Application of the Objective Impulse Assessment method in AS1055:2018

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ABSTRACT

The 2018 revision of '*AS1055 Acoustics - Description and measurement of environmental noise*' included an informative Appendix E, which provided an objective method for assessment of impulsive noise. The intent of the Appendix was to provide a standard method for impulse assessment in Australia, as at present there is no other objective method to assess such impulsive characteristics. Assessment in those States requiring 'I' (or Impulse) time response can't be implemented as there is no current international standard for the 'I' time constant in sound level meters and many sound level meters do not include it because of that. The paper describes how to apply the Standard method, which uses 'F' (or Fast) time weighting and compares results of analyses of three different and common types of impulsive industrial noise sources using 30ms, 20ms and 10ms time intervals allowed in the standard to identify if there was any difference between their calculated impulse adjustment. The 100ms and 50ms intervals were also used for comparison and 100ms was found to provide a relatively simple screening method. Because of the potential for variation in adjustment value identified using different sample intervals, jurisdictions using Appendix E of AS1055:2018 should clearly state the sample interval to be used; if one value is to be used, 10ms is recommended.

1 INTRODUCTION

Assessment and measurement of environmental noise and its acceptability includes consideration of the characteristics of the sound being measured, as well as its time of occurrence and receiver location. Characteristics which are accepted as being able to affect the acceptability of a sound and its potential for annoyance as noise include emergence above background, tonality, variation in sound level such as step-wise intermittent sound level variations, and impulsiveness and these are noted in noise guidelines and policies (EPA NSW 2017).

'*AS1055:2018 Acoustics - Description and measurement of environmental noise*' provides the basic document for methods and descriptors to assess environmental noise in Australia. Regulatory jurisdictions in each State have also provided procedures or policy documents for assessment of environmental noise and its acceptability. Impulsivity is included in AS1055 as a characteristic for which the measured time averaged sound level $L_{Aeq,t}$ should be adjusted to achieve a rating level $L_{Ar,t}$. Adjustments are also provided for characteristics of tonality and intermittency. The adjustment for impulsiveness, K_I, is added the $L_{Aeq,t}$ measured for the assessment period.

At present it is considered that impulsiveness is not adequately considered by the regulatory methods and anecdotal advice is that the method provided in AS1055:2018 is not being widely used. This is despite the fact that impulsiveness in a received noise can be highly annoying.

In New South Wales, the Noise Policy for Industry does not provide a method for consideration of impulsivity of a received sound, so presumably if present, it is done as a subjective auditory assessment. In Victoria, the recommended method for assessing major premises with potentially impulsive noise emission depends on audibility (either 'just detectable' or 'prominent'). In Queensland the 'I' time weighting is also required, while in Tasmania an 'Impulse sound level meter' is required with a time-constant of 35 μs. These are despite there being no international standard for 'I' time constant in sound level meters and many sound level meters do not include it because of that. Those meters which do include an I time constant can choose their own method of how a sound level is given because there is no standard. This problem makes the required methods difficult to apply in Tasmania and Queensland.

In Western Australia the definition of impulsive noise is where the L_{APeak} sound level measured with 'P time-weighting' exceeds the $L_{AMaxSlow}$ sound level by more than 15 dB for a single event – but P weighting doesn't exist. In South Australia the assessment of impulsive noise refers to AS1055-1:1997; as this has been replaced by the 2018 revision, it might be assumed that the latest method is used in that State.

For these reasons (of unsuitability or impossibility of using the ‘I’ time weighting), as well as providing an objective approach, the method in AS1055:2018, which uses ‘F’ time weighting, was included as an informative Appendix in the 2018 revision of the Standard. This Appendix was based on the method proposed for ISO/PAS 1996-3 (in the final stages of preparation), which was in turn based on the Nordtest Standard ACOU 112 *Acoustics: Prominence of impulsive sounds and for adjustment of LAeq* (NT ACOU 112), introduced in 2002.

Informal advice from some practitioners indicates the application of this part of the Standard is not widely used or understood. This paper describes the method given in the Standard and how to apply it, provides comparisons between three different types of industrial impulsive noise analysed using the different sample intervals from 10ms to 100ms. The ISO working group for the development of ISO1996:3 accepted the 100ms approach as suitable for a screening test.

2 THE OBJECTIVE IMPULSE ASSESSMENT METHOD

The method objectively categorises sources by determining how prominently the impulsiveness characteristic is perceived through continuous part of the noise. The ‘F’ time weighting is used. The method is for measuring the prominence of impulsive sounds for sources not identified as gunfire or high energy impulsive sound. Impulsive sound is defined as sound with a sudden onset which exceeds 10 dB/second. 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 into either regular impulsive or highly impulsive sources and apply a penalty. It is accepted that statutory authorities have the role of identifying what ‘penalty’ or adjustment shall be applied to different types of impulsive sounds and the calculated adjustment using the method could be used to inform what that regulatory penalty should be.

The A-weighted sound pressure level with time weighting ‘F’ is sampled with time intervals in the range 10 to 25ms. Figure 1 shows the values to be obtained using the method for three events. The ‘F’ time weighting over the period is shown as the continuous blue line. The Onset Rate (OR) for an event is the slope of the direct line between the start and end of an event with an increase in sound level of more than 10 dB/s. In the figure, t_{s1} is the start of event 1, t_{e1} is the end of event 1, L_{s1} is the starting sound level for event 1 and L_{e1} is the end sound level of the event 1.

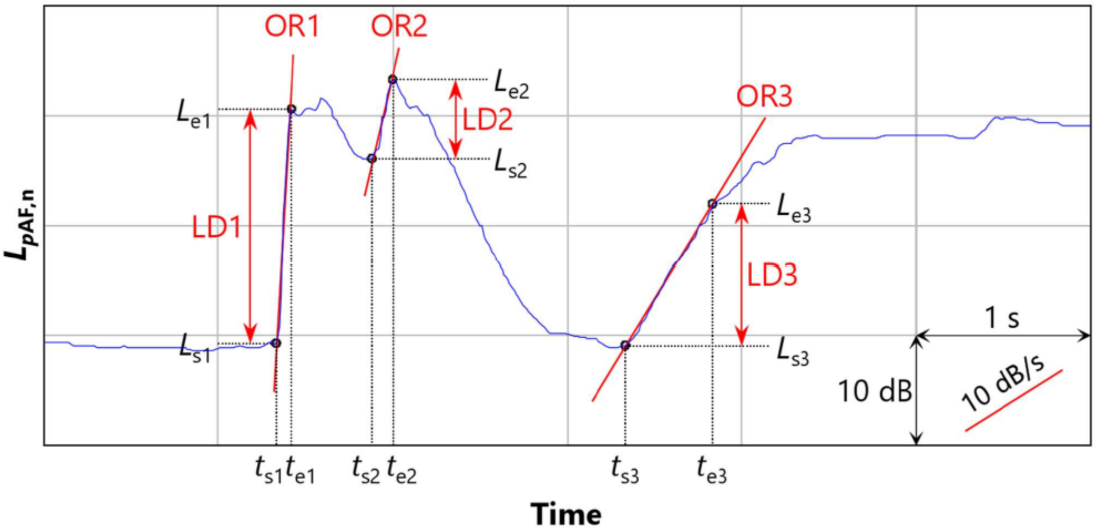

Figure 1 - Time history of the A-weighted sound pressure levels with time weighting F (ISO 2021)

In Figure 1, OR1 has the highest Onset Rate because it has the highest slope. OR3 has the lowest Onset Rate. The next step is calculation of the Prominence P from the following equation:

$$P = 3 \log_{10} (\text{Onset Rate}) + 2 \log_{10} (\text{Level Difference}) \qquad (1)$$

Prominence is calculated for each or a number of events in any reference time interval, such as 15-minutes or 30-minutes. The event with the highest value of P is then used to calculate the adjustment for the time interval.

The impulse adjustment K_I which is added to the measured $L_{Aeq,t}$ for the period to give the rating sound level $L_{Ar,t}$ is then calculated from the formula:

$$K_I = 1.8\ (P - 5),\ \text{for}\ P > 5, \quad K_I = 0\ \text{for}\ P \leq 5 \qquad (2)$$

Sounds with adjustment $K_I = 0$ at the receiver location are categorised as not impulsive. For sounds with adjustment $0 < K_I \leq 5$ at the receiver location are categorised as regular impulsive. For sounds with adjustment $K_I > 5$ at the receiver location, these are categorised as highly impulsive.

3 Selection of measurement intervals and the screening test method using 100ms sample interval

The method described above rests on identifying periods with impulsive events and then analysing the recorded sound for those events with sample intervals of 10 to 25ms. However after developing the results from this investigation, the author considered that the 100ms interval could also be used as a screening step using logging sound level meter data from which a decision could be made about whether the detailed sampling was required. There are some measurement systems which automatically assess monitored noise for impulsivity according to the method in the Standard, but they might not be readily available.

To test the difference between different sample intervals, sample intervals of 10, 20, 30, 50 and 100 ms were used on actual recordings of industrial site boundary noise which had impulsive characteristics and the Prominence P and Impulse Adjustment K_I were calculated for each. The analysis was to identify if there is a good comparison between the results for all of the time intervals used, for typical impulsive industrial sounds. This approach could also be included in a fairly simple algorithm or a*pplication* applied to the monitoring device.

The choice of using a 100ms sample interval as a screening test was based on that data being readily available from modern logging and recording sound level meters. Using 100ms stored data allows a spreadsheet approach to be used as a screening test to calculate P and K_I for the whole measurement period and then from that identify where impulsive events have occurred. The impulsive events identified from the spreadsheet calculation can then be subsequently listened-to and the source identified. Alternatively, a time history could be reviewed. From there the decision whether to do a detailed impulse analysis can be made.

Sound levels were measured near the boundaries of industrial facilities with impulsive noise sources. Four different source locations were used:

A. A location in a car-park near a downstream steel rolling mill. One source distance was 35m to a scrap pit for scrap end-cuts falling approximately 1 to 2m into a bin, what might be considered moderate to highly impulsive. The other source distance 40m to the closest point of the main mill building with sources being impacts from shearing of steel plate and rolling mill noise - what might be considered low to moderately impulsive.
B. A location from 80m to the building in item A above, on its boundary, with the same sources as in A plus hammering impacts on the tynes of a fork-lift truck, which would be considered as highly impulsive.
C. A location at the boundary of an open-air heavy scrap handling facility with impacts from scrap loading into trucks, management of a scrap-pile with front-end loaders and unloading of heavy scrap from a truck to the pile. Generally what might be considered low to moderate impulsiveness.
D. One near the boundary of a gas treatment plant under repair, with grinding (low impulsivity) and hammering on a large diameter steel pipe of what might be considered high impulsivity.

Measurements were made on the same day at each facility, with low wind speeds and moderate air temperatures. No explosive tools were measured. One bird call was also included in the measurements at the first location for comparison, as it occurred during the measurements.

3.1 Measurement and analysis method

Sound levels were measured with a Class 1 precision grade sound level meter set to ‘F’ time weighting and with the A frequency-weighting. The AC output of the meter was recorded as .wav files on a digital wave recorder set at 48 kb/s sample interval. Recording periods ranged from 5 to 10 minutes. Being in the boundary areas of industrial facilities the ambient sound levels ranged from 60 to 70 dBA.

The recorded signals were replayed through the sound level meter microphone input as an electrical signal and sampled at intervals of 10, 20, 30, 50 and 100ms. The sound level meter samples the acoustic or electrical signal at 48 kb/s and records the sound level on each integer of the sample interval as a .csv file. Each measurement was then analysed using a spreadsheet (Microsoft Excel) using the methods of the proposed standard, to calculate Onset Rate OR, Prominence P and impulsiveness adjustment factor K_I for impulsive event peaks.

Fourteen different analysis recordings were made with from two to eight peaks for analysis in each, and each of these was analysed for the five sample intervals. Each peak of interest individually had the calculations made to determine the impulsive adjustment factor K_I. A total of 309 peaks were analysed. The calculations made were for three values:

i. the steepest or highest Onset Rate of the peak for any successive sample interval – 'Steepest method';
ii. the Onset Rate for the overall peak event – 'Overall method' as used in the standard, shown in Figure 1;
iii. the Onset Rate for any other part of the peak calculated between adjoining multiple intervals less than the period of the total peak, for which the Onset Rate may be higher or lower than either of (i) or (ii) above – this was called the 'Other method' in the results.

This totalled 897 calculations made, each 'by hand' as each had to be reviewed separately. This is explained further below in terms of the calculations used in the standard method.

3.2 Method for analysis and calculation of prominence and impulse adjustment

Figure 2 shows a typical sound pressure level time history for one of the measurement periods analysed in this study. It was a measurement made at approximately 80m from the side of a rolling mill building, on the boundary of the site. The sample interval shown includes impulsive events from operation of a shear inside the building and hammering of a fork-lift truck tynes in the open doorway of the building.

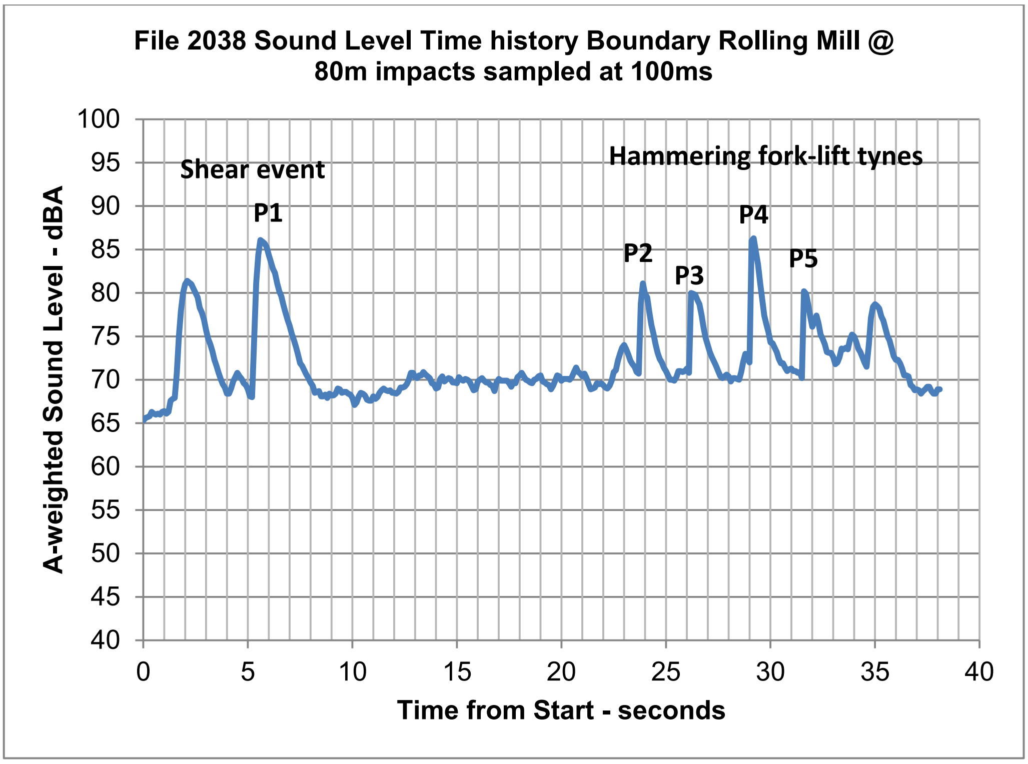

Figure 2: Time history of sound level from recording at boundary of rolling mill, sampled at 100ms

From this the impulse method was used with the stored 100ms sound level data. Values calculated from the data are:

- A-weighted sound pressure levels in each 100ms period;
- Increase (or decrease) in sound level between successive intervals;
- Periods with an increase in sound level of greater than 10 dB/sec compared to the previous interval;
- Prominence of the intervals with greater than 10 dB/sec increase;
- K_I impulse adjustment value of the intervals.

Table 1 shows the measured sound level data with a 100ms sample interval and calculated K_I adjustment values for three of the peaks in Figure 2, a shear event Peak P1 and two hammering events Peaks P4 and P5. The starting time L_s and end time L_e of the Onset Rate are also given.

Table 1: Sample and calculation data for Figure 2
Shear Event and two hammering events – sample interval 100ms

Time from start seconds	Total dBA	Δ dB	Onset Rate OR dB/s	Prominence P	K_I adjustment dB	Steepest Method	Overall Method	Other Method
			Peak P1 Shear Event					
5.2	68	-0.1	0	0.0	0.0	L_s	L_s	L_s LD = 16.4
5.3	74.6	6.6	66	7.1	3.8	L_e	LD = 18.1 OR = 45.3	OR = 54.7 P = 7.6
5.4	81.2	6.6	66	7.1	3.8		P = 7.5 K_I = 4.5	K_I = 4.8
5.5	84.4	3.2	32	5.5	0.9			L_e
5.6	86.1	1.7	17	4.2	0.0		L_e	
			Peak P4 Hammering fork-lift tynes					
29	72	-0.5	0	0.0	0.0	L_s	L_s LD = 14.3	
29.1	86	14	140	8.7	6.7	L_e	OR = 71.5 P = 7.9	
29.2	86.3	0.3	0	0.0	0.0		L_e K_I = 5.2	
29.3	84.8	-1.5	0	0.0	0.0			
			Peak P5 Hammering fork-lift tynes					
31.5	70.2	-0.7	0	0	0	L_s	L_s	-
31.6	80.2	10	100	8	5.4	L_e	L_e	-
31.7	79.9	-0.3	0	0	0			

For Peak P1 in Figure 2, the calculated K_I was 3.8 dB for the Steepest method, 4.5 dB for the Overall method and 4.8 dB for the Other method. For Peak P4 the K_I was 6.7 dB and 5.2 dB for each method respectively, with no 'Other' method available. For Peak P5 it was 5.4 dB for both methods.

Figure 3, with the same time scale as Figure 2, shows the time history of the Onset Rate for each sample interval in the full measurement period. This calculation graph was used to quickly identify the periods in the spreadsheet with high Onset Rates and therefore high K_I values.

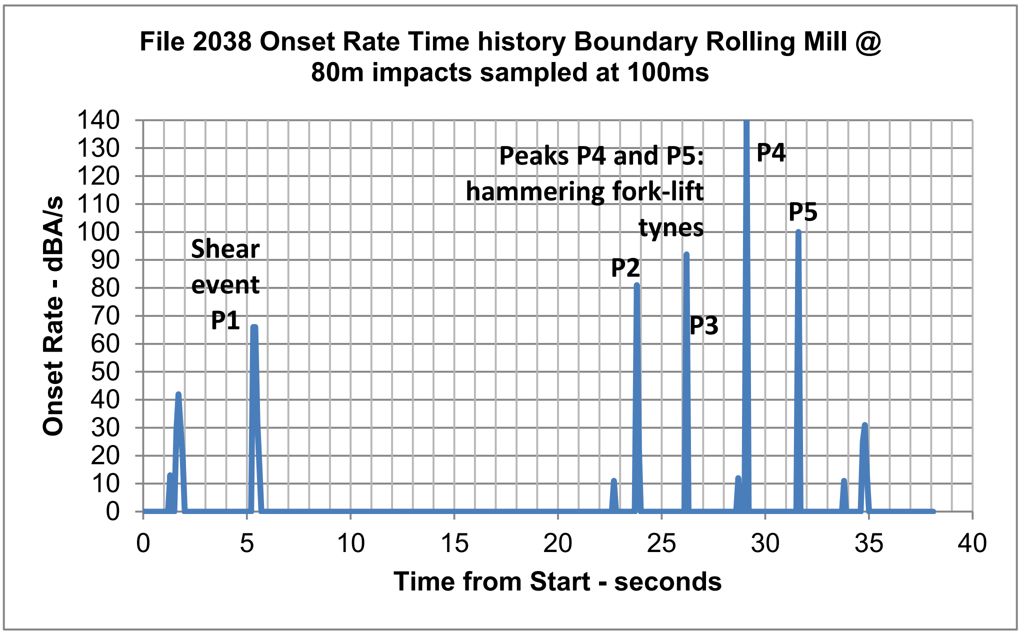

Figure 3: Calculated Onset Rate for each sample interval of 100ms for the measurement period

As the sample interval reduces, there is more data and a peak may have a higher or lower Onset Rate, depending on whether it is of low, moderate or high impulsivity. Identification of the start of a peak takes a little longer but the same process is used. Figure 4 shows the time history of the Onset Rates for the same recording using a sample interval of 10ms. The Onset Rate for the early peak at approximately 2 seconds in the time history becomes lower while those for peaks 2 to 5 stay relatively high.

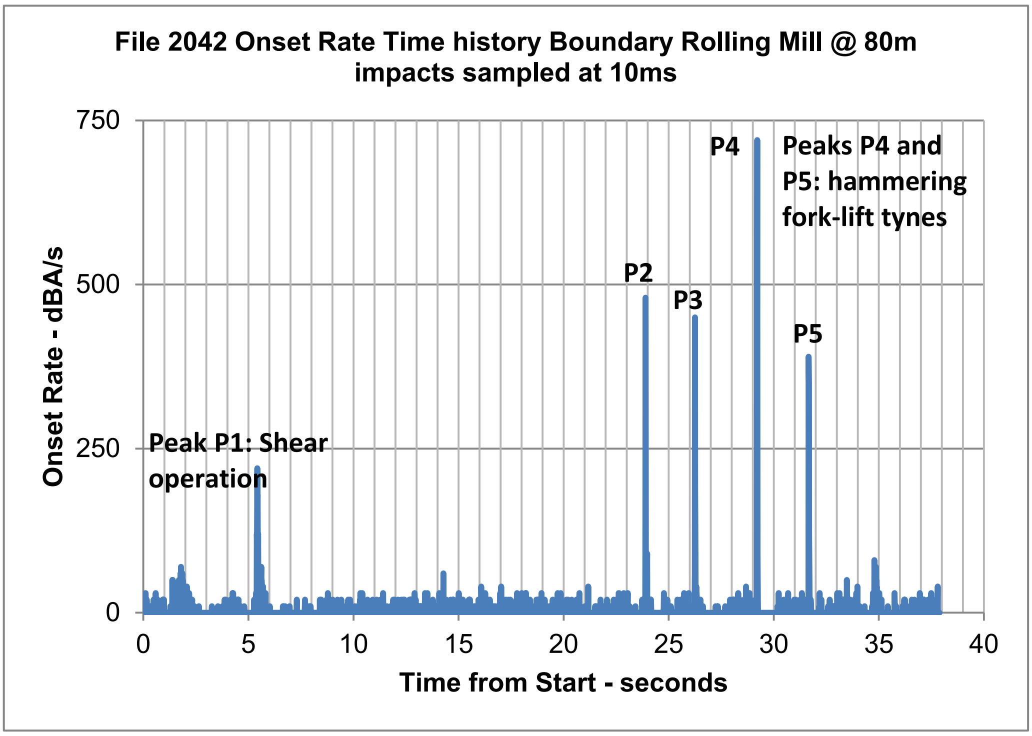

Figure 4: Calculated Onset Rate for each sample interval of 10ms for the measurement period

When using a different sample interval, the same approach is used for the calculations – find the starting and finishing time of the event or the steepest part, the sound levels at those times, and calculate the Onset Rate, Prominence P and impulse adjustment K_I for each event.

The calculated K_I values for the same three peaks but now with the 10ms sample interval were for Peak P1 steepest method 4.9 dB and 4.1 dB overall; Peak P4 steepest 10.3 dB and overall 9.5 dB; Peak P5 steepest 7.1 dB and overall 6.3 dB. More periods are required for the calculations of Peak 1, whereas the periods required for peaks P4 and P5 are relatively less.

To assess the effect of sample interval on the calculated values of K_I, this method described above was used for each of the 15 different measurement recordings analysed, with each of the sample intervals 10ms, 20ms, 30ms, 50ms and 100ms. This meant the total number of calculations done was 897. In some cases the calculated K_I value was the same for the maximum interval value and overall peak – this occurred when the event was highly impulsive. In some cases a third method called “other” was used to manually search for a higher OR, but in some cases calculations were not available because the event was over a short period and no other combinations were available. The results for the Peaks P1, P4 and P5 are given in Table 2.

3.3 Explanation of degrees of impulsivity

From the measurements and recordings, it can be seen that impulsive events occur over different time periods. High sound level events from shear operation for example, can occur with the rise in sound level occurring over a longer period than a (possibly) lower sound level event from something like a hammering event or scrap cut-off drop into a bin, which occurs with the time rise over a shorter period. The degree of impulsiveness was not always able to be predicted from the source type. A shear operation generally had a longer time period for the sound level rise. Scrap cut-off falling into a bin varied from short to medium time-rise periods, but had a higher variation in maximum sound level increase because the drop was not always the same. Hammering was found to have a relatively short time-rise and often a high maximum sound level, depending on the force of the impact.

The review of the analysis described in the next section considers the results depend to a large extent on the type of impulsivity, described here as:

- low impulsivity – such as shear operation,
- medium impulsivity for some shear events and some scrap handling
- high impulsivity for some scrap handling events and hammering.

Table 2: Comparison of calculated K_I for three impulse event peaks using 4 different sample intervals

Peak	Type	Sample Interval	Steepest Method	Overall Method	Other Method	Steepest > Overall	Overall > Steepest	Other > Steepest	Other > Overall
			K_I impulse adjustment dB			Difference in K_I values dB			
1	Shear	100ms	3.8	4.5	4.8		0.7	1	0.3
		50ms	5.5	4	5.4	1.5			1.4
		30ms	5.8	4.5	5.8	1.3			1.3
		20ms	5.6	4.4	6.1	1.2		0.5	1.7
		10ms	4.9	5	6.1		0.1	1.2	1.1
4	Fork-lift hammer	100ms	6.7	5.2	-	1.5			
		50ms	7.8	6.8	-	1			
		30ms	9.6	8.1	-	1.5			
		20ms	9	8.1	8.9	0.9			0.8
		10ms	9.5	8.1	9.3	1.4			1.2
5	Fork-lift hammer	100ms	5.4	5.4	-				
		50ms	4.9	4.4	5.4	0.5		0.5	1
		30ms	7.2	5.6	6.3	1.6			0.7
		20ms	7.7	5.9	7.3	1.8			1.4
		10ms	7.1	6.3	8	0.8		0.9	1.7

4 FINDINGS OF THE ANALYSIS

4.1 General findings

The full results of the analysis covers 7 pages. For lower impulsivity noise events, such as most shearing and the scrap handling yard, the 100ms sample for the highest single interval value, gave the highest K_I value and K_I reduced with reducing sample interval. For the overall peak value the K_I did not change significantly between different sample intervals. For the third method called ‘other’ with a manual search, the K_I did not vary significantly between sample intervals. K_I values were relatively low from 2 to 5 dB for this type of source.

The non-impulsive but time-varying source (of steel pipe grinding) had mostly negative K_I values except for one peak where it ranged from 0 to almost 3 dB. As occurred with the low impulsivity sources, the K_I values reduced with reducing sample interval. The one bird call (of three crow caws) analysed in this series had either low to negative K_I values of less than 2.

For low to medium impulsive sources such as scrap drop, K_I values were higher, between 5 and 7 dB. There was no clear pattern of K_I reducing with reducing sample interval. The 50ms interval gave the highest K_I value for the single interval calculation on more occasions, but this was not always the case. The 100ms interval gave a similar range of K_I values to the shorter intervals.

For higher impulsivity events such as some high energy shearing, some scrap drops and hammering, the K_I values were much higher, ranging from 5 to 9.5 dB. Reducing the sample interval generally gave a higher K_I value for the single interval result and ‘other specific search’ methods, but not in all cases. There was not the same pattern for the overall peak method. The ‘other’ method gave higher K_I values than for the overall peak method.

Of the differences between the Steepest and Overall Peak methods, 57% had higher values for Steepest and 37% had highest values for the Overall Peak method and 6% were equal. There were roughly equal percentages of results of the differences between both methods were < 1 dB (46%) and between 1 and 3 dB (45%) while only 3% of the differences between the methods were greater than 3dB.

4.2 Relevance of sample interval to compliance assessment for industrial operators.

Assessment of compliance with licence conditions for noise emitted by industrial operators requires comparison of measured sound level with that in the licence condition. If the emitted noise includes potentially annoying characteristics, such as impulsivity or tonality, an adjustment is added to the measured value for comparison with the licence condition. For example if the licence condition was $L_{Aeq,30\text{-}min}$ not to exceed 50 dBA, and 46 dBA was measured but included assessed impulsive noise with an adjustment of 5 dB, the total for assessment would be 51 dBA, which exceeds the compliance condition.

The objective method for assessment of impulsive noise in AS1055:2018 provides a way to determine the impulsive adjustment, K_I. At present the method allows for use of sample intervals from 10ms to 25ms. Use of the shorter time interval for calculating K_I values for highly impulsive sources will most likely give a higher result. For the noise sources measured in this study, this could lead to a difference of 4 dB between K_I values. This could affect the assessment of achievement of compliance for some industrial operations, where the K_I value is added to the total average sound level measured for comparison with a licence condition. This could be used to either advantage or disadvantage an operator. A standard should preferably provide for a single method of calculation to avoid ambiguity of results obtained using it. Because of this potential for variation in outcome, an additional approach is recommended based on both the results of this study and current regulatory approach in many jurisdictions. Jurisdictions using Appendix E of AS1055:2018 should clearly state the sample interval to be used.

The 100ms sample interval provides a good indication of the impulsivity, and for highly impulsive industrial site noise such as hammering, gave a 5 to 6.5 dB value for K_I (depending on the source measured). The current impulse adjustment in some jurisdictions is 5 dB. It is recommended on the basis of these results that the K_I used be based on 100ms sample intervals and the Steepest method. Otherwise the 10ms sample interval should be the only one used to provide clarity. This approach is not necessarily applicable to highly impulsive explosive tools used on some construction sites, as they have not been investigated in this study.

Use of the 100ms sample interval is also easier to integrate with current sound level logging systems which are based on100ms sample intervals, and could probably be easily built-in to such devices or their software.

5 Summary and conclusions

In summary, for the range of impulsive noise sources measured:

- The 100ms sample interval provides clear indication of impulsiveness and the K_I value obtained is in a similar range to that obtained for other shorter sample intervals. For example, for calculations where K_I is greater than 5dB for the single interval value, the 100ms value is within 4 dB of the highest calculated.
- The Overall method for calculating K_I can give a higher value than for the Steepest method for low to medium impulsive noise sources. In most cases the Other method gave a higher K_I than the Steepest or Overall methods.
- For the highly impulsive noise sources measured, the Steepest (or single interval) method gives a higher K_I value than the Overall method of calculation. This indicates the Steepest method is more relevant for this type of source. It is also the easiest to calculate and takes the least time to assess in comparison with the Overall method and Other method.

A sample interval of 100ms using the K_I value calculated from individual sample intervals is recommended for the objective assessment of general industrial noise sources. This would avoid variation in results for the same source using different sample intervals and ambiguity of the Standard method.

References

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