired low-frequency cut-off of the hemi-anechoic space. As a general rule, the microphones should be a quarter wavelength from the absorptive walls and the absorptive media should be nominally a quarter of the wavelength of the lowest frequency of interest. As an example, if a four-cylinder engine being tested has a lower engine rotational speed of 1 000 min^{-1}, then the lowest firing frequency of the engine is approximately 34 Hz. To design a hemi-anechoic room with a low-frequency cut-off of 34 Hz, the wedge thickness is nominally 2,6 m. For this example, the outer dimension of the test room should be approximately 18 m for a single-sided facility or 27 m for a dual-sided facility.

The length of the room depends on the length of the longest vehicle being tested plus the length of the test track (20 m) plus the space for the absorbing wedges and microphone placement. For a typical vehicle of 5 m length, the room should be 36 m long.

The height of the room follows a similar set of requirements; however, a nominal value used is 7,5 m to the wedge face (which equates to an outside dimension of 10,1 m).

All room dimensions should be adjusted to meet the specific application for the products being tested.

G.4 Dynamometer requirements

There are many dynamometer drive systems available for this use. The unit should be capable of applying a road load to the drive wheels of the vehicle, in many cases to all four. The unit should also be designed to be quiet enough to be 15 dB below the lowest level being measured in the test cell. In general, a dynamometer with an operating A-weighted sound pressure level of near 50 dB meets most requirements. In practice, many facilities exhibit ambient A-weighted sound pressure levels as low as 34 dB. A full acoustic spectrum analysis should be made of the facility to insure the acoustic quality of the test space.

Finally, the dynamometer unit should be able to follow the rapid transient of the vehicle acceleration cycle. In many cases, the operation of the vehicle is controlled using a computerized throttle application. If the vehicle is being driven by human control, extra care should be taken in the design of the facility air-handling system (see E.5). However, note that human variation increases the variation of the total measuring system.

G.5 Air-handling system requirements

To fully simulate the open-air vehicle noise test as described in this part of ISO 362, the vehicle should be tested with its exhaust system fully exposed to the acoustic space. This type of testing can lead to the dangerous accumulation of high levels of carbon monoxide and other harmful gases. For this reason, the laboratory test chamber should be sufficiently sealed to prevent leakage of these harmful gases to surrounding occupied spaces. In addition, the facility should include an exhaust system able to move sufficient clean air into the test space to remove the vehicle exhaust fumes. Such a system should be designed to be quiet if run on an automatic schedule. The facility should also be equipped with a carbon monoxide level monitoring system.

Vehicle cooling should be addressed for prolonged testing. Typically, a large volume fan can be fitted in front of the vehicle to provide sufficient airflow around the vehicle. Such fans can, however, be very noisy and should be operated only in-between test runs. The control of the ambient temperature within the test facility is also a consideration. Generally, an ambient level of (20 ± 3) °C is feasible for most applications.

G.6 Microphone placement

Typical facilities currently in use utilize 15 to 20 microphones placed in a line on either one side or both sides of the vehicle. The microphone array is placed at a distance of 7,5 m from the longitudinal centreline of the vehicle. In most cases, the array is evenly spaced along the line with the array extending from 10 m in front of the vehicle microphone to 10 m behind the rear of the vehicle.

G.7 Data analysis

Acoustic data from each of the measuring microphones are acquired and stored to computer memory as time histories. At the same time, data are acquired to quantify the vehicle speed and engine speed during the test. These various sources of information are combined, based on a trigger signal relating to line AA’ of the test track when the accelerator throttle is applied. The time data from each of the microphones are sequenced over time, based on the speed of the vehicle and its simulated position along the test track. Through the process of combining these signals, a virtual sweep is made of the microphone array to represent the movement of the vehicle past a single microphone. The digital signal processing system provides a single plot of the overall sound pressure level of the vehicle as a function of its position along the “course”. In addition, typical commercially available systems generally have the capability to provide additional time-based analysis of each of the individual microphones. This enhances the capability of defining specific noise sources, such as the level from the microphone directly in line with the exhaust outlet or at the centreline of the vehicle front axle. Most data processing systems offer an array of analysis tools that provide a detailed mapping of the vehicle noise information.

G.8 Measurement capability

Typical facilities in use today demonstrate good correlation between open-air road tests and indoor dynamometer tests for the powertrain portion of overall vehicle noise. These facilities have become valuable tools for many vehicle manufacturers.

Unfortunately, correlation for the full vehicle continues to be problematic. The primary issue remaining in the correlation of indoor test facilities to open-air facilities is the proper measurement of the tyre/road noise component of overall vehicle noise. For most facilities, when a production tyre is placed on an average diameter dynamometer roll, its contact patch is modified such that the level of noise produced increases significantly from those produced on the flat test road surface. This situation is highly dependent on the tyre size and construction, and does not necessarily affect all vehicle types in the same fashion.

To improve test correlation, the use of tyres with no tread (blank tread tyres) can be used and have been shown to provide good results. The noise produced by the tyre/road interface should then be accounted for by other means. Research is underway by some organizations to measure vehicle tyre/road noise independently then combine the results of the two tests to determine the full vehicle level of noise.

Even with the current limitation to full vehicle correlation, the ability to conduct exterior noise tests of vehicles in an indoor environment has been shown to be beneficial. The indoor method eliminates restrictions due to ambient conditions, especially in areas where rain, snow, and wind conditions result in significant time loss. Significant time is also saved in the development of vehicle components and sub-systems where iterative testing is required. Additionally, indoor testing can be used to provide validation data to verify that a component change, other than tyres, will not alter the type approval sound pressure level of a vehicle.

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