# Uncertainty of Close Proximity (CPX) tyre-road noise measurements –

# Round Robin test results

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## Introduction

In the Netherlands a considerable proportion of the motorways and of the urban and provincial roads has been paved with noise reducing road surfaces. For the purpose of quality control the noise emission characteristics of new and existing road surfaces are measured on a regular basis. These measurements are carried out with the Statistical Pass-By (SPB) method as well as the Close Proximity (CPX; trailer) method. The use of the CPX method has increased over the last years, as well as the number of operators that execute the CPX measurements. From practical experience it appeared that between the results of the different operators relatively large differences could occur. Therefore a need for an investigation of the measurement uncertainty of the CPX method, focussed on the Dutch measurement practice, arose. Five organisations that execute CPX-tests on a commercial basis participated in a Round Robin test and made their measurement trailer available for this research. The test set-up and the results achieved are discussed in this paper.

## Round Robin test scheme

### General set up

4 Trailers participated in the Round Robin. One of the trailers was used by 2 different operators that shared the trailer, but used their own measurement chain and data processing system. The participating trailers each executed 6 measurement runs over 8 different road sections that were paved with 4 different pavement types (2 layer porous asphalt; dense asphalt 0/16; SMA 0/11; thin layer noise reducing surface). Each trailer used 4 different types of test tyres.

**Figure 1** – Trailers used in the test

## Trailers used in the test

The trailers used in the Round Robin test are shown in figure 1. The specifications are as follows:

- Trailer 1 - closed, non absorbing hood; 2 measuring wheels; track width: 2,00 m;

- Trailer 2 - closed, absorbing hood; 2 measuring wheels; track width: 1,88 m;

- Trailer 3 a+b - open; 2 measuring wheels; track width: 1,84 m; 2 operators;

- Trailer 4 - closed, absorbing enclosure; 1 measuring wheel (centre).

According to the operators all trailers are in conformity with ISO/CD 11819-2 [1].

## Tyres used in the test

- Tyre type A acc. to ISO/CD 11819-2 (Avon/Cooper type ZV1, size 185/60 R15; see figure 2);

- Tyre type D acc. to ISO/CD 11819-2 (Dunlop type SP Arctic, size 185R14; see figure 3);

- Tyre type SRTT acc. to ASTM F2493-06 [2] (see figure 4). This tyre (Uniroyal Tigerpaw, size 225/60 R16) is intended to replace tyre type A; One set of these tyres was circulated amongst all operators for comparison purposes; this set is indicated as SRTTR;

- Tyre type Avon Supervan AV4 (size 195/R14 C8; see figure 5). This tyre is intended to replace tyre type D;

- Tyre type B acc. to ISIO 11819-2 (Avon/Cooper Enviro CR322, size 185/65R15; see figure 6). This tyre is used on trailer 1 as a replacement for tyre type A, which is no longer available.

- Tyre type D* (Kumho Radial 857, size 205R14C; see figure 7). This tyre is used on trailer 1 as a replacement for tyre type D, which is no longer available.

**Figure 2** –

Tyre type A



**Figure 3** –

Tyre type D



**Figure 4** –

Tyre type SRTT



**Figure 5** –

Tyre type Avon AV4
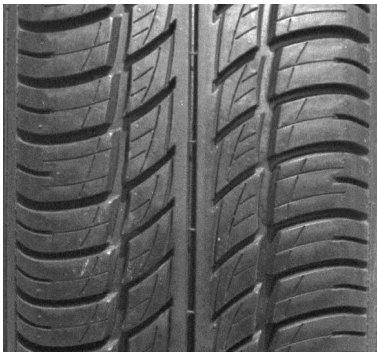


**Figure 6** –

Tyre type B



**Figure 7** –

Tyre type D*



### Executed test runs

The executed test runs are shown in table 1.

**Table 1** – Executed test scheme

| | Trailer 1 | | Trailer 2 | | Trailer 3a/b | | Trailer 4 |
|---|---|---|---|---|---|---|---|
| Run | left tyre | right tyre | left tyre | right tyre | left tyre | right tyre | |
| 1 | SRTT | SRTT | SRTT | SRTT | SRTTR | SRTTR | Avon AV4 |
| 2 | Avon AV4 | Avon AV4 | SRTTR | SRTTR | SRTT | SRTT | A |
| 3 | SRTTR | SRTTR | Avon AV4 | Avon AV4 | Avon AV4 | Avon AV4 | D |
| 4 | B | B | A | A | A | A | SRTT |
| 5 | A | D* | D | A | A | D | Avon AV4 |
| 6 | SRTT | Avon AV4 | Avon AV4 | SRTT | Avon AV4 | SRTT | SRTTR |

## Statistical Analysis

The measured and processed data from the different operators were submitted for statistical analysis according to the following specifications:

- Per 20 m:
  - A-weighted 1/3-octave band levels for the 315 to 4000 Hz mid band frequencies;
  - A-weighted sound levels by summation of the 1/3-octave band levels from 315 to 4000 Hz.
- The mounting side of the test tyre (left – right)
- The test run of the data set in question
- The air temperature above the road surface during the measurement.

The data were supposed to be temperature corrected according to ISO/CD 11819-2. In a few cases the temperature correction was not carried out by the operator; in these cases the temperature correction was applied during the statistical analysis.

The measurement series of all operators on a specific test section were synchronized, so that the location of all 20 m sections exactly matched before the data were converted into 100 m average values and the A-weighted sound levels were computed.

The 100 m average A-weighted noise level values were grouped per test section. From these results it appeared that the data from trailer 1 were systematically higher than those from the other trailers, except for tyre type A (see figure 8). This trailer was equipped with a non absorbent hood that was likely to create a significant influence of sound reflections within the hood. According to ISO/CD 11819-2 a trailer correction factor should have been determined by a calibration procedure and the data should have been corrected with this factor. This correction had not been determined and applied for trailer 1. After it was established that the results of tyre A were faulty due to an exhausted microphone power supply at the end of the test runs it was decided to reject the data of tyre A. Without the results of tyre A all data from trailer 1 were systematically higher that the data from the other trailers, so a correction factor of -1,8 dB(A) could be applied to account for the systematic deviation of these data.
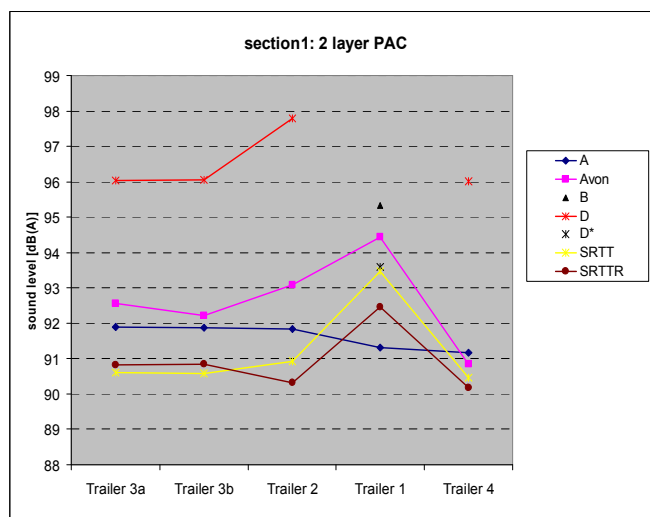


**Figure 8** – Analysis results of section 1 before correction

The results after correction are shown in figure 9.

From further evaluation of the data it appeared that also the results of trailer 4 were in many cases deviating from the other results. This deviation was supposed to be caused by the central position of the measuring wheel of this trailer. The road surfaces characteristics in the centre of the lane may be different from the characteristics in the left and right wheel tracks. Therefore the data from trailer 4 cannot be considered to belong to the same data set as the other results. These data were therefore not included in the determination of average values and standard deviations of the various data subsets.

All data were then analyzed with the method of analysis of variance. By this method the total variance of the measurement series can be divided into contributions of the various factors of influence, in this case: trailer characteristics, mounting side of the tyres and residual variance.
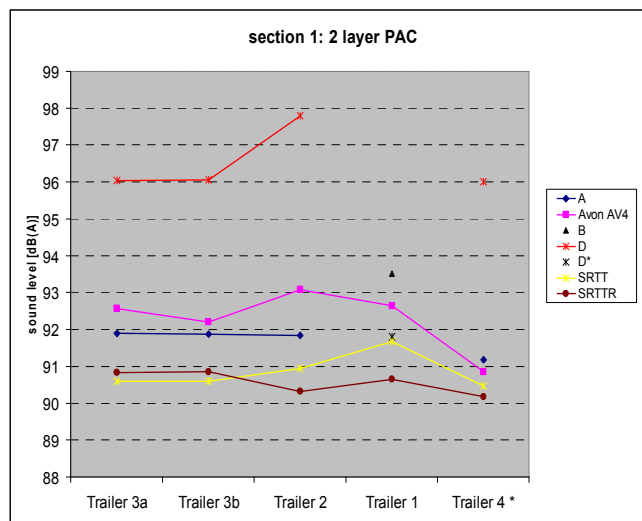


**Figure 9** – Analysis results of section 1 after correction.

# Results of the Round Robin test

## Overall average results

From the results of the statistical analysis it appeared that after correction for the systematic deviations of trailer 1 no further significant, generally occurring, deviations could be detected.

The overall averages (after correction) shown in table 2 demonstrate that the results of the trailers do not deviate much from the general average, be it that for individual tyre-road combinations the results of one trailer may deviate considerably from the average for that combination. Unfortunately the deviations of the trailers from the average are slightly larger when only the tyres intended for future use (SRTT and Avon AV4) are included in the comparison.

## Influence of test surface on trailer correction

According to ISO/CD 11819-2 a trailer correction that accounts for the effect of reflections within the enclosure on the measured sound levels has to be determined and applied for closed trailers. The trailer correction factor is determined in a stationary test on a reflective surface. From a comparison of the average results for the SRTTR circulation tyre set on trailers 2 (closed) and 3 (open) it appeared that a small but significant average difference (0,3 dB(A)) between the trailers could be detected for absorbent road surfaces, but not for reflective surfaces. This could indicate that the trailer correction of the closed trailer was not adequate for absorbent surfaces. However, a comparison between trailers 1 (closed) and 3 (open) did not show such a significant difference. Moreover, the difference between trailers 2 and 3 also showed considerable variation on similar absorbent road surfaces. Therefore a specific study into this effect and the method of determination of the trailer correction factor is recommended, but a final conclusion can not be drawn at this moment.

## Sources of measurement uncertainty

In table 3 the contributions of the sources of influence on the overall measurement uncertainty are shown for the different tyres. The blue figure of 0,6 dB(A) as the total standard deviation for the circulation tyre SRTTR demonstrates the possible minimum uncertainty that would occur if no tyre variations would be present.

An important source of variation between the trailers is the trailer design. The results of a trailer with a central measuring wheel are fundamentally different from the results of two wheeled trailers. The difference between an open and a closed trailer design does not lead to significantly different results, as long as the closed trailer is equipped with an absorbent lining in the hood and as long as the influence of reflections under the hood is corrected for with a trailer correction factor. If the hood is non absorbent this calibration and correction for reflections becomes even more important. These reflections were shown to produce a systematic deviation of the test results. Instead of the ISO calibration procedure also an overall correction factor determined by statistical analysis of trailer comparison data might be used.

A second aspect of the trailer related uncertainties is the variability of the tyre properties. Due to spread in the production and to ageing of the rubber the properties of the tyres of the different trailers may differ considerably. This fact has been recognised by ISO and further procedures for purchase and handling of tyres during their operational life time are under development.

## Mounting side of the tyres

A rather unexpected source of differences between measurements is the mounting side of the tyres. These differences are caused by different characteristics of the surface in the left and the right track, by the differences of properties of the left and right test tyres and by differences between the left and right measurement chain. As shown in table 3 this effect appeared to be even more important than the effect of the trailer related factors. This effect can be cancelled rather easily by using two similar test tyres on either side of the trailer and to average the results of the two tyres. In that case the standard deviation due to mounting side disappears and the residual standard deviation will be divided by a factor √2, because the number of measurements doubles. The resulting values of the standard deviations when two test tyres are used are shown in red in table 3.

## Other sources of measurement uncertainty

According to ISO the noise emission data are corrected for air temperature and measuring speed. This implies that the accuracies of the measurement devices for temperature end speed are relevant for the measurement uncertainty. From the recorded data it appeared that regular calibration of these devices and a more uniform procedure for the air temperature measurement may help to reduce the CPX measurement uncertainty.

## Additional guidelines

Base on the findings in this Round Robin test a set of additional guidelines is being drafted that may supplement the instructions given in ISO/CD 11819-2 and will help to reduce the measurement uncertainty of the CPX test method. These guidelines will aim to uniformize the trailer design or to enhance the conformity between trailers by means of calibration. The additional instructions given in the guidelines will prescribe testing with two similar tyres on either side of the trailer, while the calibration of measurement devices for temperature, speed and distance will also receive more attention.

The ISO procedures under development for purchase, handling and storage of test tyres will probably be introduced in the Dutch CPX measurement practice earlier than the ISO publication as part of the additional guidelines.

## Acknowledgement

## References

[1]  ISO/CD 11819-2, *Acoustics- Measurement of the influence of road surfaces on traffic noise – Part 2: The close-proximity method*, ISO, Geneva, 13 December 2000.

[2]  ASTM F2493-06, *Standard Specification for 225/60R16 97S Radial Standard Test Tyre*.

| | Difference | Trailer 1 | Trailer 2 | Trailer 3a | Trailer 3b | Trailer 4 |
|---|---|---|---|---|---|---|
| Average of test tyres A, Avon AV4, SRTT and SRTTR | **Average** | **0,07** | **0,05** | **-0,09** | **-0,11** | **-0,50** |
| | Minimum | -0,79 | -0,32 | -0,78 | -0,80 | -1,93 |
| | Maximum | 0,87 | 0,55 | 0,43 | 0,40 | 1,87 |
| Average of future test tyres Avon AV4, SRTT and SRTTR | **Average** | **0,23** | **0,08** | **-0,29** | **-0,32** | **-0,49** |
| | Minimum | -0,18 | -0,32 | -0,78 | -0,80 | -1,93 |
| | Maximum | 0,87 | 0,39 | 0,11 | 0,12 | 1,87 |
| Test tyre D | **Average** | - | **0,77** | **-0,78** | **-0,76** | **-1,30** |
| | Minimum | - | -0,05 | -1,41 | -1,39 | -2,18 |
| | Maximum | - | 1,40 | 0,03 | 0,05 | -0,92 |

**Table 2** – Average differences in dB(A) between the individual trailers and the average of the 3 two wheeled trailers

| | A | Avon AV4 | D | SRTT | SRTTR |
|---|---|---|---|---|---|
| Trailer | 0,16 / 0,16 | 0,32 / 0,32 | 1,02 | 0,39 / 0,39 | 0,25 / 0,25 |
| Mounting side | 0,95 / - | 0,83 / - | | 0,68 / - | 0,47 / - |
| Residue | 0,24 / 0,17 | 0,32 / 0,23 | 0,19 | 0,41 / 0,29 | 0,29 / 0,21 |
| Total | 1,00 / 0,23 | 0,94 / 0,39 | 1,03 | 0,88 / 0,49 | 0,60 / 0,32 |

**Table 3** – Measurement uncertainty expressed in standard deviations in dB(A) for each test tyre type, divided in sources of measurement uncertainty. Blue figures for 1 test tyre; red figures for 2 test tyres.