SOUND LEVEL METER STANDARDS FOR THE 21ST CENTURY

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Abstract A new Sound Level Meter standard IEC61672-1:2002 has just been published. The IEC working group 4 (Sound Level Meters) of the IEC Technical Committee 29 (Electroacoustics) has been engaged for some years in the task of writing this new standard that will replace, update and combine the sound level meter standards IEC60651–1979 and IEC60804-1985. It is reasonable to expect that in due course this new standard will become accepted as an Australian standard and will replace AS1259-1990 parts 1 & 2 which have their technical basis in the older IEC standards of the 80s. As most new Sound Level Meters now coming onto the market have anticipated the new standard it is timely to investigate the differences.

1. INTRODUCTION

The first International Electrotechnical Commission standard for sound level meters was published in 1961 as IEC123. There has been a number of versions of an Australian standard for sound level meters; the earliest was AS Z37-1967, which, after several revisions, was re-published as AS1259-1976 culminating in AS1259-1990 Parts 1,2 [1,2]. These were to follow closely the standards IEC60651 and IEC60804 [3,4]. However, by the time that IEC60804 was published in 1985, it and IEC60651 were regarded as technically obsolete as the construction of sound level meters had advanced rapidly with the use of digital technology including the use of digital rather than analogue displays. This is even more true today, as modern designs have become completely digital from the preamplifier with functions now built in as "firmware". There is no longer reliance on hardware components and the dynamics of analogue pointer displays, rather the skill of a programmer to emulate a design goal.

The new standard IEC61672-1:2002 [5] to replace 60651 and 60804 was begun in the early 1990's and is to be published in 3 parts. Part 1 (Specifications) was published in May 2002, Part 2 (Pattern Evaluation Tests) is expected to be published in late 2002 and Part 3 (Periodic Verification) is currently at working draft stage. Part 4 will cover detailed format for reporting tests to Part 2, and Part 5 will provide procedures for the estimation of measurement uncertainties during tests due to the presence of the sound level meter in various acoustical environments [6].

2. AUSTRALIAN CONTEXT

The new series of standards embodied in 61672 are significant for the Australian acoustical community which is no longer represented only by equipment users. There is at least one successful Australian manufacturer and exporter of airport noise monitoring equipment who will in future work with this new standard to enable pattern evaluation to be carried out successfully in whatever part of the world market sales are made. There are also several other manufacturers of noise logging equipment for Australian domestic consumption, at least one with limited export experience.

There are a number of changes in design goals in 61672 that will result in different performance and facilities in instruments which must be taken into account when framing local ordinances and statutes.

In the Australian market there is currently a void as regards local pattern evaluation and the National Measurement Act [7] and its regulations do not list equipment for the measurement of sound in Certified Measuring Equipment. Most if not all of the sound level meters imported at the cheaper end of the market (Type 2) may be non-compliant or marginal and there is in general only the manufacturer's assurance that the equipment complies with the standard. Further, it appears that none of the equipment manufactured for domestic consumption in Australia has been subjected to a rigorous pattern evaluation as defined by the OIML in OIML R88-1998 [8]. Australia subscribes to the OIML (Organisationale Internationale Metrology Legale) via the National Standards Commission which is responsible for legal metrology in Australia. There is consequently little protection for the user unless the equipment being sold in Australia has a demonstrated pattern evaluation from a recognized overseas authority.

The new IEC61672 parts 2 and 3 have been formulated in co-operation with the OIML to have regard for the provisions of legal metrology. The coming of the new standard IEC61672 affords an excellent opportunity for the Australian situation to be clarified by encouraging equipment to be pattern approved. With the increased protection afforded by pattern evaluation there will unfortunately be some increased cost to the user and this may make many of the cheaper instruments suitable only for survey purposes.

Some statutory authorities or services engaged in sound level testing, for example motor vehicle muffler testing, are requiring the provision of a "Regulation 13" [7] certificate that verifies proof of traceability to National Standards for veracity during court proceedings. It is not feasible to issue such a certificate for non-type approved equipment; this hiatus knocks out the present Type 2 equipment thus increasing the cost to the authority at least 5 fold.

In the following sections the technical differences between the current and new standards will be explored.

3. CHANGES

3.1 Measurement Uncertainty

In line with accepted metrological practice, the estimated uncertainty of the measurements must be taken into account when making judgments of pass or fail to a design goal with tolerances. Without taking uncertainties into account when framing the tolerances around design goals in standards, this leads to an effective reduction in the tolerances. The new standard has "loaded" the tolerances with "typical" uncertainties and they are tabulated in the standard for guidance to the test house. This effectively removes the effect of the uncertainties during the judgment process providing the actual test uncertainties are no greater than the tabulated uncertainty. For the purposes of comparison between 60651/60804 and 61672 in this paper, the uncertainties are not included in any tolerances quoted. The "loaded" tolerances may be found in the new standard.

3.2 Change from Type to Class

The old standards 60651 and 60804 allowed for 4 performance types from Type 3 to Type 0 with increasingly tighter tolerances. The new standard 61672 [5] will allow 2 performance categories designated as Classes 1 and 2 with the same design goals but with Class 2 having, in general, wider tolerances. The descriptor "Type" has been changed to avoid confusion with types of instrument in the context of facilities fitted. The older Type 0 and Type 3 have not been included. Type 0 represented a laboratory level seldom used and Type 3 is seen to be unnecessary, as modern manufacturing techniques should ensure improved performance. In practice Types 2 and 3 were seldom subjected to type approval so performance could not be substantiated.

The effect of environmental conditions has been rationalised to allow more realistic ranges of environmental effects such as temperature; Class 2 (0°C to 40°C) as distinct from the higher performance expectation of Class 1(-10°C to 50°C). In 60651 all types were required to demonstrate performance from -10°C to 50°C albeit with different tolerances and this prohibited most manufacturers taking the risk of pattern approval for their Type 2 instruments. In addition reference conditions have been changed from 20°C/65% RH to 23°C/50% RH which brings the equipment into line with most electrical metrology.

3.3 Directional Response

The tolerance limits in 61672 have been extended to include an incidence angle of 150° and have been tightened at higher frequencies. These changes are shown in Table 1 below, where the existing 60651 tolerances are shown in parenthesis. The implication of this change will impact equipment with larger diameter microphones which probably will not meet these specifications, Marsh [6].

3.4 Weighting Networks

The design goals for A and C have not changed and a Z (Zero) or "Flat" weighting has been introduced. There is however no specification for unweighted Peak, see below. In line with greater expectations of performance, the tolerances around the design goals (including Z) have been tightened for Class 1 instruments below 80 Hz and above 6.3 kHz. This is intended to ensure a minimum microphone response at 16 Hz and 16 kHz (20 Hz and 8 kHz for Class 2). This limit was previously +3/-∞ dB in IEC60651, that is, no specific requirement for response. These differences were summarized in [6] and are reproduced below in Table 2 for emphasis.

3.5 Display Linearity

In IEC60651 linearity requirements were based on the available technology of the time and included provision for range changing. Display linearity errors arise from the inability of the detector/squaring circuit or the display circuit to provide a linear display of the sound pressure level at the microphone. The requirement in 60651 was for an indicator range of at least 15 dB with at least 10 dB specified as a "primary" display range. Within those ranges 2 sets of tolerances applied, firstly for increments between 1 and 10 dB within the primary range, (±0.2 dB to ±0.4 dB for Type 1) and secondly, outside the primary range for any signal the tolerances were increased (±1.0 dB for Type 1). Where any range changing, automatic or manual occurred, the tolerance was ±0.7dB within the primary range.

Table 1. Directional response tolerance limits for Class 1 and 2 sound level meters as required by 61672 and compared to 60651 (in parentheses)

Frequency kHz	Maximum absolute difference in displayed sound levels at any two sound-incidence angles within ± θ degrees from the reference direction dB					
	θ = 30°		θ = 90°		θ = 150° (not in 60651)	
	Class/Type					
	1	2	1	2	1	2
0.25 to 1	1	2	1.5	3	2	5
(0.035 to 1)	(1)	(2)	(1.5)	(3)		
>1 to 2	1 (1)	2 (2)	2 (2)	4 (5)	4	7
>2 to 4	1.5 (1.5)	4 (4)	4 (4)	7 (8)	6	12
>4 to 8	2.5 (2.5)	6 (8)	7 (8)	12 (14)	10	16
>8 to 12,5	4 (4)	...	10 (16)	...	14	...

Table 2. Frequency weightings and tolerance limits, IEC60651 compared to IEC 61672

Nominal frequency a) Hz	Tolerance limits (dB)					
	Class 1 (Type 1)			Class 2 (Type 2)		
	60651	61672-1	Change	60651	61672-1	Change
10	+3;-∞	+3; -∞		+5; -∞	+5; -∞	
12,5	+3;-∞	+2.5; -∞	*	+5; -∞	+5; -∞	
16	+3;-∞	+2; -4.5	*	+5; -∞	+5; -∞	
20	±3	±2	*	±3	±3	
25	±2	+2; -1.5	*	±3	±3	
31,5	±1.5	±1.5		±3	±3	
40	±1.5	±1	*	±2	±2	
50	±1.5	±1	*	±2	±2	
63	±1.5	±1	*	±2	±2	
80	±1.5	±1	*	±2	±2	
100	±1	±1		±1.5	±1.5	
125	±1	±1		±1.5	±1.5	
800	±1	±1		±1.5	±1.5	
1 000	0 b)	±0.7c)	*	0 b)	±1c)	*
1 250	±1	±1		±1.5	±1.5	
4 000	±1	±1		±3	±3	
5 000	±1.5	±1.5		±3.5	±3.5	
6 300	+1.5; -2	+1.5; -2		±4.5	±4.5	
8 000	+1.5; -3	+1.5; -2.5	*	±5	±5	
10 000	+2; -4	+2; -3	*	+5; -∞	+5; -∞	
12 500	+3; -6	+2; -5	*	+5; -∞	+5; -∞	
16 000	+3;-∞	+2.5; -16	*	+5; -∞	+5; -∞	
20 000	+3;-∞	+3;-∞		+5; -∞	+5; -∞	

a) The tolerances from 160 Hz to 630 Hz and from 1600 Hz to 3150 Hz have not changed from 60651 to 61672.

b) Tolerance limits were 0 dB at the reference frequency as the design goal was in terms of sound levels relative to the sound level at the reference frequency, assumed to be 1 kHz for this purpose.

c) In 61672 the tolerance limits are nonzero as the design goal frequency weightings are relative to the unweighted sound pressure level at the position of the microphone on the sound level meter, but in the absence of the meter.

In IEC 61672 these requirements have been clarified by a requirement for a defined reference range with linear operating span of at least 60 dB at 1 kHz for either class of instrument. These requirements are intended to apply from 16 Hz to 16 kHz for Class 1 sound level meters and from 20 Hz to 8 kHz for Class 2. A maximum error of ±0.8 dB (±1.1 dB for Class 2) applies to any range and includes errors introduced by range controls. On a linear operating range, errors for changes in input signal of from 1 dB to 10 dB must not exceed ±0.3 dB for Class 1 or ±0.5 dB for Class 2.

3.6 Time Weighting and Tone Burst Response

There was a clear separation between Time Weighting and Integrating/Averaging functions in IEC 60651 and IEC 60804 with L_{Aeq} (equivalent continuous) as the prime metric and S_{EL} (dose) derived from L_{Aeq} in terms of time. Specifications for Time Weighting and Integrating have been brought together in IEC61672 under the title "Toneburst Response" and the Table 3 is reproduced below. The terminology has been clarified and L_{AE} (S_{EL}) has now become the prime metric.

The quantity L_{AT} (L_{Aeq}) is specified under the heading "Response to repeated tonebursts" in terms of the difference δ_{ref} between the theoretical time-average sound level of a sequence of N tonebursts extracted from a steady signal and the time-average sound level of the steady signal as:

$\delta_{ref} = 10\ \lg(NT_b/T_m)$ where

T_b is the toneburst duration and

T_m is the total measurement duration, both in seconds.

For L_{AT} the tolerances from Table 3 are used. Thus the emphasis has changed to be time independent for L_{AE}. This does not, as has been feared, remove $L_{AT}(L_{Aeq})$ from the specifications in 61672 which apply for an electrical signal at toneburst durations from 0.25 ms to 1 s. IEC 60804 as amended required a minimum toneburst duration of 1 ms.

3.7 Peak C Sound Level

In 60651 the performance specification was for a test of the onset time (charging time) of the peak detector (unweighted)

Table 3. Reference 4 kHz toneburst responses and tolerance limits including maximum expanded uncertainty of measurement

Toneburst duration, T_b ms	Reference 4 kHz toneburst response, δ_{ref}, relative to the steady sound level dB		Tolerance limits dB	
			Class	
	$L_{AFmax} - L_A$ $L_{CFmax} - L_C$ and $L_{ZFmax} - L_Z$; Eq. (15)	$L_{AE} - L_A$ $L_{CE} - L_C$ and $L_{ZE} - L_Z$; Eq. (16)	1	2
1 000	0.0	0.0	±0,5	±1.0
500	-0.1	-3.0	±0.5	±1.0
200	-1.0	-7.0	±0.5	±1.0
100	-2.6	-10.0	±1.0	±1.0
50	-4.8	-13.0	±1.0	+1.0-1.5
20	-8.3	-17.0	±1.0	+1.0-2.0
10	-11.1	-20.0	±1.0	+1.0-2.0
5	-14.1	-23.0	±1.0	+1.0-2.0
2	-18.0	-27.0	+1.0-1.5	+1.0-2.5
1	-21.0	-30.0	+1.0-2.0	+1.0-3.0
0,5	-24.0	-33.0	+1.0-2.5	+1.0-4.0
0,25	-27.0	-36.0	+1.0-3.0	+1.5-5.0
	$L_{ASmax} - L_A$ $L_{CSmax} - L_C$ and $L_{ZSmax} - L_Z$; Eq. (15)			
1 000	-2.0		±0.5	±1.0
500	-4.1		±0.5	±1.0
200	-7.4		±0.5	±1.0
100	-10.2		±1.0	±1.0
50	-13.1		±1.0	+1.0-1.0
20	-17.0		+1.0-1.5	+1.0-2.0
10	-20.0		+1.0-2.0	+1.0-3.0
5	-23.0		+1.0-2.5	+1.0-4.0
2	-27.0		+1.0-3.0	+1.0-5.0

NOTE 1 For the purpose of this standard and for conventional sound level meters, reference 4 kHz toneburst response δ_{ref} for maximum time-weighted sound levels shall be determined from the following approximation

$$\delta_{ref} = 10\ \lg\left(1 - e^{-T_b/\tau}\right) \tag{15}$$

where T_b is a specified duration of a toneburst in seconds,
τ is a standard exponential time constant specified in 5.7.1, and
e is the base of the natural logarithm.
Equation (15) applies for isolated 4 kHz tonebursts.

NOTE 2 For the purpose of this standard and for integrating and integrating-averaging sound level meters, reference 4 kHz toneburst response δ_{ref} for frequency-weighted sound exposure levels is determined from the following approximation

$$\delta_{ref} = 10\ \lg(T_b / T_0) \tag{16}$$

where T_b is a specified duration of a toneburst in seconds, and
T_0 = 1 s is the sound-exposure reference duration.

NOTE 3 Reference 4 kHz toneburst responses in table 3 are valid for the A, C, and Z weightings. Other frequency weightings may have other reference toneburst responses.

and which was specified to be less than 100 μs for Type 1. In practice the actual onset time varies from meter to meter from 10 μs to over 50 μs and the unweighted peak response to an acoustic event using unweighted Peak (Flat) may vary widely between individual sound level meters meeting Type 1 specifications in the presence of infrasound or high audio frequencies. IEC 61672 has adopted C weighting for the Peak design goal which is demonstrated by response to a single cycle input signal at 31.5 Hz, 500Hz and 8 kHz with additional tests using positive and negative $^1/_2$ cycles of 500 Hz. The response in these cases is compared to the steady signal from which the single or $^1/_2$ cycle signals are extracted. This approach will lead to consistent measurement of common events with individual instruments meeting the design goal.

Concerns have been expressed that the use of C weighting for Peak measurement of a noise event may bring about lower indications where there are impulsive signals at the extremes of both very short and very long time constants. The alternative is to have the much greater probability of inconsistent measurements from the use of Peak (flat) unweighted under the specification in 60651. The high frequency roll off at the lower limit of the old 60651 tolerances is essentially the same as the design response of the C weighting network where both are – 3dB at 8 kHz. Thus a marginal Type 1 meter under 60651 may well have had by default a C weighting response when operating unweighted.

Measurements at low frequencies will still present problems and are ultimately limited by microphone response which varies widely amongst SLMs, even those that would comply with 61672. It would seem logical to consider standards for the measurement of blasting events using Peak outside the SLM standard as this is a special case and requires specialist equipment.

3.8 Time weighting I (impulse)

It has been found by the working group that time weighting I is not suitable for rating impulsive sound with respect to loudness hence it is not recommended for use in assessing the risk of hearing impairment. The design goal for time weighting I has been placed in the standard as an informative Annex since I weighting is still referenced in many documents.

4. CONCLUSION

The new IEC61672 standard will ensure that sound level meters built to its design goals will have enhanced and more consistent performance than under the older standards. If the Australian community adopts IEC61672 [5] as an Australian standard then an ideal opportunity will arise to resolve the present hiatus involving pattern approval of noise measuring equipment.

REFERENCES

1. Australian Standard AS1259.1-1990. "Sound level meters Part 1: non-integrating.
2. Australian Standard AS1259.2-1990. "Sound level meters Part 2: Integrating-averaging.
3. International Electrotechnical Commission Standard IEC61651-1979."Sound level meters.
4. International Electrotechnical Commission Standard IEC61804-1985. "Sound level meters integrating-averaging.
5. International Electrotechnical Commission Standard IEC61672-1:2002. "Electroacoustics - Sound level meters Part 1.
6. Alan H. Marsh, IEC 61672, "The new international standard for sound level meters", Proceedings of the 2001 International Congress and Exhibition on Noise Control Engineering, The Hague, The Netherlands, 2001 August 27-30.
7. National Measurement Act of the Parliament of Australia, Regulation 13.
8. Organisationale Internationale de Metrology Legale recommendation R88-1999.