R51 ASEP measurement method and options for analysis method

Attempt to translate in to text
the measurement protocol and the alternatives for data processing
On the basis of TRANS/WP.29/GRB/2005/2/Rev.2
Distributed as an interim paper after the 4th meeting
In order to facilitate the measurements before the 5th meeting

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Introduction:

The text reproduced below is an attempt of the Dutch delegate in the GRB IG ASEP to translate the status of the discussion after the 4th meeting in to a text which would be suitable to incorporate in to Annex 10 of R51.03.
Currently there are four alternatives for data processing under discussions. All four alternatives are incorporated in this text in order to facilitate the evaluation by the group. It is the intention that the final proposal to GRB will contain only one alternative for data processing.
The text is a personal interpretation of the alternatives, based on the presentations and discussions in the group. Other delegates are encouraged to check if the text indeed sufficiently reproduces the intent of the respective proposals and to come up with improvements well before the 5th meeting on 8-10 November in the Hague. This will enable parties to analyze and compare their noise measurements in the most up to date and uniform way.
Further more it should be stressed that the concrete numbers in the text (like boundary conditions of valid measurements, or slope of expected sound increase) by no means reflect a final decision by the group. In fact delegates are invited to explore over the indicated boundaries in order to be able to better judge the temporary figures in place.

As discussed in the last meeting, the total ASEP evaluation has been split up in three parts:

- measurements
- data processing
- setting of limits

This is done in order to better separate the remaining issues from the agreements. These three parts are also reflected in the text proposal below.
In the description of some alternatives it was hard to decouple the data processing from the setting of limits. In those cases a personal interpretation was used. An example of this was the introduction of an expected noise behavior, for which a uniform slope of 4.5 dB/1000 rpm was introduced. This is the average of the slopes currently under discussion (3-6 and 4-5 dB/1000 rpm). As a consequence, the discussion about acceptable slopes can be moved to the discussion on limits (x dB offset + y dB/1000rpm slope)

Annex 10

ADDITIONAL SOUND EMISSION PROVISIONS
applicable for M1 and N1 only

1. General

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2. Requirement

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3. Measuring method

3.1 measuring instruments and condition of measurements

Unless specified differently here after, the measuring instruments, the conditions of the measurements and the condition of the vehicle are equal to those specified in Annex 3 paragraph 1 and 2.

Some vehicles may have different software programs or modes which affect the acceleration behavior of the vehicle. Such programs may include, but are not limited to, the transmission (e.g. sporty, winter, adaptive, etc.), the electronic stability program (on/off) and the intelligent cruise control (on/off). If the vehicle has different modes leading to valid accelerations, all these modes shall be in compliance with the requirements in this annex.

3.2. Method of testing.

Unless specified differently here after, the conditions and procedures of Annex 3 paragraph 3.1 until 3.1.2.1.2.2. have to be used.

3.3 Target conditions and boundary conditions

There is not a single target condition for the measurements. There is a range of valid operation conditions which have to fall within the following boundary conditions:

Vehicle speed: $20 \leq V_{BB} \leq 80$ km/h
Vehicle acceleration: $a_{wot} \leq 3.5$ m/s^2
Engine speed: $n_{BB} \leq 2.6*PMR^{-0.29}*(s-n_{idle}) + n_{idle}$
and: $n_{BB} \leq 0.9*(s- n_{idle}) + n_{idle}$

3.4 Reference conditions:
Vehicle speed: $(V_{ref}) = 50$ km/h

Engine speed: (n_{ref}) = the engine speed at line BB' in the lowest gear ratio i as tested in Annex 3

3.5. Gear ratio selection

The selection of gear ratios for the test depends on their specific acceleration potential a_{wot} under full throttle condition. All gear ratios leading to a valid operation condition within the boundary condition as specified in 3.3. can be used for the test. Some vehicles may have different software programs or modes for the transmission. In that case the demands of paragraph 3.1 apply.

In case of automatic gear boxes (including adaptive transmissions and CVT's) the test may 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. A gear shifting to a gear ratio which is leads to an acceleration higher than the boundary condition shall be avoided. In that case, it is permitted to establish and use electronic or mechanical devices, including alternate gear selector positions, to prevent a downshift to a gear ratio which leads to an acceleration higher than the boundary condition.

3.6. Acceleration test

Pre-acceleration before line AA'may be used to adjust the gear setting of automatic gear boxes and to achive a more stable acceleration between line AA'and BB'. At the latest at line AA' the accelerator shall be fully depressed (as rapidly as is practicable). The accelerator shall be kept in this depressed condition until the rear of the vehicle reaches line BB'. The accelerator shall then be released as rapidly as possible.

The maximum A-weighted sound pressure level indicated during each passage of the vehicle between the two lines AA' and BB' (see Annex 8, Figure 1) shall be measured and noted, mathematically rounded to the first decimal place. If a sound peak obviously out of character with the general sound pressure level is observed, the measurement shall be discarded. Left and right side may be measured simultaneously or sequentially. The results of each side shall be evaluated separately.

For every separate noise measurement the following parameters should be determined and noted:

- The vehicle speed measurements at AA', BB', and PP' shall be noted and used in calculations to the first significant digit after the decimal place.
- The engine speed measurements at AA', BB', and PP' shall be noted and used in calculations to the first significant digit before the decimal place.
- The calculated acceleration $a_{wot\ test}$ shall be determined in accordance to the formulas in annex 3 par 3.1.2.1.2 and noted to the second digit after the decimal place.

- The position of the gear selector and (for vehicles with automatic gear boxes) the gear ratio at the moment of measuring the maximum noise.

At least eight valid measurements shall be carried out. At least four of them shall have an engine speed n_{BB} which is higher than the reference engine speed (n_{ref}) which is the highest engine speed as tested in Annex 3 (n_{BB} in gear i). The measurements shall be equally distributed over the range of valid operation conditions.

Additional text for proposal "de Graaff" only:

if tests are made in a gear ratio j other than gear i, at least two reference noise measurements shall be made, at an engine speed between 95-105% of n,ref.

3.7. Coast by test

The maximum sound level expressed in A-weighted decibels (dB(A)) shall be measured to the first decimal place as the vehicle is coasting between lines AA' and BB' (see Annex 8, Figure 1- front end of the vehicle on line AA', rear end of the vehicle on line BB'). This value will constitute the result of the measurement.

At least two measurements shall be made on each side of the test vehicle at test speeds lower than the reference speed of 50 km/h. and at least two measurements at test speeds higher than the reference speed of 50 km/h. The speeds shall be approximately equally spaced over the speed range between 30 and 70km/h.

For every noise measurement, the corresponding vehicle speed measurement at PP' shall be noted and used in calculations to the first significant digit after the decimal place.

4. Analysis and Interpretation of results

4.1 Data processing of coast by noise measurements

The individual coast by noise measurements shall be used to calculate the tyre rolling noise level L_{tyre} at the reference speed of 50 km/h, by means of a regression analysis according to:

$$L_{tyre} = \overline{L} - a \cdot \overline{v}$$

where:

$\overline{L}$ is the mean value of the rolling noise levels L_i, measured in dB(A):

$$\overline{L} = \frac{1}{n}\sum_{i=1}^{n} L_i$$

n is the measurement number ($n \geq 8$),

$\overline{v}$ is the mean value of logarithms of speeds V_i:

$$\overline{v} = \frac{1}{n}\sum_{i=1}^{n} v_i \quad \text{with} \quad v_i = \lg(V_i / V_{ref})$$

V_{ref} is the reference speed of 50 km/h
a is the slope of the regression line in dB(A):

$$a = \frac{\sum_{i=1}^{n} (v_i - \overline{v})(L_i - \overline{L})}{\sum_{i=1}^{n} (v_i - \overline{v})^2}$$

4.2 Data processing of accelerated noise measurements

Note1: the following sub-paragraphs 4.2.a to 4.2.d contain the four alternatives for data processing yet under discussion. It is currently not the intention that more than one alternative for data processing will be incorporated into the regulation.

Note2: in the following sub-paragraphs, readings are assumed to be taken at line BB'. Currently it is still under discussion whether readings should be taken at BB' or at Lmax. In the latter case more sophisticated (continuous) measuring equipment is necessary, both for annex 3 and annex 10 measurements as compared to the current annex 3 procedure.

4.2.a. proposal Germany/France:

For the purpose of this regulation the following simplified noise model applies:

The total expected vehicle noise is a function of engine speed (n) and vehicle speed (v) and is an energetic sum of engine noise and tyre noise according to

$$L_{vehicle,expected}(n,v) = 10*\log\left(10^{(Lengine(n)/10)} + 10^{(Ltyre(v)/10)}\right)$$

Where

- $L_{tyre} = L_{tyre}(v_{ref}) + a*\log(v/v_{ref})$, and
- $L_{engine} = L_{engine}(n_{ref}) + b*(n-n_{ref})$

In which

- v_{ref} = 50 km/h
- $L_{tyre}(v_{ref})$ and a have to be determined by coast by measurements according to the procedure in paragraph 3.7 and 4.1

and

- n_{ref} is equal to the engine speed at BB' as measured in annex 3 in gear i ($n_{BB,i}$)
- b = 4,5* dB/1000 1/min for $n > n_{ref}$ and
  = 4,5* dB/1000 1/min for $n < n_{ref}$
- $L_{engine}(n_{ref}) = 10*\log(10^{(Lwot,i/10)} - 10^{(Ltyre(vBB',i)/10)})$
- $L_{wot,i}$ and $v_{BB',i}$ are taken from the measurement results in gear i in annex 3.

* *Note1: this double notation is used for clarity. The discussion on different slopes for $n > n_{ref}$ and $n < n_{ref}$ is shifted to paragraph 5 "limits".*

If $L_{wot,i} - L_{tyre}(v_{BB,i}) < 3$ dB(A), the vehicle is excluded from further evaluation and is considered to be in compliance with the annex 10 demands**.

***Note 2: this is the personal interpretation of the author, based on the presentations available. Within the Dutch delegation it was not completely clear whether this is the correct interpretation.*

Every individual noise measurement Lwot as derived from 3.6, together with its simultaneously measured engine speed and vehicle speed at line BB' ($n_{BB'}$,$v_{BB'}$), shall be compared to the expected vehicle noise Lvehicle,expected($n_{BB'}$,$v_{BB'}$).

$$L_{delta} = L_{wot} - L_{vehicle,expected}$$

All results shall be noted in a table. The columns shall contain the test and analysis results (L_{delta}, L_{wot}, $L_{vehicle,expected}$, $n_{BB'}$ $v_{BB'}$, gear ratio), the rows shall contain the sequential measurements (1,2,3…).
For easy evaluation, a graph may be used where the noise values are plotted as a function of vehicle speed. Measurements in different gear ratios shall be grouped together with specific colors or markings. In case of fixed gear ratios, lines shall be drawn for the $L_{vehicle,expected}(v)$ in every gear ratio separately. The measurement from annex 3 $L_{wot,i}$ shall be marked separately.

4.2.b. proposal based on presentation of Japan

For the purpose of this regulation the following simplified noise model applies:

The total expected vehicle noise is a function of engine speed (n) according to

$$L_{vehicle,expected}(n) = L_{wot,i} + b*(n - n_{BB',i,ref})$$

Where:

- $L_{wot,i}$, $n_{BB',i,ref}$ are the results of the acceleration tests in gear i in annex 3.
- n is the test result $n_{BB'}$ according to paragraph 3.6
- b = 4,5* dB/1000 1/min for $n > n_{BB',i,ref}$ and
  = 4,5* dB/1000 1/min for $n < n_{BB',i,ref}$

* *Note: this double notation is used for clarity. The discussion on different slopes for $n > n_{ref}$ and $n < n_{ref}$ is shifted to paragraph 5 "limits".*

Every individual noise measurement L_{wot} as derived from 3.6, together with its simultaneously measured engine speed at line BB' ($n_{BB'}$), shall be compared to the expected vehicle noise $L_{vehicle,expected}(n_{BB'})$.

$$L_{delta} = L_{wot} - L_{vehicle,expected}$$

All results shall be noted in a table. The columns shall contain the test and analysis results (L_{delta}, L_{wot}, $L_{vehicle,expected}$, $n_{BB'}$), the rows shall contain the sequential measurements (1,2,3…).
For easy evaluation, a graph may be used where the noise values are plotted as a function of engine speed. A line shall be drawn for the $L_{vehicle,expected}(n)$. The measurement from annex 3 ($L_{wot,i}$) shall be marked separately.

4.2.c. proposal based on presentation of mr. Gerhard

For the purpose of this regulation the following simplified noise model applies:

The total expected vehicle noise is a function of vehicle speed (v) and vehicle acceleration (a) according to

$$L_{vehicle,expected}(v,a) = L_{wot,i} + b*(v*a - v_{BB',i,ref}*a_{wot,i,ref})$$

Where:

- $L_{wot,i}$, $v_{BB',i,ref}$ and $a_{wot,i,ref}$ are the results of the acceleration tests in gear i in annex 3.
- v and a are the test results $v_{BB'}$ and $a_{wot,test}$ according to paragraph 3.6
- b = [xx] dB/(km/h*m/s2) (xx to be determined).

Every individual noise measurement L_{wot} as derived from 3.6, together with its simultaneously measured vehicle speed at line BB' ($v_{BB'}$) and its $a_{wot,test}$, shall be compared to the expected vehicle noise $L_{vehicle,expected}(v_{BB'}, a_{wot,test})$.

$$L_{delta} = L_{wot} - L_{vehicle,expected}$$

All results shall be noted in a table. The columns shall contain the test and analysis results (L_{delta}, L_{wot}, $L_{vehicle,expected}$, $v_{BB'}$, $a_{wot,test}$), the rows shall contain the sequential measurements (1,2,3…).

For easy evaluation, a graph may be used where the noise values are plotted as a function of vehicle speed times acceleration (km/h*m/s2). A line shall be drawn for the $L_{vehicle,expected}(v,a)$. The measurement from annex 3 ($L_{wot,i}$) shall be marked separately.

4.2.d. proposal based on presentation of mr. de Graaff

For the purpose of this regulation the following simplified noise model applies:

The total expected vehicle noise is a function of engine speed (n) according to

$$L_{vehicle,expected}(n) = L_{wot,i} + b*(n - n_{BB',i,ref}) - D_{gear,j}$$

Where:

- $L_{wot,i}$, $n_{BB',i,ref}$ are the results of the acceleration tests in gear i in annex 3.
- n is the test result $n_{BB'}$ according to paragraph 3.6
- b = 4,5* dB/1000 1/min for $n > n_{BB',i,ref}$ and
  = 4,5* dB/1000 1/min for $n < n_{BB',i,ref}$
- $D_{gear,j} = \max(0 , L_{wot,i}(n_{BB',i,ref}) - L_{wot,j}(n_{BB',i,ref}))$, this factor shall be determined for every gear ratio separately.
- $L_{wot,j}(n_{BB',i,ref})$ = the reference noise level measured in gear j at the same engine speed $n_{BB,i,ref}$ as measured in gear i in annex 3. This noise level is determined as an arithmetic average from all noise measurements in gear j in the range of 95-105% of $n_{BB',i,ref}$.

* *Note: this double notation is used for clarity. The discussion on different slopes for $n > n_{ref}$ and $n < n_{ref}$ is shifted to paragraph 5 "limits".*

Every individual noise measurement L_{wot} as derived from 3.6, together with its simultaneously measured engine speed at line BB' ($n_{BB'}$), shall be compared to the expected vehicle noise $L_{vehicle,expected}(n_{BB'})$.

$$L_{delta} = L_{wot} - L_{vehicle,expected}$$

All results shall be noted in a table. The columns shall contain the test and analysis results (L_{delta}, L_{wot}, $L_{vehicle,expected}$, $n_{BB'}$, gear ratio), the rows shall contain the sequential measurements (1,2,3…).
For easy evaluation, a graph may be used where the noise values are plotted as a function of engine speed. A line shall be drawn for the $L_{vehicle,expected}(n)$ for every gear ratio separately. The measurement from annex 3 ($L_{wot,i}$) shall be marked separately as well as the reference noise levels in the other gears tested ($L_{wot,j}(n_{BB',i,ref})$).

5. Noise limit

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e.g. The difference between the measured noise level L_{wot} and the expected noise level $L_{vehicle,expected}$ shall be less than xxxxx + yyyy/1000 rpm.