DIFFERENT LOGGING RATES FOR MEASURING THE PROMINENCE OF IMPULSIVE SOUNDS AND FOR ADJUSTMENT OF LAEQ

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1 INTRODUCTION

As noise with prominent impulsive sound is more annoying than continuous types of noise (without impulses) with the same equivalent sound pressure level, an adjustment is added to the measured LAeq if prominent impulsive sound is present. In ISO 1996[1,2], three categories of impulsive sound have been found to correlate best with community response, and adjustments are given for each. Several sources with impulsive characteristics are categorised in ISO 1996-1. The non-exhaustive list of examples includes compressed air release, scrap handling, goods delivery, fork lifts with rattling forks, skateboard ramps, industrial shearing, gas discharges, percussive tools in demolition, powered riveting, etc. However, the list of sources of impulsive sound for each category is incomplete.

Therefore, ISO developed a method, ISO/PAS 1996-3[3], which defines an objective method to measure the prominence of impulsive sound relative to residual sound. ISO/PAS 1996-3 is a development of BS 4142[4] and the objective method has been refined based on discussions among UK and international experts.

Annex A of ISO/PAS 1996-3 encourages further research to support the development of a full ISO standard. This includes the application of real-world sources assessed at receiver locations including typical signal to residual noise ratios.

2 THE ISO/PAS 1996-3 OBJECTIVE METHOD

The objective measuring method in ISO/PAS 1996-3 categorises sources by determination of the prominence of impulsive sound, with the aim of correlating to community response. The method is intended for sources not identified as gunfire or high-energy impulsive sound. It typically produces adjustments in the range 0,0 dB to 9,0 dB. These adjustments are intended to be used to categorise the sources as either regular impulsive or highly impulsive sound sources and apply the penalty indicated in ISO 1996-1. However, the adjustments may be applied directly, as is done in Nordtest Acou 112[5], and in BS 4142:2014+A1:2019 where it has also been adopted.

The method is based on the onset rate and level difference for the A-weighted time history of the sound pressure level with time weighting F. The method was originally developed and tested in a Nordtest project that led to Nordtest Acou 112 where the influence of the sampling interval for the A-weighted sound pressure level with time weighting F was tested[6]. The sampling interval had an effect on the result but, to enable the use of several types of measuring equipment, it was decided that sampling intervals in the range of 10-25 ms could be allowed, with 10 ms preferred for the best accuracy. The shorter the logging interval, the more precisely the method follows the actual impulse. However, this does not take account of human response accounted for in the method.

During development in the ISO Working Group, ISO TC43 SC1 WG45, the method was reviewed and refined, and its description and application made more rigorous. One example was the review of a study of the different logging intervals as well a comparison of the Onset Rate determination method to 2 alternative methods, covering 14 different impulsive sound sources, subsequently published by Tickell[7].

In the published method, measurements are made with instruments conforming with Class 1 as specified in IEC 61672-1[8] with the additional logging of L_{pAF}, the A frequency-weighted and F time-weighted sound pressure level, at time intervals in the range 10-25 ms (incl.). Use of short-term L_{Aeq} (e.g. 10 ms), although not preferred, is permitted to compute the L_{pAF} values. Measurements based on samples with time intervals of 100 ms may be used for surveys and screening, as many modern sound level meters can do this while recording the audio in sufficient detail for later analysis. However, it was identified that using this time interval results in a higher uncertainty.

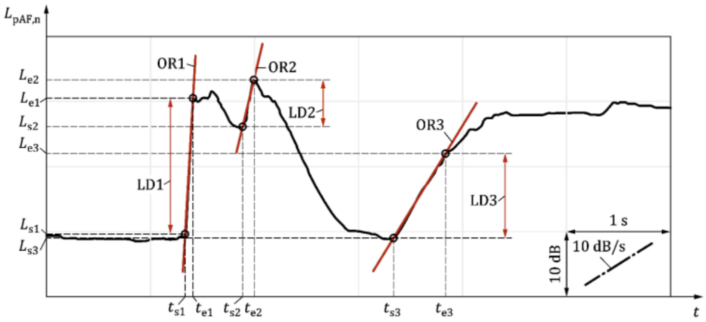

Figure 1: Time history of the L_{pAF} sound pressure levels. LD is the level difference, L_s and t_s relate to the starting point, L_e and t_e relate to the end point, OR is the onset rate, and gradients of over 10 dB/s are indicated in red (source ISO PAS 1996-3).

ISO 1996-2 provides additional guidance for performing these measurements. The ISO PAS 1996-3 method is intended to complement the ISO 1996-2 measurement method for general purpose environmental noise assessment.

A comparison of the PAS to BS 4142:2014+A1:2019 shows the following main differences:

- a 100 ms sampling rate is permitted for survey measurements
- a default 30 minute "assessment time interval" over which the impulse adjustment is applied, with shorter intervals permitted for short-duration reference time intervals

Further details of the method as well as the changes made during development can also be found in a Euronoise 2021 paper by Manvell & Pedersen[9].

Figure 2: Automatic ISO PAS 1996-3 compliant impulse detection in Enviro Noise Partner.

The method is supported by commercial solutions such as HBK's 2255 Sound Level Meter and Enviro Noise Partner[10,11,12]. This enables impulse assessment with a 16 ms L_{pAF} sample rate in accordance with ISO PAS 1996-3. The solution automatically detects the impulses and identifies the most significant one (example shown in Figures 2 and 3). In addition, this solution enables the analysis to be done for multiple assessment time intervals such as the method's default interval of 30 minutes.

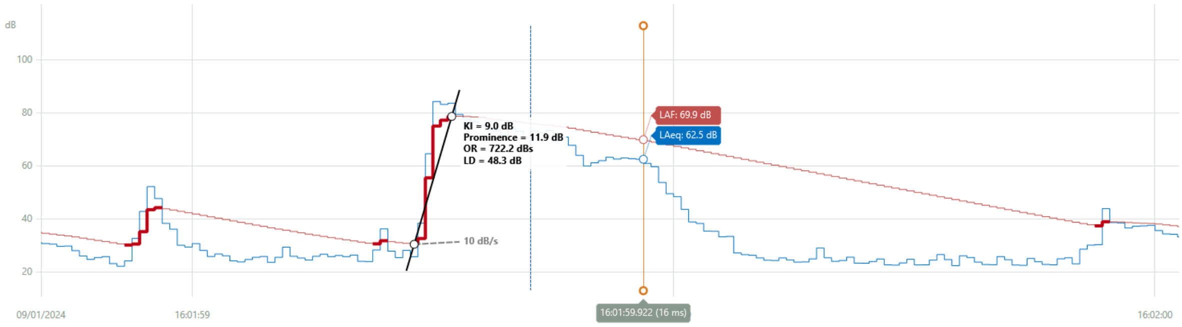

Figure 3: Impulse detection based on 16 ms L_{pAF} sampling (thick red line) showing slope (black), start and end points (circles). The short L_{Aeq} is in blue, the thin red line is the 1 ms L_{pAF}.

3 THE STUDY

3.1 Scope

This study studies the application of the method with real-world sources assessed at receiver locations, including typical signal to residual noise ratios, with focus on the impact of the LAF sampling time intervals on results. The sources targeted are ones that are not listed in ISO 1996 Part 1 as being clearly identified and categorised sources. A handful of sources are selected for investigation, primarily with focus on construction sites.

In order to investigate the impact of the LAF sampling time interval, the following test equipment were used:

- A HBK 2255 sound level meter, software version 1.8.1.0, with a BZ-7450 Advanced Logging Licence. Although not required to fulfil the method, the meter also had BZ-7404 MP3 Audio Licence and BZ-7403 Frequency Analysis Licence
- HBK's BZ-7301 Enviro Noise Partner, Version 1.8.1.0, specifically modified for this research project as described below

The commercial Enviro Noise Partner software was modified to enable the emulation of different sample rates from a single measurement. The standard 2255 sound level meter's "fast logging" function supports 1 ms L_{pAF} sampling time intervals (actually 1/1024 s) which was used in the measurements to enable the modified Enviro Noise Partner to emulate measurements with different LAF sampling time intervals by analysing only every 10th or 25th sample, etc..

This decimation algorithm enabled the 2255's 1 ms "fast logging" data to be decimated such that to fall within the standard's range (10-25 ms, or 100 ms). Basically, it skips samples, meaning that if you run with a decimation factor of 10, it will use sample 10, 20, 30, etc., depending on which sample is chosen in the setup, as described below. This matches what the sound level meter is doing when "fast logging" measuring such that, when running with a decimation factor of 10 you will get the same results as if you had measured with a 10 ms sampling time interval.

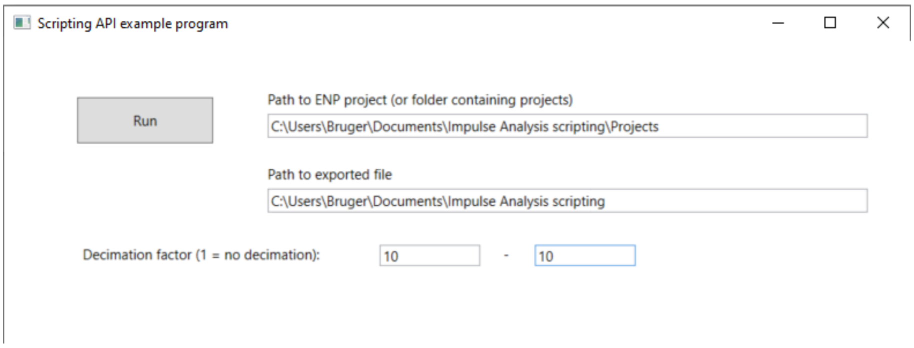

Figure 4: The modified Enviro Noise Partner software's decimation algorithm sampling configuration user interface.

In addition, the software enables us to choose which sample to use in the decimation method: the first, middle or last sample:

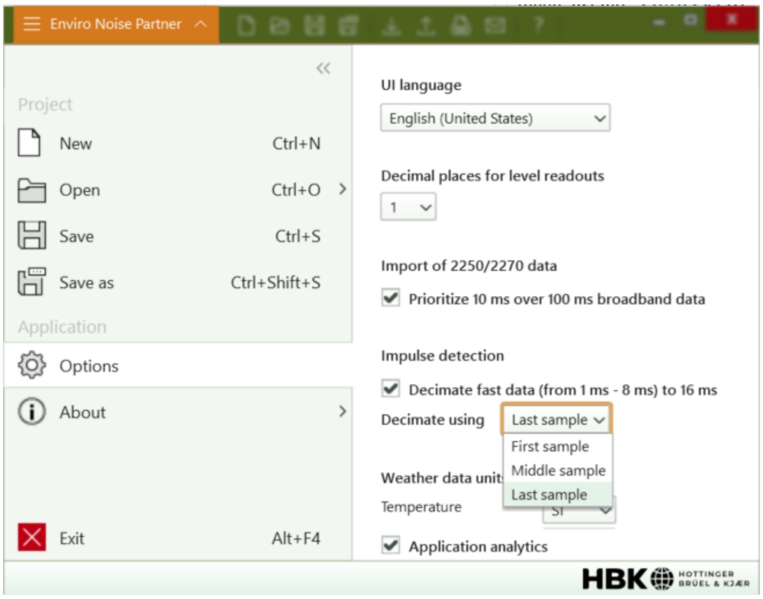

Figure 5: The Enviro Noise Partner software's decimation algorithm set up sampling.

How the sampling is done is not clearly defined in ISO 1996-3. It states "The A frequency-weighted and F time-weighted sound pressure level shall be sampled with time intervals in the range 10-25 ms (incl.)". It could be argued that this indicates that it is the last sample. For this study, we decided to use the last sample, in line with the L_{pAF} time weighting sound level logic of IEC 61672.

As we are interested in looking at the differences between 10-25 ms, and potentially 100 ms, sampling as defined in ISO 1996-3, we decided to set the decimation to 10, 16, 25 and 100. Comparing L_{pAF} to L_{Aeq} with different sampling rates is outside the scope of this study.

The study intends to analyse the uncertainty of these assessments. Therefore, it is intended that we measure multiple impulses from each of the sources. In some cases, for example with percussive equipment like jack hammers or pile driving where we naturally have multiple impulses, it is expected that this will relatively simple.

3.2 Initial Focus

After the project scope was agreed and the analysis tools developed, inclement weather has delayed the collection of sufficient real-life measurements at any of the test sites under consideration. Therefore, the authors contacted Cheol-Ho Jeong, Associate Professor at the Danish Technical University (DTU), for assistance which led to data collection being done as part of DTU's Masters in Engineering Environmental Acoustics module in June 2024. Various impulsive sources from a construction site were successfully measured over a period of 3 days and form the basis for further analysis.

This data set of measurements contained 292 impulses detected with 16 ms logging. Therefore, in order to get initial results in time for submission of this paper, we have taken the following approach based on the fact that ISO 1996-3 states that:

- Sounds with adjustment $K_I = 0$ (P≤5) at the receiver location are not impulsive.
- For sounds with adjustment $0 < K_I \leq 5$ (5<P≤10) at the receiver location, categorise these as regular impulsive.
- For sounds with adjustment $K_I > 5$ (P>10) at the receiver location, categorise these as highly impulsive.

Therefore, it is worthwhile to initially look at the variability of the logging interval around the break points in the K_I penalty (ie P=5 or 10 dB). So if we can easily find and analyse for example at least 3-5 impulses in each of the following groups where 16 ms analysis results gave:

- $4< K_I \leq 5$ dB
- $5{,}01< K_I \leq 6$ dB
- $9< K_I \leq 10$ dB
- $10{,}01 \leq K_I$ dB

Then we can look at:

- how much the logging interval affects the categorisation as either regular or highly impulsive
- how the logging interval compares to the variability per source found and reported by the during a separate analysis done by the Danish Technical University (see acknowledgements)

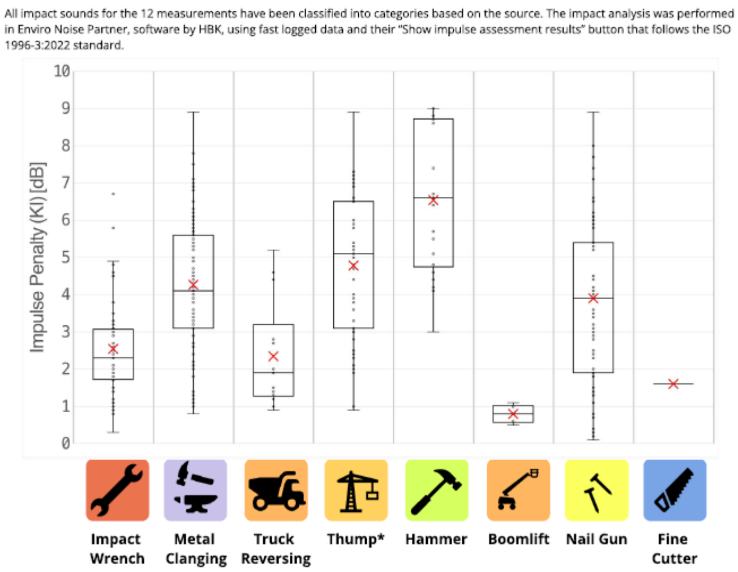

Figure 6: DTU's analysis of impulse sources from a construction site (unpublished data)

Based on the results shown in the table above, it was decided to focus on how much the logging interval affects the categorisation as either (regular) impulsive or not: ie $4< K_I \leq 6$ dB determined when logging $L_{pAF,16ms}$. In addition, it was decided to look at one type of source with a significant number of impulses in order to enable statistics to be assessed. As the Nail Gun was an appropriate source with a good, clear source description, it was selected for further investigation.

Cate-gory	K_I (dB)	No. impulses (16 ms interval)	Hammer	Impact Wrench	Metal clanging	Nail gun	Thumps	Truck reverse
Cat 1	**4-5**	41	5	5	17	7	5	2
Cat 2	**5-6**	43	3	1	12	15	11	1
Cat 3	**9-10**	4	4	0	0	0	0	0
Cat 4	**>10**	0	0	0	0	0	0	0
ISO Category			High	Unknown	High	High	Unknown	Unknown

4 RESULTS

Analyses were made for the selected Nail Gun measurements where 4< K_I <6 when logging $L_{pAF,16ms}$. This resulted in an average K_I of 5,06 dB with a standard deviation of 0,637 dB for 22 impulses.

K_I (dB)	Average	STD Dev
Nail Gun **16 ms logging 4,01< K_I ≤6 dB**	5,06	0,637

These initial impulses were reanalysed with different logging intervals by decimation. Filtering further analysis to those where 4< K_I <6 when logging $L_{pAF,16ms}$ resulted in 15 impulses. Ignoring 100 ms time intervals gave a slightly higher average K_I of 5,32 dB with a standard deviation of 0,457 dB.

Impulse		KI (dB) / Log Interval (ms)				All		10-25 ms	
ID	Time	10	16	25	100	Ave	Stddev	Ave	Stddev
1	08:16:43,4	4,36	4,22	4,41		4,33	0,098	4,33	0,098
2	08:16:51,8	6,02	5,97			6,00	0,033	6,00	0,033
3	08:27:24,2	7,36	5,27	5,19	4,53	5,59	1,229	5,94	1,232
4	08:27:36,3	4,40	4,47	4,40	3,27	4,13	0,580	4,42	0,038
5	08:28:46,5	8,10	5,23	5,45	6,01	6,20	1,309	6,26	1,596
6	10:27:45,0	5,14	5,11	4,69	2,21	4,29	1,402	4,98	0,251
7	10:27:45,8	5,19	4,89	4,67		4,91	0,260	4,91	0,260
8	12:56:37,3	6,63	5,13	5,23	4,26	5,31	0,978	5,66	0,836
9	12:56:42,2	5,69	5,37	4,21	2,57	4,46	1,410	5,09	0,776
10	12:56:42,8	5,44	5,36			5,40	0,059	5,40	0,059
11	12:56:44,7	6,07	5,93	4,11		5,37	1,096	5,37	1,096
12	12:57:25,1	5,36	5,42	5,45	5,13	5,34	0,144	5,41	0,045
13	13:00:07,4	5,43	5,27	5,38		5,36	0,085	5,36	0,085
14	13:00:08,1	5,10	4,99	5,07	4,12	4,82	0,470	5,05	0,052
15	13:00:18,5	5,20	5,55	5,99		5,58	0,393	5,58	0,393
Ave		5,70	5,21	4,94	4,01	5,14	0,636	**5,32**	**0,457**

5 DISCUSSION

The study has found that the sampling method description in ISO PAS 1996-3 is ambiguous and could be more specific regarding the determination of the L_{pAF} parameter – whether the maximum during the interval or last one. However, until the impact of this ambiguity has been studied, there are no recommendations on whether this needs refining.

Our initial study of the results using 16 ms logging indicate a possible difference in the aggregate measured K_I compared to the impulse category's range of K_I values for a number of sources. It can be seen in the table in section 3.2 that there may not be a clear, unequivocable determination of the appropriate category of these sources from the measurements. Rather than immediately hypothesise on actual differences and their possible causes, further study is being undertaken. 3 sources, categorized as highly impulsive in ISO 1996, could potentially be categorized from these measurements as regularly impulsive.

A 100 ms logging interval is not recommended as it misses several impulses and seems to underestimate K_I.

Our initial analysis could indicate that the logging interval has some influence on the assessment result as the standard deviation of the assessment is only slightly smaller than that of the initial assessment done only using $L_{pAF,16ms}$. However, further study is recommended, also to investigate the differences in numbers of impulses identified with the two different methods when using $L_{pAF,16ms}$.

During the development of the Nordtest method, it was found that the logging interval has only a small influence on the assessment result. The results are not conclusive enough to confirm whether this is the case when using a logging interval of 10-25 ms. However, it could be important when dealing with situations where the result could affect categorization.

6 NEXT STEPS

The following next steps are planned:

- Further analysis
- IOA Acoustics 2024 conference presentation, discussion on BS 4142 experiences
- Further analysis with possible subsequent conference papers
- ISO TC43 SC1 WG45 review
- ISO PAS 1996-3 systematic review 2025

7 ACKNOWLEDGEMENTS

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8 CONCLUSIONS

An adjustment is added to the measured LAeq if prominent impulsive sound is present. The list of sources of impulsive sound for each of the three categories of impulsive sound and their adjustments defined in ISO 1996 is incomplete. The ISO/PAS 1996-3 method, basically identical to BS 4142, to measure the prominence of impulsive sound relative to residual sound and categorize the impulsive sources permits the logging of LpAF with different time intervals.

This study investigates the impact of the time intervals on results for real-world sources assessed at receiver locations including typical signal to residual noise ratios.

Our initial results show that a 100 ms logging interval is not recommended as it misses several impulses and seems to underestimate K_I. In addition, the logging interval seems to have some influence on the assessment result. Whether this is significant, particularly when dealing with situations where the result could affect categorization needs more study. A more detailed comparison of the processing methods to emulate the logging is under consideration. Comparison of the results with those expected from the listed source categories and analysis of the differences and their possible causes is worth further study.

Further study is recommended and is underway. It is expected that, once complete, its results can be compared to those from Nordtest, Tickell, ISO TC43 SC1 WG 45 and Danish EPA studies.

We encourage others to share their findings with us and ISO TC43 SC1 WG 45. Feedback and experience from UK is welcome.

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