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Superseding ARP1323A

Type Measurements of Airplane Interior Sound Pressure Levels During Cruise

RATIONALE

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

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FOREWORD

This Aerospace Recommended Practice (ARP) recommends instruments and procedures for the measurement and reporting of sound pressure levels in the interior of passenger airplanes for the purpose of providing a general description of the acoustical environment during stabilized cruise conditions. The procedures are recommended to ensure uniformity when conducting tests to determine compliance with noise level goals or contractual requirements.

1. SCOPE:

1.1 The primary measurement procedure recommended in this ARP includes the recording of sound pressure signals in the interior of an airplane during steady state cruise conditions with analysis after the flight into octave band (or one-third octave band) sound pressure levels.

1.2 Alternatively, spectral analyses of the sound pressure signals may be performed directly on board an airplane. Though less flexible than the primary measurement procedure, the alternative procedure offers the advantage of immediate availability of frequency band or frequency weighted sound pressure levels that are consistent with those measured in accordance with the procedures in ISO 5129 (Reference 2.1).

1.3 In view of the range of possible measurement systems, this ARP provides electroacoustical performance requirements for a complete system from a microphone to the readout device. Various individual components of a measurement system may be selected so long as the total measurement system complies with the requirements.

1.4 Recommendations of this ARP are not intended to satisfy the stringent requirements for airplane design or development. Also, they may not be directly applicable to measurements of sound pressure levels in the interior of helicopters or general aviation airplanes where special constraints on measurement locations and test procedures may exist. Specific recommendations for measurement of interior sound pressure levels in helicopters are given in 2.2.

2. REFERENCES:

The following standards and recommended practices contain provisions which, through reference in this text, constitute provisions of this ARP. At the time of publication, the editions indicated were valid. All standards and recommended practices 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, or equivalent national standards.

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

2.2 SAE ARP1964, Measurement of Rotorcraft Interior Sound Pressure Levels

2.3 IEC 651:1979, Sound Level Meters

2.4 ANSI S1.4-1983, American National Standard Specification for Sound Level Meters

2.5 IEC 804:1985, Integrating-Averaging Sound Level Meters

2.6 IEC XXXX:199X, Random-Incidence and Diffuse Field Calibration of Sound Level Meters[1]

2.7 IEC 225:XXXX, Octave-Band and Fractional-Octave-Band Filters [Revision of IEC 225:1966.][2]

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

2.9 ISO 266:1991, Acoustics - Preferred Frequencies for Measurements [Revision of ISO 266.][2]

2.10 ANSI S1.6-1984(R1990), American National Standard Preferred Frequencies, Frequency Levels, and Band Numbers for Acoustical Measurements

2.11 IEC 942:1988, Sound Calibrators

2.12 ANSI S1.40-1984(R1990), American National Standard Specification for Acoustical Calibrators

2.13 ANSI S1.10-1966(R1986), American National Standard Method for the Calibration of Microphones

[1]At present, at the stage of draft.
[2]See Footnote 1.

3. MEASUREMENT SYSTEM PERFORMANCE REQUIREMENTS:

3.1 General:

3.1.1 Systems for measurement of sound pressure levels in the interior of airplanes include an acoustical calibrator, microphone, microphone preamplifier and power supply, microphone holding device and extension cables, and signal conditioning and recording devices. Frequency band sound pressure levels are determined by playing the recorded signals through a single or multichannel spectrum analyzer with a readout device. Requirements in this section apply to each channel of a measurement and analysis system.

3.1.2 Alternatively, a conventional or integrating-averaging sound level meter meeting the Type 1 (Class 1) accuracy requirements of 2.3, 2.4, or 2.5, as appropriate, may be employed in conjunction with an attached set of bandpass filters for direct measurement of frequency band sound pressure levels.

3.1.3 The intent of this ARP is to describe a measurement system that will provide time averaged, frequency band sound pressure levels, L_{pfT} in decibels, in accordance with the following equation:

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

where:

T is the averaging time
t is the time variable of integration
$p_f^2(t)$ is the square of the instantaneous sound pressure signal at the output of a bandpass filter of nominal midband frequency f
p_o^2 is the square of the reference sound pressure of 20 μPa
lg represents base-10 (common) logarithms

3.1.4 This ARP specifies tolerances on the deviation of the frequency and level linearity responses of a complete sound measurement system. Tolerances on frequency response are relative to deviations from a "flat" frequency response. Tolerances on level linearity are relative to the deviation from an ideal linear relationship between the level of output signals and the level of corresponding steady sinusoidal electrical input signals over a specified minimum total measurement range. The total measurement range may include separate operating/display ranges selected by a level range control.

3.2 Reference Conditions:

Measurement system performance requirements in this ARP apply for reference environmental conditions that include an air temperature of 20°C, an air pressure of 1013 hPa, and a relative humidity of 65%. Measurements made to demonstrate compliance with the electroacoustical performance requirements of this ARP shall account for the effects, if any, on the indicated sound pressure levels if the air temperature, atmospheric pressure, and relative humidity prevailing at the time of a demonstration test differ from the reference conditions.

3.3 Microphone:

3.3.1 The preferred microphone is an air capacitor (e.g., condenser) type that is sensitive to the pressure of a sound wave with known variation of its sensitivity with changes in atmospheric pressure and air temperature. The preferred diameter of the microphone is not greater than 13.5 mm. The microphone should be vented to equalize the air pressure on each side of the diaphragm.

3.3.2 The microphone system includes any microphone extension rods or cables, along with a windscreen, if placed around the microphone for protection when measuring airplane interior sound pressure levels.

3.4 Performance Requirements:

3.4.1 Microphone Operating Range: For steady sinusoidal signals at nominal frequencies of 63, 1000, and 8000 Hz, the manufacturer specified sound pressure level at the microphone, which causes the total harmonic distortion of the signal at the output of the microphone preamplifier to exceed 3%, shall be not less than 130 dB re 20 µPa. The microphone system shall be able to measure frequency band sound pressure levels at least as low as 30 dB without introducing significant electrical background noise at any frequency of interest; see 6.5.

3.4.2 Operating/Display Range: An operating or display range is a part of the total measurement range that is selected by a setting of a level range control. The operating/display ranges shall overlap such that measurements may be made on the linear portion of each range.

3.4.3 Reference Range and Reference Level: One of the operating/display ranges shall be specified as the reference range for calibration and for recording the acoustical sensitivity check. A reference level on the reference range shall be specified as the reference for determining frequency response and level linearity.

3.4.4 Frequency Response: Over the nominal frequency range from 40 Hz to 12 kHz, the random incidence (diffuse field) frequency response level of a complete measurement system shall be within the Class 1 (Type 1) tolerances given in 2.3 and 2.4 for frequency weighting characteristics.

NOTES: 1. In accordance with 2.6, random incidence frequency response level, in decibels, of a sound level meter, for a given frequency or frequency band centered on that frequency, is the time average sound pressure level indicated by the instrument due to a random incidence sound field, minus the time average sound pressure level due to sound waves from the same source in the absence of the instrument.

2. Random incidence frequency response levels for a microphone may be determined by applying appropriate manufacturer provided directivity corrections to the pressure response of the microphone as measured in a closed coupler or equivalent device.

3. The frequency response level of a complete measurement system may be determined by arithmetic summation of the random incidence frequency response level of the microphone system and the electrical frequency response level of the other components of a measurement system, with both frequency response levels relative to the response at the nominal frequency of the acoustical sensitivity check.

4. An electrical frequency response level is the sound pressure level indicated by the readout device from the spectrum analyzer, for the frequency band of any bandpass filter used for data analysis, minus the indicated sound pressure level for the frequency band containing the nominal frequency of the acoustical sensitivity check; see 3.5.

3.4.5 Level Linearity Range:

3.4.5.1 The level linearity range for steady sinusoidal signals on any operating/display range of a complete measurement system, exclusive of the microphone, shall be at least 50 dB over which the deviation from a linear relationship between the levels of the input and ouput signals shall not exceed ±0.5 dB relative to the linearity of the specified reference level on the specified reference range. Tolerances on level linearity include the errors, relative to the nominal gain or attenuation, introduced by level range controls, if present.

3.4.5.2 For the purpose of this ARP, the minimum level linearity range of 50 dB, within tolerances of ±0.5 dB, applies at least for nominal midband frequencies of 63, 1000, and 8000 Hz, along with the frequency of the acoustical sensitivity check if it is not 1000 Hz.

3.4.6 Spectrum Analyzer:

3.4.6.1 The spectrum analyzer shall comply with the requirements of 2.7 and 2.8, as appropriate, for a Type 1 (Class 1) instrument. The functions of squaring and time averaging the filtered signal shall follow the principle of Equation 1.

3.4.6.2 The nominal band center frequencies (see 2.9 and 2.10) of the octave band filters shall be in the range from 63 Hz to 8 kHz; nominal band center frequencies of one-third octave band filters shall be in the range from 50 Hz to 10 kHz. The frequency range may be extended to lower or higher frequency bands if appropriate for the spectrum of the sound in the airplane.

3.4.7 Resolution of Readout Device: The resolution of the readout device shall be not greater than 0.2 dB.

3.5 Acoustical Calibrator:

The sound pressure level in the cavity of the acoustical calibrator used to check the acoustical sensitivity of each channel of a measurement system, at a nominal frequency of 250 or 1000 Hz, shall be known, under reference conditions, within ±0.3 dB. Additionally, the calibrator shall meet the applicable Class 1 (Type 1) requirements of 2.11 and 2.12. The variation of the level of the sound pressure in the cavity of the calibrator with atmospheric pressure and air temperature shall be known.

3.6 System Stability:

After a specified period of time for "warm-up," but not to exceed 15 min, the output level from the measurement system in response to the signal from an acoustical calibrator shall be constant within 0.3 dB.

4. VERIFICATION OF ELECTROACOUSTICAL CHARACTERISTICS:

4.1 General:

The electroacoustical characteristics of all components of a measurement system shall be measured before the start of a test to ensure compliance with the requirements of Section 3. Electrical signals applied through the input to a microphone preamplifier shall utilize a device such as a dummy microphone or input adapter having an electrical impedance equivalent to that of the microphone.

4.2 Frequency Response and Level Linearity:

4.2.1 The frequency response of the measurement system shall be measured within three months prior to the start of an airplane interior noise test. The absolute acoustical sensitivity of each microphone shall be established before the start of a test, and within one week after completion of the test, by the procedures of 2.13, or equivalent.

4.2.2 In addition, the level linearity of the system shall be measured within three months before the start of an airplane interior noise test. The electrical performance characteristics of the spectrum analyzer (filters) shall also be checked within three months before the start of the test.

4.2.3 If the recording system includes a magnetic tape recorder, a frequency response calibration shall be made using at least 10-s duration sinusoidal signals at the nominal midband frequencies of the filters to be used for data analysis, or at least a 30-s duration of a broadband "pink noise" signal. Additionally, a check of the electrical system noise floor shall be obtained by a recording of a "shorted" input signal or the signal from the microphone with a device placed around it to reduce the contribution of ambient noise.

4.3 Acoustical Sensitivity Checks:

4.3.1 For each microphone, the signal from the acoustical calibrator shall be recorded at least once on every reel of magnetic recording tape, or equivalent recording medium, as an "end-to-end" discrete frequency sound pressure sensitivity check for each channel of a measurement system. A similar sensitivity check shall be made for an alternative measurement system that does not include a recording device.

4.3.2 Checks of the acoustical sensitivity of the measurement system shall be performed on the ground before takeoff and again after landing. An adjustment shall be applied for the effect of differences between the prevailing atmospheric pressure and air temperature and the reference pressure and temperature. If in-flight checks of acoustical sensitivity are made, an adjustment shall be included for the influence of the prevailing cabin pressure and temperature on the sound pressure level in the cavity of the calibrator.

4.3.3 The acoustical calibrator shall be calibrated within six months prior to the tests. Its calibration shall be traceable by verification from a national standards organization.

5. MEASUREMENT PROCEDURES:

5.1 Measurement Locations:

5.1.1 Passenger Compartments: Sound pressure levels shall be measured at the typical head position of a seated passenger, with the passenger not present. The microphone shall be located on the seat centerline, with the axis vertical and pointed up, a distance of 150 m ± 25 mm from the headrest and 1 m ± 50 mm from the floor. The microphone shall be held in a bracket attached to the seat back or at the end of a rod to minimize shielding effects. Seat number, or distance from cabin sidewall and fuselage station, shall be noted for each measurement location. The distribution of measurement locations in a passenger cabin will depend on the airplane's seating arrangements and specific test objectives.