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Quantities for Description of the Acoustical Environment of the Interior of Aircraft

RATIONALE

This document has been determined to contain basic and stable technology which is not dynamic in nature.

STABILIZED NOTICE

This document has been declared "Stabilized" by the SAE A-21 Aircraft Noise Measure and Noise Aviation Emission Modeling Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

1. SCOPE:

1.1 This Aerospace Recommended Practice (ARP) defines quantities that may be used to describe various attributes of the sound field in the interior of aircraft. For a particular aircraft, or for a specific situation in a particular aircraft, it may not be necessary to utilize all the quantities included here to provide an adequate description of an aircraft's interior acoustical environment.

1.2 The scope of this document includes frequency-band sound pressure levels, wideband sound pressure levels, frequency-weighted sound pressure levels, and quantities that may be calculated from band sound pressure levels. The primary frequency bandwidths are those of octaves and one-third octaves.

1.3 This ARP does not include recommendations for specific quantities to use in a given situation, nor does it include specific numerical values of any quantity for use in evaluating the acceptability of the acoustical environment in the interior of an aircraft.

1.4 Definitions in this document are compatible with procedures in SAE ARP1323A (Reference 1), ARP1964 (Reference 2), and the International Standard ISO 5129 (Reference 3) for measurement of aircraft interior noise. The definitions are also compatible with standards on acoustical terminology (References 4 and 5) and with standards on preferred abbreviations, quantity symbols, units, and unit symbols (References 6 and 7). If no abbreviation or quantity symbol is given, then, for the purposes of this document, none is recommended.

1.5 Quantities defined in this document may be used to describe the acoustical environment in the interior of any kind of aircraft including jet-propelled and propeller-driven airplanes and rotorcraft. The quantities are applicable to measurements of aircraft interior noise where the sound pressure levels are relatively steady so that valid time-averaged measurements may be obtained in a reasonably short measurement period. If the sound pressure level is not relatively steady, then additional quantities other than those in this document may be needed for an adequate description of the acoustical environment. Examples of nonsteady sounds include those that occur during takeoff, climbout, descent, and landing.

1.6 Table 1 presents a summary of the terms defined along with recommended abbreviations, quantity symbols, units, and unit symbols. Abbreviations are most useful for column headings in tables and for printing by machines not able to print lowercase letters. Quantity symbols are recommended for use in equations.

TABLE 1 - Summary of Terms Defined, Abbreviations, Quantity Symbols, Units, and Unit Symbols

Def.	Term	Abbrev.	Quantity Symbol	Unit	Unit Symbol
3.1	instantaneous sound pressure	---	p(t)	pascal	Pa
3.2	time-average, frequency-band sound pressure level[1]	SPL	L_{pfT}	decibel	dB
3.3	one-third-octave-band sound pressure level	TOBSPL	$L_{p(1/3)T}$	decibel	dB
3.4	octave-band sound pressure level	OBSPL	$L_{p(1/1)T}$	decibel	dB
3.5	wideband ("overall") sound pressure level	WBSPL	L_{pWBT}	decibel	dB
3.6	frequency weighting	A,C	---	decibel	dB
3.7	time constant	---	τ	second	s
3.8	exponential-time-weighted and A-weighted sound pressure level; sound level[1]	---	$L_{A\tau}$	decibel	dB
3.9	fast A-weighted sound level[1]	FAL	L_{AF}	decibel	dB
3.10	slow A-weighted sound level[1]	SAL	L_{AS}	decibel	dB
3.11	time-period equivalent-continuous, A-weighted sound pressure level; time-average sound level[1,2]	TQL	L_{AeqT}	decibel	dB
3.12	speech interference level	SIL[3]	L_{SI}[3]	decibel	dB

[1]The C-frequency weighting or a flat frequency weighting also may be used for measurements of sound levels in the interior of an aircraft.
[2]The general symbol T should be replaced by the actual duration of the averaging time.
[3]See 3.12 for modifications of the general abbreviation and general letter symbol to indicate which octave-band sound pressure levels are included in the calculation of a speech interference level.

2. REFERENCES:

The following documents contain provisions which, through reference in this text, constitute provisions of this ARP. At the time of publication, the editions indicated were valid. All documents are subject to revision, and parties to agreements based on this ARP are encouraged to investigate the possibility of applying the most recent editions of the documents listed below.

1. SAE ARP1323A-AUG90, Type Measurements of Airplane Interior Sound Pressure Levels During Cruise

2. SAE ARP1964-SEP88, Measurement of Rotorcraft Interior Sound Pressure Levels

3. ISO 5129:1987, Acoustics - Measurement of Noise Inside Aircraft

4. IEV 50(801):1984, Advance Edition of the International Electrotechnical Vocabulary, Chapter 801: Acoustics and Electroacoustics

5. ANSI S1.1-1960(R1976), American National Standard Acoustical Terminology (Including Mechanical Shock and Vibration)

6. ISO 31/7:1978 with Amendment 01-1985, Quantities and Units of Acoustics

7. ANSI/ASME Y10.11-1984, American National Standard Letter Symbols and Abbreviations for Quantities Used in Acoustics

8. ISO 1683:1983, Acoustics - Preferred Reference Quantities for Acoustic Levels

9. ANSI S1.8-1989, American National Standard Reference Quantities for Acoustical Levels

10. IEC XXXX:199X, Octave-Band and Fractional-Octave-Band Filters (Revision of IEC 225:1966 under preparation)

11. ANSI S1.11-1986, American National Standard Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters

12. ISO 266:199X, Acoustics - Preferred Frequencies for Measurements (Revision of ISO 266:1975 under preparation)

13. ANSI S1.6-1984, American National Standard Preferred Frequencies, Frequency Levels, and Band Numbers for Acoustical Measurements

14. IEC 651:1979, Sound Level Meters

15. ANSI S1.4-1983 and Amendment ANSI S1.4A-1985, American National Standard Specification for Sound Level Meters

16. IEC 804:1985, Integrating-Averaging Sound Level Meters

2. (Continued):

17. ISO TR 3352:1974, Acoustics - Assessment of Noise With Respect to Its Effect on the Intelligibility of Speech

18. ANSI S3.14-1977(R1986), American National Standard for Rating Noise With Respect to Speech Interference

3. DEFINITIONS OF QUANTITIES:

For the purposes of this ARP, the following definitions apply:

3.1 INSTANTANEOUS SOUND PRESSURE: At a point, the total instantaneous pressure at that point in the presence of a sound wave, minus the static pressure at the point. Quantity symbol, p(t); unit, pascal; unit symbol, Pa.

NOTE: The static pressure at a point is the pressure that would exist at that point in the absence of sound waves.

3.2 TIME-AVERAGE, FREQUENCY-BAND SOUND PRESSURE LEVEL: Ten times the base-ten logarithm of the ratio of the square of the instantaneous sound pressure, averaged over a stated time interval and in a specified frequency band, to the square of the standard reference sound pressure (References 8 and 9) of 20 µPa. Abbreviation, SPL; quantity symbol, L_{pfT}; unit, decibel; unit symbol, dB.

NOTES:

1. Time-average, frequency-band sound pressure level, in decibels, is determined according to the following equation:

$$L_{pfT} = 10\ \mathrm{lg}\{[(1/T)\int_0^T p_f^2(t)\ dt]/p_0^2\} \qquad \text{(Eq.1)}$$

where:

T is the averaging time
t is the time variable of integration
$p_f(t)$ is the instantaneous sound pressure, in pascals, in a stated frequency band centered on frequency f
p_0 is the reference sound pressure of 20 µPa
lg represents base-10 (common) logarithms

2. The averaging time in the subscript of the quantity symbol for time-average, frequency-band sound pressure level may be omitted if the duration of the averaging time is specified in the accompanying text, table, or figure.

3. The frequency band may be specified by its nominal lower and upper bandedge frequencies, or by the combination of the nominal bandwidth in octaves between the lower and upper bandedge frequencies (References 10 and 11) and the nominal midband frequency (or preferred frequency) (References 12 and 13) that identifies the band, or by standard frequency band numbers (Reference 13).

3.2 (Continued):

4. For fractional-octave bands, the nominal relative bandwidth should be indicated by an appropriate modifier such as one-third-octave-band sound pressure level.

5. For the purposes of this document, band sound pressure levels have no frequency weighting other than that provided by the bandpass filters.

3.3 ONE-THIRD-OCTAVE-BAND SOUND PRESSURE LEVEL: Time-average, frequency-band sound pressure level in a stated one-third-octave band and averaged over a stated time period. Abbreviation, TOBSPL; quantity symbol, $L_{p(1/3)T}$; unit, decibel; unit symbol, dB.

NOTES:

1. To simplify the notation of the quantity symbol, the p in the subscript may be omitted if the sound pressure is the only physical measurement of the sound field in the interior of an aircraft. Also, if the bandwidth of the spectrum analyzer is stated in the accompanying text, the (1/3) in the subscript for the general quantity symbol $L_{p(1/3)T}$ may be replaced by the nominal midband frequency of the filter as $L_{1000,20s}$ for the 20-second-average sound pressure level in the one-third-octave band at 1000 Hz.

2. Electrical characteristics of fractional-octave-band filters are specified in References 10 and 11.

3.4 OCTAVE-BAND SOUND PRESSURE LEVEL: Time-average, frequency-band sound pressure level in a stated octave band and averaged over a stated time period. Abbreviation, OBSPL; quantity symbol, $L_{p(1/1)T}$; unit, decibel, unit symbol, dB.

NOTES:

1. Octave-band time-mean-square sound pressure may be calculated from the sum of the time-mean-square sound pressures in the included one-third-octave bands. An octave-band sound pressure level in a stated time period and in frequency band N may be computed from the corresponding one-third-octave-band sound pressure levels included within the octave by the following equation:

$$L_{N(1/1)} = 10 \lg[10^{0.1\, L_{N-1}} + 10^{0.1\, L_N} + 10^{0.1\, L_{N+1}}] \quad \text{(Eq.2)}$$

where:

N-1, N, and N+1 are frequency band numbers (Reference 13) for three contiguous one-third-octave bands, e.g., 26, 27, and 28 for one-third-octave bands with nominal midband frequencies of 400, 500, and 630 Hz.

TABLE 2 - Relative Frequency Response Level, in decibels, for A- and C-Frequency Weightings, A(N) and C(N), Corresponding to One-Third-Octave Band Number N and Nominal Midband Frequency f, in Hertz

N	f, Hz	A(N), dB	C(N), dB	N	f, Hz	A(N), dB	C(N), dB
11	12.5	-63.4	-11.2	29	800	-0.8	0.0
12	16*	-56.7	-8.5	30	1 000*	0	0
13	20	-50.5	-6.2	31	1 250	+0.6	0.0
14	25	-44.7	-4.4	32	1 600	+1.0	-0.1
15	31.5*	-39.4	-3.0	33	2 000*	+1.2	-0.2
16	40	-34.6	-2.0	34	2 500	+1.3	-0.3
17	50	-30.2	-1.3	35	3 150	+1.2	-0.5
18	63*	-26.2	-0.8	36	4 000*	+1.0	-0.8
19	80	-22.5	-0.5	37	5 000	+0.5	-1.3
20	100	-19.1	-0.3	38	6 300	-0.1	-2.0
21	125*	-16.1	-0.2	39	8 000*	-1.1	-3.0
22	160	-13.4	-0.1	40	10 000	-2.5	-4.4
23	200	-10.9	0.0	41	12 500	-4.3	-6.2
24	250*	-8.6	0.0	42	16 000*	-6.6	-8.5
25	315	-6.6	0.0	43	20 000	-9.3	-11.2
26	400	-4.8	0.0				
27	500*	-3.2	0.0				
28	630	-1.9	0.0				

NOTE: *Indicates the nominal midband frequency for the octave band.

3.4 (Continued):

2. Standard frequency band numbers from 11 to 43 are given in Table 2 for one-third-octave bands covering a range of nominal midband frequencies from 12.5 Hz to 20 kHz. Nominal midband frequencies for corresponding octave bands are also noted.

3. If sound pressure is the only physical quantity measured in the interior of an aircraft, the letter p may be omitted from the general subscript to the symbol for an octave-band sound pressure level. Also, if the bandwidth of the octave-band sound pressure levels is clearly stated in the accompanying text, the (1/1) in the general subscript may be replaced by the nominal midband frequency of the octave band; see Note 1 to 3.3.

3.5 WIDEBAND ("OVERALL") SOUND PRESSURE LEVEL: Time-average sound pressure level for a specified wide frequency band that includes frequencies in a range of interest. Abbreviation, WBSPL; quantity symbol, L_{pWBT}; unit, decibel; unit symbol, dB.

NOTES:

1. "Overall" sound pressure level, abbreviation OASPL, has been used as a synonym for wideband sound pressure level, without specification of frequency bandwidth.

2. The frequency range of a wideband sound pressure level should always be indicated, preferably by the nominal bandedge frequencies of corresponding band sound pressure levels, e.g., as 45 Hz to 11.2 kHz.

3. Preferably, wideband sound pressure level is calculated from ten times the base-ten logarithm of the sum of the time-mean-square sound pressures in specified octave or one-third-octave bands. If a wideband sound pressure level is measured directly with a sound level meter, the frequency weighting should be indicated, e.g., C-weighting, flat with limited bandwidth, or allpass with limited, but wider bandwidth; see 3.6, Note 2.

4. A wideband, time-average, sound pressure level in a stated time period should be calculated from corresponding one-third-octave-band, time-average sound pressure levels according to the following equation:

$$L_{WB} = 10 \lg \left\{ \sum_{N=NS}^{NF} 10^{0.1\, L_N} \right\} \quad \text{(Eq.3)}$$

where:

the range of the summation index N is selected to cover specified one-third-octave band numbers from NS (start) to NF (finish), e.g., NS = 11 to NF = 43 for the 33 nominal midband frequencies from 12.5 Hz to 20 kHz, or NS = 17 to NF = 40 for the 24 nominal midband frequencies from 50 Hz to 10 kHz.

5. A wideband, time-average, sound pressure level in a stated time period should be calculated from corresponding octave-band sound pressure levels according to the following equation:

$$L_{WB} = 10 \lg \left\{ \sum_{K=KS}^{KF} 10^{0.1\, L_{3K}} \right\} \quad \text{(Eq.4)}$$

3.5 (Continued):

where:

the frequency-band index for octave-band sound pressure levels increments by three between successive octave bands as summation index K increments by one over the range of summation. A range of the summation index is selected from K = KS (start) to K = KF (finish), e.g., from KS = 4 (N = 12) to KF = 14 (N = 42) for the eleven nominal octave-band midband frequencies from 16 Hz to 16 kHz, or the eight octave bands with nominal midband frequencies from 63 Hz to 8 kHz with KS = 6 (N = 18) to KF = 13 (N = 39).

3.6 FREQUENCY WEIGHTING: The A- or C-frequency weightings standardized in References 14 and 15 for measurements of frequency-weighted sound pressure levels. Unit, decibel; unit symbol, dB.

NOTES:

1. **Table 2 gives the nominal A- and C-frequency weightings at nominal midband frequencies from 12.5 Hz to 20 kHz.**

2. Sound level meters may also provide flat and allpass frequency weightings with flat frequency response over a manufacturer-specified frequency range and within specified tolerance limits; see 3.5, Note 3.

3.7 TIME CONSTANT: Time required for the amplitude of that component of a quantity which varies exponentially with time to increase by the factor $[1 - (1/e)] \simeq 0.63212$ or to decrease by the factor $1/e \simeq 0.36788$, where e is the base of the natural logarithm ($e \approx 2.71828$). Quantity symbol, τ; unit, second, unit symbol, s.

3.8 EXPONENTIAL-TIME-WEIGHTED AND FREQUENCY-WEIGHTED SOUND PRESSURE LEVEL; SOUND LEVEL: Ten times the base-ten logarithm of the ratio of an exponential-time-weighted, squared and frequency-weighted sound pressure to the square of the reference sound pressure. The frequency-weighting and exponential time weighting actually employed shall always be stated. Unit, decibel; unit symbol, dB.

NOTES:

1. As an example, time-varying exponential-time-weighted and A-frequency-weighted sound pressure level, $L_{A\tau}(t)$, for any one exponential time constant τ, is expressed in the following equation:

$$L_{A\tau(t)} = 10\ \lg\{[(1/\tau)\int_{t_s}^{t} p_A{}^2(\xi)\ e^{-(t-\xi)/\tau}\ d\xi]/p_0{}^2\} \qquad \text{(Eq.5)}$$

3.8 (Continued):

where:

$p_A(\xi)$ is the instantaneous time-varying, A-frequency-weighted sound pressure varying with time t, p_0 is the reference sound pressure, and ξ is a dummy variable of integration. The exponential time weighting in Equation 5 applies equally to all portions of a sound-pressure signal.

2. By Equation 5, running integration of squared frequency-weighted sound pressure occurs from some time in the past at starting time t_s to the present at observation time t. Division of the result of the integration by time constant τ yields a running time average with exponential time weighting. The sense of a running time average is that the exponential-time-weighted sound level is continuously updated as a function of observation time.

3. If a frequency weighting other than the A-frequency weighting is used when measuring an exponential-time-average, frequency-weighted sound pressure level (e.g., flat or allpass weighting), change the subscript A to another symbol in Equation 5, e.g., FL for flat and AP for allpass. Also change the name of the quantity and the corresponding quantity symbol.

4. If the frequency weighting for the sound pressure is clear from the text of a report, the symbol for the frequency weighting may be given within parentheses after the unit symbol to indicate that a frequency-weighted sound pressure level has been measured; for example: a slow sound level of 72 dB(A) or a fast sound level of 86 dB(C) for measurements of A-weighted or C-weighted sound levels. The unit of a sound level, however, remains the decibel and is not frequency weighted.

3.9 FAST A-WEIGHTED SOUND LEVEL: Sound level obtained with a nominal 125-ms "fast" time weighting and A-frequency weighting. Abbreviation, FAL; quantity symbol, L_{AF}; unit, decibel; unit symbol, dB.

3.10 SLOW A-WEIGHTED SOUND LEVEL: Sound level obtained with a nominal 1000-ms "slow" time weighting and A-frequency weighting. Abbreviation, SAL; quantity symbol, L_{AS}; unit, decibel; unit symbol, dB.

NOTES:

1. A fast sound level always is more strongly influenced by recent sounds, and less influenced by sounds occurring in the distant past, than the corresponding slow sound level.

2. A maximum sound level is the greatest exponential time average sound level occurring in a stated time period at some specified measurement location. For the same nonsteady sound, the maximum fast sound level is generally greater than the corresponding maximum slow sound level.