



AEROSPACE RECOMMENDED PRACTICE

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Aircraft Noise Level Reduction Measurement of Building Façades

RATIONALE

This SAE Aerospace Recommended Practice (ARP) provides methods for the measurement of aircraft noise level reduction of a building envelope.

Standard methods for measuring the noise reduction of façades have been published by the International Organization for Standards (ISO) and the American Society for Materials and Standards (ASTM), but these methods do not provide the details necessary to obtain reproducible results when applied to realistic field situations, particularly when the façades are exposed to aircraft noise sources. This ARP generally follows these methods, but has been developed to provide these additional details and the rigor necessary for application to airport residential sound insulation projects.

FOREWARD

Historically, there have been two methods used to measure the noise reduction of structures. The Flyover Measurement Procedure employs aircraft as the exterior noise source. Since aircraft are the source of the noise, outside and inside noise measurements are made simultaneously with aircraft overflights. This method has the advantage of simulating the noise problem experienced by the residents, provided that the measured overflights are representative of the airport's annual average daily operations for the year of interest. However, aircraft as noise sources are uncontrollable and the measurement results can sometimes be difficult to replicate if aircraft fly different tracks on different days or arrive some days and depart others on a specific runway. The result is that the data obtained is often representative only for the day of measurement. Furthermore, the testing procedure requires multiple sound level meters to conduct noise measurements simultaneously in multiple rooms, and can be time-consuming if airport runway usage does not always match the need for measurements. The aircraft fly-over measurement method is presented in Part 1 of this ARP6973.

The Loudspeaker Measurement Method for measuring noise reduction adapts the ASTM E966-18a test procedure that incorporates an outdoor loudspeaker as the noise source, together with noise level measurements outdoors and indoors. The loudspeaker is a controlled source, and so the measured data is more accurate and repeatable than that using aircraft as the source, and is not subject to the day-to-day variations in aircraft operations. However, the data obtained using the ASTM method is not necessarily reproducible by consultants as it lacks procedural details for applying the method to realistic field situations.

The loudspeaker measurement method presented in Part 2 of this ARP is based on research designed to provide the necessary test details to obtain reproducible results in realistic situations.

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Documents

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TABLE OF CONTENTS

1.	SCOPE.....	4
2.	REFERENCES.....	4
2.1	Applicable Documents	4
2.1.1	ANSI Accredited Publications	4
2.1.2	ASTM Publications	4
2.1.3	ISO Publications.....	4
2.1.4	IEC Publications.....	4
2.2	Related Publications	4
2.3	Definitions	5
2.4	Abbreviations	5
3.	PART 1: AIRCRAFT FLYOVER MEASUREMENT METHOD.....	6
3.1	Overview of the Aircraft Flyover Measurement Method.....	6
3.2	Equipment and Measurement Conditions.....	6
3.2.1	Measurement Equipment Specifications.....	6
3.2.2	Windscreen	6
3.2.3	Background Noise.....	6
3.2.4	Weather Conditions.....	6
3.3	Measurement of Exterior Sound Level.....	6
3.4	Measurement of Interior Sound Level.....	7
3.5	Determination of Noise Level Reduction (NLR).....	7
3.6	Documentation	8
4.	PART 2: LOUDSPEAKER MEASUREMENT METHOD.....	8
4.1	Overview of the Loudspeaker Measurement Method	8
4.2	Equipment and Test Conditions	9
4.2.1	Measurement Frequency Range	9
4.2.2	Loudspeaker Specifications	9
4.2.3	Instrumentation Specifications	9
4.2.4	Windscreen	9
4.2.5	Background Noise.....	9
4.2.6	Weather Conditions.....	9
4.3	Loudspeaker Configuration	10
4.3.1	Background	10
4.3.2	Loudspeaker Distance and Angle of Incidence	10
4.3.3	Loudspeaker Height	11
4.4	Measurement of Exterior Sound Level.....	11
4.4.1	General.....	11
4.4.2	Flush Microphone Method	12
4.4.3	Near-Façade Microphone Method	12
4.4.4	Loudspeaker Calibration Method	13
4.4.5	Measurement of Exterior Background Noise Level	14
4.5	Measurement of Interior Sound Level.....	15
4.5.1	Measurement of Average Interior Sound Level	15
4.5.2	Measurement in Open Floor Plans	16
4.5.3	Measurement of Interior Background Noise Level.....	16
4.6	Correction for Background Noise	16
4.7	Noise Reduction Measurement for Specific Building Types and Situations	16
4.7.1	Rooms with a Single Façade	17
4.7.2	Outside Corner Rooms with Two Façades	17
4.7.3	Inside Corners.....	18
4.7.4	Rooms with Multiple Façades	19
4.7.5	Permanent Attachment to a Façade	19
4.7.6	Corrections for Roof Transmission	20
4.7.7	Multiple-Story Buildings.....	21

4.8 Determination of Noise Level Reduction (NLR)..... 22

4.8.1 Aircraft Spectrum 22

4.8.2 Calculation of Noise Level Reduction (NLR) 22

4.9 Measurement Repeatability 24

4.10 Documentation 24

5. NOTES 24

5.1 Revision Indicator..... 24

Figure 1 Design chart for determining loudspeaker distance and angle of incidence to achieve a maximum variation of 3 dB over a façade surface 10

Table 1 Corrections for roof transmission 21

Table 2 Example of octave band calculation of NLR 23

1. SCOPE

This Aerospace Recommended Practice (ARP) provides two methods for measuring the aircraft noise level reduction of building façades. Airports and their consultants can use either of the methods presented in this ARP to determine the eligibility of structures exposed to aircraft noise to participate in an FAA-funded Airport Noise Mitigation Project, to determine the treatments required to meet project objectives, and to verify that such objectives are satisfied.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 ANSI Accredited Publications

Copies of these documents are available online at <http://webstore.ansi.org/>.

ANSI S1.43 Specifications for Integrating Averaging Sound Level Meters

2.1.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM E966-18a Standard Guide for Field Measurements of Airborne Sound Attenuation of Building Facades and Façade Elements, November 2018

2.1.3 ISO Publications

Copies of these documents are available online at <http://webstore.ansi.org/>.

ISO 16283-3 Acoustics – Field measurements of sound insulation in buildings and of building elements - Part 3: Façade sound insulation, 2016

2.1.4 IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC 61672-1 Electroacoustics – Sound level meters

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

“Study of Noise Level Reduction (NLR) Variation,” April 2013, at https://www.faa.gov/about/office_org/headquarters_offices/apl/research/science_integrated_modeling/media/BTV_NLR_report.pdf.

“Review and Evaluation of Aircraft Noise Spectra used to Estimate Noise Level Reduction for Airport Sound Insulation Programs based on the Loudspeaker Test Method,” March 2016, at https://www.faa.gov/about/office_org/headquarters_offices/apl/research/science_integrated_modeling/media/pears_to43.pdf.

“Evaluating Methods for Determining Interior Noise Levels Used in Airport Sound Insulation Programs,” ACRP 02-51, October 2015, at <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3697>.

“Investigation of ASTM E966 Adjustment Factors,” DOT/FAA/TC-18/15, April 2018, at <https://www.airporttech.tc.faa.gov/Products/Airport-Safety-Papers-Publications/Airport-Safety-Detail/ArtMID/3682/ArticleID/160/Investigation-of-ASTM-E966-Adjustment-Factors>.

“NLR Measurement Method Equalization and Normalization,” DOT/FAA/TC-19/34, September 2019, at <https://www.airporttech.tc.faa.gov/Products/Airport-Safety-Papers-Publications/Airport-Safety-Detail/ArtMID/3682/ArticleID/2678/Noise-Level-Reduction-Measurement-Method-Equalization-and-Normalization>.

2.3 Definitions

DAY-NIGHT AVERAGE SOUND LEVEL (DNL): The Day-Night Average Sound Level (DNL) is the energy average sound level over a period of 24 hours with a 10 dB adjustment to levels occurring between the hours of 2200 and 0700.

COMMUNITY NOISE EQUIVALENT LEVEL (CNEL): The Community Noise Equivalent Level (CNEL) is the energy average sound level over a period of 24 hours with a 5 dB adjustment to levels occurring between the hours of 1900 to 2200, and a 10 dB adjustment to the levels occurring between the hours of 2200 and 0700.

FAÇADE: A façade is one exterior side of a room in a building.

NOISE REDUCTION (NR): The noise reduction (NR) of a building façade is defined as the difference between the free-field sound pressure level, generated by an exterior noise source, that would exist at the exterior of the façade if the building and façade were not present, and the sound pressure level in the room behind the façade. Noise reduction is measured and reported as a function of frequency in one-third octave or octave bands.

NOISE LEVEL REDUCTION (NLR): The Noise Level Reduction (NLR) of a building façade is a single-number metric representing the difference between an A-weighted exterior aircraft noise spectrum and the corresponding A-weighted interior noise level in the room behind the façade.

SOUND EXPOSURE LEVEL (SEL): The level, in decibels, of the time-integral of the square of the instantaneous A-weighted sound pressure for a specific period of time, such as the duration of an aircraft sound measurement, and relative to the reference sound exposure of $(20 \mu\text{Pa})^2(1\text{s})$.

2.4 Abbreviations

CNEL	Community Noise Equivalent Level, dB
DNL	Day-Night Average Sound Level, dB
NR	Noise Reduction, dB
NLR	Noise Level Reduction, dB
SEL	Sound Exposure Level, dB
SLM	Sound Level Meter

3. PART 1: AIRCRAFT FLYOVER MEASUREMENT METHOD

3.1 Overview of the Aircraft Flyover Measurement Method

The noise level reduction (NLR) of a building façade is determined by measuring the difference between the exterior and interior Sound Exposure Levels (SELs) from an aircraft flyover.

Because the noise exposure differs for each aircraft flyover, it is necessary to conduct the measurements for a sufficiently large number of aircraft events in order to obtain a reliable average value of Noise Level Reduction (NLR). Statistical analysis is applied to establish an acceptable sample size to achieve a 95% confidence that the reported value of noise reduction is within ± 0.5 dB of the correct value (this usually requires at least 10 to 15 overflights).

Note that the data obtained is often representative only for the time of measurement as aircraft flight tracks and fleet mix may vary from hour to hour and day to day.

3.2 Equipment and Measurement Conditions

3.2.1 Measurement Equipment Specifications

Measurements of exterior and interior SELs require an integrated, time averaging, Sound Level Meter (SLM) instrumentation system meeting the Type 1 requirements of ANSI S1.43 that includes a 1/2-inch microphone and protective windscreen, or the Class 1 requirements of IEC 61672-1. The sampling interval for such a system shall preferably be 0.5 second, but not greater than 1 second.

Calibration checks of the measurement equipment must be performed before the start and at the end of each set of measurements. The clocks on all SLMs must be synchronized daily with no more than a 2 second difference.

3.2.2 Windscreen

The measurement microphone shall be covered by an open cell foam windscreen to reduce the direct effect of moving air on the microphone, and to protect the microphone from the environment, such as from dust or possible mechanical contact with hard objects.

3.2.3 Background Noise

Sound level measurements shall not be conducted in the presence of intermittent background noise sources, such as truck pass-bys, public address system announcements, lawn mowers, construction equipment, etc., noise sources should be disabled where possible, or measurements limited to time periods between background noise events.

3.2.4 Weather Conditions

Noise measurements should not be conducted when the wind speed exceeds 23 ft/s (15 mph).

3.3 Measurement of Exterior Sound Level

The exterior microphone should be positioned adjacent to the structure so that it is exposed to the entire aircraft flyover with no obstructions to interfere with the sound propagated from the aircraft. The microphone shall be placed at a height of 5 feet above the ground, and located away from the structure and other structures as well as away from reflections from large objects or buildings to achieve as much as possible a free-field measurement. Alternatively, the microphone can be placed 5 feet above the roof of the test structure. Microphones should not be placed close to a busy roadway or other source of noise.

During the noise measurements, the operator should monitor the site from the outside to identify any contamination of the measured data due to non-aircraft events occurring at the same time as an aircraft event.

If noise event triggering is used, the trigger threshold should be chosen so that maximum sound levels during aircraft noise events are at least 10 dB above the threshold value. If this condition is not satisfied, the measurement is considered invalid.

3.4 Measurement of Interior Sound Level

The interior noise level in a room is determined by arithmetically averaging the individual sound level measurements made simultaneously at two locations within the room. The microphones should be mounted on tripods at different heights and positioned at least 2 feet from any major reflective surface such as a wall, ceiling, or floor, and 2 feet from the center of the room. If open floor space is not available, the microphones may be mounted above soft furnishings such as sofas, beds, soft chairs, etc., but not immediately above hard furniture, such as tables.

All household noise sources should be temporarily deactivated during the measurements to the extent possible. This includes televisions, stereos, radios, ceiling fans, aquarium pumps, and ventilation systems in all rooms of the house. Pets and children should not be present in the test room. No speech should occur during the measurements. The microphones must not be placed close to household noise sources, such as ticking clocks or refrigerators, that cannot be deactivated. These noise sources will be quieter than the aircraft flyover but may be loud enough to accidentally trigger the measuring threshold of the sound level meter. The windows and doors must be closed and latched.

The setup of all microphones/tripods must be documented with photos of each location, together with a simple sketch. Photos of all rooms where microphones have been placed must document the room conditions for absorption and the condition of the elements in the rooms (windows, walls, exterior doors, roof/ceiling, or in-wall air conditioning units).

3.5 Determination of Noise Level Reduction (NLR)

The interior and exterior sound level data for each recorded aircraft event shall be examined to ensure that the maximum sound level for each event is at least 10 dB greater than the background sound level before and after the event. Events that do not meet this requirement should be removed from subsequent analysis.

The noise level reduction for the test room, NLR_i , for the i th aircraft flyover event is given by the following expression:

$$NLR_i = SEL_{ext,i} - SEL_{int,i} \quad (\text{Eq. 1})$$

where $SEL_{ext,i}$ is the Sound Exposure Level (SEL) measured by the exterior microphone, and $SEL_{int,i}$ is the arithmetic average of the measured interior SELs for the same event. The average NLR for the test room, NLR_{av} , taken over N aircraft events is then calculated by the expression:

$$NLR_{av} = \frac{1}{N} \sum_{i=1}^N NLR_i \quad (\text{Eq. 2})$$

In almost all situations, a minimum sample size, N , of 10 to 15 overflights is required to achieve a 95% confidence that the reported value of NLR is within ± 0.5 dB of the real value.

In performing the analysis, the measured data should be studied to identify any outliers, namely values of noise level reduction that appear to be inconsistent with the remainder of the data. If the reason for the outlier value can be determined, and it is a once-only occurrence, or the data belongs to a different population, then the outlier value should be deleted from the calculation of NLR_{av} . Examples would be a single turboprop aircraft event in a data set of jet aircraft events, or contamination of the interior sound level. If the cause cannot be identified, the analysis should be conducted with and without the outlier. If the conclusions are significantly different, then the outlier is influential and this should be noted in the report.

If there are multiple values that appear inconsistent, or if the standard deviation of the sample set is large, then the analysis should be conducted using the median value of the noise reduction data set.

An alternative approach is to calculate the 95% confidence level after each flyover using a spreadsheet as the aircraft noise is measured and events are downloaded from the sound level meters. The data from each event are entered into a spreadsheet and the 95% confidence interval updated after each event until it reaches ± 0.5 dB. The spreadsheets that calculate the NLR must be saved and included as part of the documentation for each property.

3.6 Documentation

The documentation of the measurements shall include the following:

- Property address, geographical coordinates (optional), and description.
- Exterior and interior building photographs and floorplan sketches.
- DNL/CNEL contour zone value.
- Weather conditions during tests - temperature, wind speed.
- Instrumentation
- Documentation of exterior and interior microphone locations.
- Documentation of aircraft events - time, aircraft type, arrival/departure, runway end (optional).
- Measured SEL for each event for each microphone (exterior and interior).
- Process for determining NLR.

All spreadsheets that calculate the NLR measurement results must be saved and included as part of the documentation for each property.

4. PART 2: LOUDSPEAKER MEASUREMENT METHOD

4.1 Overview of the Loudspeaker Measurement Method

The loudspeaker measurement method is designed to measure the noise reduction of a building façade using an external loudspeaker as the noise source. This is the preferred measurement method as the repeatability of the measurements is increased by utilizing a controlled noise source. Research conducted at several airports has shown that this method leads to lower measured values of noise reduction and higher estimates of interior noise levels than the aircraft flyover measurement method, which includes the effects of shielding of some rooms from direct exposure to the aircraft flight path. The difference can be as much as 2 dB.

Specialized equipment as described in 4.2 is used to perform the measurements. A loudspeaker is used to generate the exterior sound exposure on the test façade. The height, distance to the façade, and angle of incidence of the loudspeaker are selected to ensure a uniform exposure over the entire façade (4.3). The level of the sound incident to the façade can be measured at the façade surface (4.4.2) or close to the façade (4.4.3), with adjustments applied to account for reflections from the façade. The incident sound level can also be determined using a calibrated loudspeaker (4.4.4) which eliminates the need to apply such adjustments.

The selection of the most appropriate method for measuring the exterior incident sound level will depend on the layout of the room to be tested and the external building environs, and may differ from room to room within the building. Section 4.7 provides guidance on the selection of the most appropriate method suitable for application in different field situations.

The average interior sound level in the room behind the façade is measured by means of a volume or spatial average scan over the central portion of the room (4.5). The noise reduction (NR) is then defined as the difference between the exterior and interior sound levels as a function in each of the one-third or octave frequency bands. The noise level reduction (NLR) is a single-number metric representing the difference between an A-weighted exterior aircraft noise spectrum and the corresponding A-weighted interior noise level in the room behind the façade (4.8).