U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: NOISE STANDARDS: AIRCRAFT TYPE AND AIRWORTHINESS CERTIFICATION

Date: 10/12/2017
Initiated by: AEE-100

AC No: 36-4D
Change:

1. PURPOSE

This advisory circular (AC) is intended to promote uniformity of implementation of part 36 of the noise certification requirements of the United States Code of Federal Regulations (CFR) Title 14. It provides (1) guidance to certificating authorities and applicants regarding the intended meaning and stringency of the Standards in part 36 as amended through October 4, 2017 (Amendment 36-31), and (2) the specific procedures that are deemed acceptable in demonstrating compliance with those Standards.

Note.— All references in this AC to parts such as part 36, part 21, etc. refer to parts of Title 14 of the United States Code of Federal Regulations.

a. Contents: This AC provides FAA policies for implementation of the regulatory language in the form of guidance material and technical procedures relating to the requirements of Appendices A, B, G, J, H and K of part 36 as appropriate. Those appendices describe the noise evaluation methods for compliance with the corresponding chapters of part 36 for jet airplanes, propeller-driven heavy and light airplanes, helicopters, and tiltrotor aircraft. Guidelines are also provided on flight test windows and adjustment of land-use planning data for rotorcraft.

The document also includes general information (including administrative information), general and technical references, definitions and bibliographies related to part 36. Information is also provided on equivalent procedures and demonstrating “no acoustical change” for jet airplanes, propeller-driven heavy and light airplanes, and helicopters.

b**.** Scope: This AC provides information for interested parties (such as regulatory authorities, aircraft manufacturers, acoustic consultants, airline and airport operators and others) on compliance with the part 36 noise certification regulations, including FAA policies and interpretations of regulatory language and other technical guidance applicable to noise certification processes for airplane and rotorcraft classes of aircraft. It is applicable for noise certification of normal, utility, acrobatic, commuter and transport category airplanes and normal and transport category rotorcraft as defined in part 21. Information is also provided on flight test windows and adjustment of land-use planning for rotorcraft as developed by the International Civil Aviation Organization (ICAO).

This AC does not change regulatory requirements and does not authorize changes in, or deviations from, regulatory requirements. This document contains some mandatory language, where it is appropriate, as well as language that is permissive and advisory in nature. Mandatory language (e.g., the term “must”) is used in the AC for “Explanations of regulatory language”. Mandatory language is also used for certain “Guidance material” and “Technical procedures” to reflect FAA policies regarding compliance with the intent of regulatory language. Permissive language (e.g., the term “should”) is used in this AC, to identify conditions and/or methods and procedures that may be acceptable to the FAA for purposes of aircraft noise certification based upon experience to date, but where an applicant is not constrained from considering or validating and proposing alternatives for compliance with part 36.

c. Document structure: The basic framework of this AC is structured to provide various forms of noise certification guidance material for these aircraft. To a major extent this document follows the structure of the ICAO Environmental Technical Manual (ETM) document 9501 (Reference G5). Chapter 1 provides information on noise certification requirements in part 21. Chapter 2 provides information on FAA regulatory policies. Chapter 3 provides guidance applicable for all aircraft types and subsequent chapters provide guidance unique to different aircraft types. The general format of Chapters 1 through 8 includes one or more of three types of information: explanatory information, equivalent procedures and technical procedures which are described as follows:

Explanatory information

Explanatory information has the following purpose:

a) explains the language of part 36 noise Standards;

b) states current policies of the FAA regarding compliance with part 36; and

c) provides information on critical issues concerning approval of applicants' compliance methodology proposals.

Explanatory information may take the form of either:

a) guidance material (GM) which helps to illustrate the meaning of a specification or requirement; or

b) acceptable means of compliance (AMC) which illustrates a means, but not the only means, by which a requirement specified in part 36, can be met. It may contain reference to an equivalent procedure described in this AC.

In the Explanatory sections of Chapters 4 through 8, a heading is provided for each AC section, including a subject or title, and the part 36 appendix and section number to which it refers. For example, GM §A36.2.1.1 is guidance material concerning §2.1.1 of Appendix A. Adjacent to this heading is a bracketed reference to the corresponding section of the ICAO ETM. For this example, "[ETM GM A2 2.1]" is guidance material concerning §2.1 of Appendix 2 of ICAO Annex 16, Volume I (Reference G7). Similarly, AMC §A36.2.1.1 presents an acceptable means of compliance concerning §2.1.1 of Appendix A and "[ETM AMC A2 2.1]" is an acceptable means of compliance concerning §2.1.1 of Appendix 2 of Annex 16, Volume 1.

Equivalent procedures

The FAA Office of Environment and Energy (AEE) (located in Washington DC) has approved a substantial number of equivalent procedures proposed by applicants. An equivalent procedure is by definition a test or analysis procedure which, while differing from one specified in part 36, in the technical judgment of the FAA, yields effectively the same noise levels as the specified procedure. Therefore, equivalent procedures provide some flexibility for the applicant in conducting noise certification in accordance with part 36, and may be approved for the convenience of an applicant in conducting measurements that are not strictly in accordance with the part 36 procedures, or when a departure from the specifics of part 36 is necessitated by field conditions.

Many of these equivalent procedures are referred to in this document because, through their extensive usage by applicants, they have become acceptable practices for aircraft noise certification applications. The acceptability of an equivalent procedure for an aircraft noise certification application is subject to FAA review and approval on a project by project basis. Equivalent procedures such as flight intercept need FAA approval as all other equivalencies, but may not require AEE involvement.

Equivalent procedures fall into two broad categories:

a) those which are generally applicable; and

b) those which are applicable to a particular aircraft type; for example, some equivalencies dealing with measurement equipment may be used for all types of aircraft, but a given test procedure may be appropriate only for jet airplanes and not for turboprop airplanes.

Typical applications of equivalent procedures requested by applicants are to:

a) use previously acquired certification test data for the aircraft type;

b) permit and encourage more reliable demonstration of small level differences among derived versions of aircraft; and

c) minimize the cost of demonstrating compliance with the requirements of part 36 by keeping aircraft test time, airfield usage, and equipment and personnel costs to a minimum.

Technical procedures

A technical procedure is a test or analysis procedure not defined in detail in part 36 but which the FAA have approved as being acceptable for compliance with the general provisions of part 36.

The procedures described in part 36 must be used unless an equivalent procedure or alternative technical procedure is approved by the FAA. Procedures should not be considered as limited only to those described herein, as this AC will be expanded as new procedures are developed. Also, their presentation does not infer limitation of their application or commitment by the FAA to their further use.

Chapter 9 provides guidelines for recertification of airplanes to Stage 4 or Stage 5 based upon assessment of those with approved existing noise levels or those specially “modified” to achieve compliance with Stage 4 or Stage 5.

Conversion of units

Conversions of some non-critical numerical values between U.S. Customary (English) and SI units are shown in the context of acceptable approximations.

2. CANCELLATION

Advisory Circular 36-4C, Noise Standards: Aircraft Type and Airworthiness Certification, dated July 15, 2003, is cancelled.

3. REFERENCES

General references

References that identify FAA Orders, Advisory Circulars, and Reports that provide direction and/or guidance on acceptable processes and procedures for aircraft noise certification are listed in Appendix 1. GENERAL REFERENCES of this AC. These references also include current ICAO noise standards and are noted as Reference G1, Reference G2, etc. in the text. As these documents are referenced in this AC, information is also provided as to the extent that their provisions apply to a given type of aircraft noise certification process. Applicants are encouraged to contact FAA AEE to determine if more recent editions are available and applicable to noise certification actions that are being considered for FAA approval.

Technical references

References that identify technical documents other than part 36 are listed in Appendix 2. TECHNICAL REFERENCES of this AC. These documents include international instrumentation standards incorporated by reference in part 36 and are noted as Reference T1, Reference T2, etc. in the text.

Bibliography

A suggested bibliography relating to certain texts of this AC is provided in Appendix 3. BIBLIOGRAPHY.

FAA/DOT addresses

Appendix 4. DOT/FAA ADDRESSES lists current addresses of U.S. Department of Transportation and FAA organizations (and noise certification specialists) that might provide assistance to an applicant.

4. DEFINITIONS

This section contains two categories of definitions that are used within the regulatory language, policies or other guidance information of this Advisory Circular. The first category defines general terms or organizational designations that depict FAA and applicant roles in the part 36 noise certification process. The second category defines specific aircraft types that must comply with part 36 regulations and other items related to those aircraft. References to part 1 are to the definitions of 14 CFR Part 1.

General definitions:

Administrator: The Federal Aviation Administrator or any person to whom he has delegated his authority in the matter concerned. (Ref: part 1)

Aircraft certification office (ACO): The (FAA) office that administers the type certificate and production approval of products in the area where the manufacturer is located.

Applicant: Section 21.13 of part 21, states: "Any interested person may apply for a type certificate". The person that applies to the FAA for an aircraft type certificate, whether a new (original), amended, supplemental or provisional type certificate, is identified as the "applicant" and is the entity that must comply with the procedural, certification and production requirements of part 21.

Noise certification specialist (NCS): The Directorate (Transport, Small Airplane, or Helicopter) Noise Certification Specialist.

Person: An individual, firm, partnership, corporation, company, association, joint-stock association, or government entity. It includes a trustee, receiver, assignee, or similar representative of any of them. (Ref: part 1).

Type inspection authorization (TIA): The TIA is the official FAA document that provides direction and communication between the local ACO engineering group and the FAA flight test crew. The TIA usually mandates the provisions of an applicant's approved demonstration compliance plan and any additional restrictions, inspections, tests, limitations, procedures, etc., that are required by the ACO to be observed during the conduct of the flight or ground testing.

Definitions related to aircraft:

Acrobatic category airplane: The acrobatic category is limited to airplanes that have a seating configuration, excluding pilot seats, of nine or less, a maximum certificated takeoff weight of 12,500 pounds or less, and intended for use without restrictions, other than those shown to be necessary as a result of required flight tests. Acrobatic category airplanes are required to show compliance with part 23.

Aircraft: A device that is used or intended to be used for flight in the air. (Ref: part 1)

Aircraft engine: An engine that is used, or intended to be used, for propelling aircraft. It includes turbosuperchargers, appurtenances, and accessories necessary for its functioning, but does not include propellers. (Ref: part 1)

Airplane: An engine-driven fixed-wing aircraft heavier than air that is supported in flight by the dynamic reaction of the air against its wings. (Ref: part 1)

Airport: An area of land or water that is used or intended to be used for the landing and takeoff of aircraft, and includes its buildings and facilities, if any. (Ref: part 1)

Civil aircraft: Aircraft other than a public aircraft. (Ref: part 1)

Commuter category airplanes: The commuter category is limited to propeller-driven, multiengine airplanes that have a seating configuration, excluding pilot seats, of 19 or less, and a maximum certificated takeoff weight of 19,000 pounds or less, intended for non-acrobatic operations. Commuter category airplanes are required to show compliance with part 23.

Helicopter: A rotorcraft that, for its horizontal motion, depends principally on its engine-driven rotors. (Ref: part 1)

Large aircraft: Large aircraft means aircraft of more than 12,500 pounds, maximum certificated takeoff weight. (Ref: part 1)

Normal category airplane: The normal category is limited to airplanes that have a seating configuration, excluding pilot seats, of nine or less, a maximum certificated takeoff weight of 12,500 pounds or less, and intended for nonacrobatic operation. Normal category airplanes are required to show compliance with part 23.

Normal category rotorcraft: A normal category rotorcraft is a rotorcraft with a maximum weight of 7000 pounds or less and that meets the regulatory requirements of part 27.

Primary category aircraft: A primary category aircraft is an aircraft that (1) is unpowered, or is an airplane powered by a single, naturally aspirated engine with a 61-knot or less stall speed, or is a rotorcraft with a 6-pound per square foot main rotor disc loading limitations, and (2) weighs not more than 2700 pounds, and (3) has a maximum seating capacity of not more than four persons, including the pilot, and (4) has an unpressurized cabin. A primary category aircraft is required to meet the regulatory requirements of §21.24 of part 21.

Propeller: A device for propelling an aircraft that has blades on an engine-driven shaft and that, when rotated, produces by its action on the air, a thrust approximately perpendicular to its plane of rotation. It includes control components normally supplied by its manufacturer, but does not include main and auxiliary rotors or rotating airfoils of engines. (Ref: part 1).

Public aircraft: Aircraft used only in the service of a government, or a political subdivision. It does not include any government-owned aircraft engaged in carrying persons or property for commercial purposes. (Ref: part 1)

Restricted aircraft: Used for special purpose operations as defined in §21.25 of part 21.

Rotorcraft: A heavier-than-air aircraft that depends principally for its support in flight on the lift generated by one or more rotors (Ref: part 1).

Small aircraft: Small aircraft means aircraft of 12,500 pounds or less, maximum certificated takeoff weight. (Ref: part 1)

Subsonic airplane: A subsonic airplane means an airplane for which the maximum operating limit speed, $M_{MO,}$ does not exceed a Mach number of 1.

Supersonic airplane: A supersonic airplane means an airplane for which the maximum operating limit speed, $M_{MO,}$ exceeds a Mach number of 1.

Transport category aircraft: Those aircraft (large or small) that are demonstrated to meet and are certificated to the regulatory requirements of part 25 for transport category airplanes or part 29 for transport category rotorcraft.

Jet Airplane: Any fixed wing airplane that is powered by a turbojet or turbofan engine regardless of whether it is an airplane certificated to part 23 (small or commuter aircraft) or part 25 (transport category aircraft).

Turbo-propeller airplane: An airplane whose primary source of thrust is from a propeller driven by a gas turbine engine.

Utility category airplane: The utility category is limited to airplanes that have a seating configuration, excluding pilot seats, of nine or less, a maximum certificated takeoff weight of 12,500 pounds or less, and intended for limited acrobatic operation. Utility category airplanes are required to show compliance with part 23.

5. ABBREVIATIONS AND ACRONYMS

The following abbreviations and acronyms are used within the text of this AC

AC = FAA advisory circular
ACO = Local FAA aircraft certification office
AEE = FAA Office of Environment and Energy
AFM = Airplane Flight Manual
AMC = Acceptable means of compliance
APU = Auxiliary power unit
C/A = Coarse/Acquisition
CAEP = Committee on Aviation Environmental Protection
CDI = Course deviation indicator
CG = Center of gravity
CFR = Code of Federal Regulations
CPA = Closest point of approach
DAT = Digital audiotape
dB = Decibel
DER = Designated Engineering Representative
DGPS = Differential global positioning system
DMU = Distance measuring unit
EPNL = Effective perceived noise level
ETM = Environmental Technical Manual ("ICAO Environmental Technical Manual. Volume 1, Procedures for the Noise Certification of Aircraft")
FAA = Federal Aviation Administration
GDI = Glide-slope deviation indicator
GM = Guidance material
GPS = Global positioning system
Hz = Oscillatory frequency, cycles per second
IAS = Indicated airspeed
ICD = Inflow control device
INS = Inertial navigation system
ICAO = International Civil Aviation Organization
ILS = Instrument landing system
IOD = Issue of data

IRIG = Inter-Range Instrumentation Group
IRIG B = Inter-Range Instrumentation Group Standard Serial Time Code Format B
ISA = International standard atmosphere
LAAS = Local area augmentation system
L_{Amax} = Maximum A-weighted sound level
log = Logarithmic value to base 10
LUP = Land-use planning
MAP = Manifold air pressure
MLW = Maximum landing weight
MSL = Mean sea level altitude, feet
MTOW = Maximum takeoff weight
NAC = No acoustical change
NCS = Noise Certification Specialist
NIST = National Institute of Standards and Technology
NMEA = National Marine Electronics Association
NPD = Noise-power-distance
OAT = Outside air temperature
RFM = Rotorcraft Flight Manual
RH = Relative humidity, %
rms = Root-mean-square
rpm = revolutions per minute
SAE = Society of Automotive Engineers
SBV = Surge bleed valve (engine internal operating valves)
SR = Slant range
STC = Supplemental Type Certificate
TIA = Type Inspection Authorization
TC = Type Certificate
TSPI = Time-space-position information
UTC = Coordinated universal time
VLA = Very Light Aircraft
VNTSC = Volpe National Transportation System Center (DOT)
V_{REF} = Reference Landing Speed

6-7. RESERVED.

Curtis Holsclaw
Acting Director of Environment and Energy

Table of Contents

Chapter 1

CERTIFICATION PROCEDURES FOR PRODUCT AND PARTS 14 CFR PART 21

CHAPTER TABLE OF CONTENTS

101 EXPLANATORY INFORMATION

101(a) Part 21 General

As part of the overall aircraft certification requirements identified in part 21, applicants must comply with the noise certification requirements of part 36. Section 21.17 of part 21 specifies that an applicant for a type certificate must show that the aircraft meets the applicable requirements of part 36. In addition, §§21.21 and 21.25 of part 21 specify that an applicant is entitled to a type certificate for an aircraft if the applicant submits the type design, test reports, and computations necessary to show that the product to be certificated meets the applicable airworthiness and aircraft noise requirements. Similar requirements are imposed for aircraft manufactured in a foreign country for import into the United States (§21.29 of part 21). Refer to the part 21 regulations for specific regulatory language.

101(b) Airworthiness Certification

All aircraft requiring noise certification by the FAA are required to meet the applicable airworthiness requirements of part 21, which identifies the specific airworthiness standards for each aircraft type and product, such as:

a) part 23 for normal, utility, acrobatic, and commuter category airplanes;

b) part 25 for transport category airplanes;

c) part 27 for normal category rotorcraft;

d) part 29 for transport category rotorcraft;

e) part 33 for aircraft engines;

f) part 35 for propellers;

g) primary category aircraft; and

h) JAR-VLA aircraft.

101(c) Changes in Type Design

(1) *General*

Section 21.93(b) of part 21 requires compliance with the appropriate part 36 "acoustical change" requirements for a voluntary type design change of an aircraft that may increase the noise levels of that aircraft, regardless of whether the change in type design is classified as a minor or major change in §21.93(a) of part 21.

(2) *Voluntary changes*

A general description of FAA handling of various forms of voluntary changes in the type design of an aircraft is addressed in 201(a)(3) of this AC. Procedures for demonstration of compliance with part 21 for specific types of "no acoustical change" (NAC) are presented in 101(d) & (e).

101(d) No acoustical changes (NAC)

(1) *NAC definition*

Aircraft/engine model design changes and airframe/engine performance changes may result in very small changes in aircraft noise certification levels that are not acoustically significant. These changes are referred to as no acoustical changes (NACs). For this AC NACs, which do not result in modification of an aircraft's noise certification levels, are defined as:

a) changes in airplane noise certification levels approved by the FAA which do not exceed 0.10 dB at any noise measurement point and which an applicant does not track;

b) cumulative changes in airplane noise certification levels approved by the FAA whose sum is greater than 0.10 dB but not more than 0.30 dB at any noise measurement point and for which an applicant has an approved tracking procedure;

c) for helicopters certificated according to the standards of Appendix H, changes in any one of the noise certification levels approved by the FAA which do not exceed 0.30 EPNdB; and

d) for helicopters certificated according to the standards of Appendix J, changes in the noise certification level approved by the FAA which does not exceed 0.30 dB(A).

(2) *Tracking procedures*

With respect to the tracking procedure referred to in 101(d)(1)(b), noise certification approval has been given based upon the following criteria:

a) ownership by the certification applicant of the noise certification database and tracking process on an aircraft/engine model basis;

b) when the 0.30 dB cumulative change in the airplane noise certification level is exceeded, compliance with the part 36 requirements is required; the aircraft noise certification levels may not be based upon summation of NAC noise increments;

c) decreases in noise levels should not be included in the tracking process unless the type design change will be retrofitted to all aircraft in service and included on newly produced aircraft;

d) aircraft/engine design changes resulting in noise level increases should be included in the tracking process regardless of the extent of retrofit to aircraft in service;

e) tracking of an aircraft/engine model should, in addition to engine design changes, include airframe and performance changes;

f) tracked noise increments should be determined on the basis of the most noise-sensitive condition and be applied to all configurations of the aircraft/engine model;

g) the tracking should be revised to account for a tracked design change increment that is no longer applicable;

h) changes should be tracked to two decimal places (i.e., 0.01 dB). Round-off should not be considered when judging an NAC (e.g., 0.29 dB = NAC; 0.30 dB = NAC; 0.31 dB = acoustical change); and

i) an applicant should maintain formal documentation of all NACs approved under a tracking process for an airframe/engine model; the tracking list will be reproduced in each noise certification demonstration document.

Due to the applicability dates, some light propeller-driven airplanes are not required to have noise certification levels. However some modifications to these aircraft can be applied which may impact the noise characteristics. In this case, the NAC criteria application should be treated with a procedure approved by the FAA.

(3) *Criteria for helicopter certification*

Noise certification approval of modified helicopters should be granted according to the following criteria:

a) an NAC approval for a derived version can be made only if the parent "flight datum" helicopter was flight tested to obtain the noise certification levels;

b) noise levels for a helicopter designated as an NAC design cannot be used as the "flight datum" for any subsequent design changes; and

c) for changes exceeding 0.30 dB, compliance with part 36 requirements may be achieved either by testing or, subject to approval of the FAA, by analytical means; if analytical means are employed, the noise certification levels cannot be used as the "flight datum" for any subsequent design changes.

Note.— Definition for parent "flight datum" aircraft is shown in Table 1.

A flow chart illustrating the criteria for dealing with modified helicopters is presented in Figure 1.

Due to the applicability dates, some helicopters are not required to have noise certification levels. However some modifications to these helicopters can be applied which may impact the noise characteristics. In this case, the NAC criteria application should be treated with a procedure approved by the FAA.

(4) *Helicopters modifications defined as NACs*

Changes in helicopter noise level(s) arising from modifications associated with the installation or removal of external equipment are defined as NACs and thus need not be determined. For the purposes of this section "external equipment" means any instrument, mechanism, part, appurtenance, or necessary accessory that is attached to, or extends from, the helicopter exterior but is not used, nor is intended to be used, in operating or controlling the helicopter in flight and is not part of an airframe or engine.

The following examples are considered to be no acoustical changes:

a) the addition or removal of external equipment;

b) changes to the airframe made to accommodate the addition or removal of external equipment, to provide for an external load attaching means, to facilitate the use of external equipment or external loads, or to facilitate the safe operation of the helicopter with external equipment mounted to, or external loads carried by, the helicopter;

c) reconfiguration of the helicopter by the addition or removal of floats and skis;

d) flight with one or more doors and/or windows removed or in an open position; or

e) any changes in the operational limitations placed on the helicopter as a consequence of the addition or removal of external equipment, floats, skis, or flight operations with doors and/or windows removed or in an open position.

(5) *Helicopters with variable noise reduction systems (VNRS)*

Aircraft can incorporate variable systems, primarily intended to reduce the takeoff/approach noise. Such aircraft can be noise certificated using the guidance provided for aircraft with VNRS. For such changes to existing type designs, the guidelines provided for NAC are applicable.

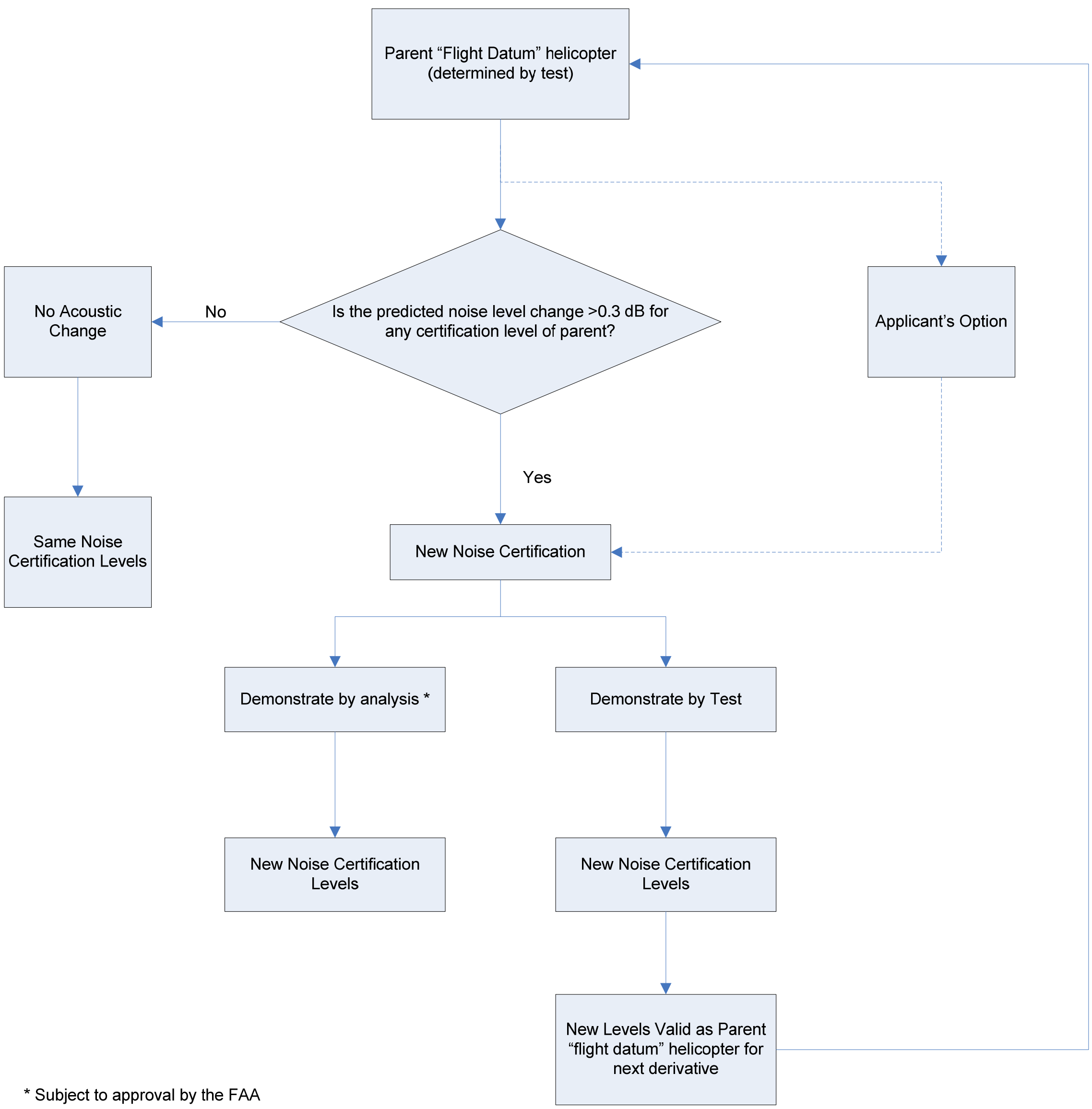

Figure 1. "No-acoustical change" criteria for modifications to noise certificated helicopters

101(e) Methods for Demonstrating No Acoustical Change (NAC) for Propeller-Driven Small Airplanes and Commuter Category Airplanes

(1) *Procedures*

The methods, as referred to in this section, are aircraft measurement, flight test, analytical or evaluation methods that differ from the methods specified in the text of Appendix G of part 36. The particular method(s) employed must be approved by the FAA. These methods differ from equivalent procedures in that they are used for a finding of NAC under §21.93(b) of part 21 and are not pertinent to part 36.

(2) *Acoustical changes*

The regulatory need to evaluate all voluntary changes for acoustical change is found in §21.93(b) of part 21. An acoustical change in the type design of an airplane is defined in §21.93(b) as "…any voluntary change in the type design of an aircraft that may increase the noise levels of that aircraft is an acoustical change…"; note that a change in design that decreases the noise level is not an acoustical change in terms of the rule. There are four categories of small propeller-driven airplanes excluded from this evaluation of voluntary changes: 1) Airplanes designated for "agricultural aircraft operations" as defined in §137.3 of part 137; 2); Designated for dispensing firefighting materials; 3) U.S. registered and had flight time prior to January 1, 1955; and 4) Land configured airplanes reconfigured with floats or skis (non-permanent seasonal changes to the landing gear). The exclusions noted in §21.93(b) differ from an earlier definition that applied to propeller-driven small airplanes certificated under Appendix F of part 36. In the earlier definition, acoustical changes were restricted to (1) any change or removal of a muffler or other component of an exhaust system designed for noise control, or (2) any change to an engine or propeller installation which would increase maximum continuous power or propeller tip speed.

The current definition of acoustical change in §21.93(b) for propeller-driven small airplanes and commuter category airplanes is more in line with that for all other aircraft categories. For example, an increase in takeoff weight without any change in engine/propeller installation would not be considered an acoustical change under the earlier definition. Now it would be, since the reference height for noise level measurement would be lower with the increased weight, which would result in a higher noise level.

Section 36.9 defines the noise compliance requirements for propeller-driven small airplanes and commuter category airplanes for which an acoustical change approval is applied for under §21.93(b). Section 36.9 recognizes two airplane categories: those that have previously been shown to comply with part 36, and those that have not. For the first group, any acoustical change must not increase noise levels beyond the limits stated in Part D of Appendix G. For the second group, noise levels may not exceed either these same limits, or "the noise level created prior to the change in type design, measured and corrected as prescribed in §36.501 of this part," whichever is greater. This may require that two noise certification tests need be run. The first is to establish the unmodified noise level standard and the second is to measure the modified noise level. Section 36.501(c) also requires that "compliance must be shown with noise levels as measured and prescribed in Parts B and C of Appendix G, or under approved equivalent procedures."

The FAA considers any change in type design that will increase the noise level by more than 0.10 dB(A) an acoustical change. However, no acoustical change results as long as any change that can be expected to increase the noise level is offset by other changes in design or performance that will decrease the noise level in such a way that the sum of the changes does not increase the expected noise level by more than 0.10 dB(A).

The purpose of this section is to examine methods for calculating changes in noise level introduced by common type design changes and methods for showing compensating noise level effects that will result in a demonstration of NAC.

(3) *Factors that change noise level*

Noise levels under Appendix G test procedures are affected by both the basic noise producing properties of the propeller/engine installation and by the takeoff and climb performance of the airplane. Regardless of what mechanical change is made to the airplane, noise levels can be expected to increase if any of the following conditions results from a type design change (without compensating changes):

a) decrease in the height of the airplane at the reference distance of 8200 ft (2500 m) from brake release;

b) increase in engine horsepower;

c) removal or alteration of exhaust mufflers;

d) increase in propeller helical tip Mach number;

e) increase in propeller tip thickness;

f) decrease in airplane climb path angle;

g) increase in airplane drag;

h) increase in propeller inflow angle; or

i) change in the number of propeller blades.

Increases expected in the Appendix G noise levels caused by any of the above changes must be offset by a compensating change to achieve NAC, and an appropriate analysis of the effects of such a change must be provided. Removal of exhaust mufflers or other changes in the exhaust system may require some form of testing to determine the acoustical effect. Similarly, increasing propeller tip thickness, such as by cutting the tips off an existing propeller to decrease its diameter, may cause an increase in noise level (which might be offset by the decrease in the propeller rotational Mach number at the same rpm). In both the case of the altered exhaust system and that for the cut-down propeller, a comparison test, during which noise levels are measured for the modified and the unmodified airplanes utilizing part 36 Appendix G flyovers at the same height and airspeed, may be approved as a satisfactory method to determine whether an acoustical change has occurred.

Comparison tests are not generally cost saving methods since they may become as complex as a full part 36 Appendix G test.

(3.1) *Parent aircraft definition*

Before making any analysis or conducting any test it is necessary to determine what defines the Parent (unmodified) airplane. The Parent airplane represents the noise characteristics existing prior to the change in type design. Table 1 will help identify the Parent aircraft for use in no-acoustical change evaluations.

Table 1. Definition for parent "flight datum" aircraft

Modification	Parent Aircraft
STC/Field Approval/Type Design Change (All changes contained in the same approval).	Aircraft defined on the dataplate (Original T.C. configuration)
Multiple STC's/Field Approvals/Type Design Changes (None of which provided noise levels)	Aircraft defined on the dataplate (Original T.C. configuration)
Multiple STC's/Field Approvals/Type Design Changes (Where at least one* provides new noise levels and including any previously approved changes that provided noise levels). * The approval that provides new noise values (STC, Service Bulletin, Field Approval, etc.) must be listed in the approval documentation as required to be previously or concurrently installed.	Aircraft defined on the dataplate (Original T.C. configuration) plus the modification that included noise value(s). [Should more than one of the included changes contain noise value(s), the approval that provides the lowest value(s), in all applicable reference profiles, will be used. For approvals with more than one reference profile (e.g., Appendix B & H), when one modification does not provide lower, or equal, noise levels in all three profiles, then only one of the previously approved changes may be used as the acoustic parent definition. All other alterations are treated as acoustical changes.]
Conversion from one aircraft model into another with no change to the aircraft dataplate.	Aircraft defined on the dataplate (Original T.C. configuration)
Conversion from one aircraft model into another with a new or additional dataplate being added.	Aircraft defined on the later installed dataplate.

(3.2) *Definitions*

Following are definitions used in this section:

c = Speed of sound at reference height

C_D	=	Airplane coefficient of drag
C_L	=	Airplane coefficient of lift
D	=	Diameter of propeller
D_{50}	=	Distance from brake release to and aircraft height of 50 feet at sea level conditions.
H	=	Reference height over the prescribed measurement location
HP	=	Horsepower
F	=	Force (thrust)
M	=	Mach number
RC	=	Rate of climb at V_y
rpm	=	Revolutions per minute
T	=	Standard temperature at reference altitude
V	=	Airspeed
V_y	=	Best rate of climb airspeed.
W	=	Maximum gross takeoff weight
α	=	Propeller inflow angle
δ	=	Pressure ratio at reference height.
γ	=	Climb angle
θ	=	Temperature ratio at reference height
σ	=	Density ratio at reference height.
Subscripts		
P	=	Parent
M	=	Modified
R	=	Rotational
A	=	Airplane
TAS	=	True Airspeed
h	=	Helical tip

(4) *Examples of type design changes that may affect noise levels*

Typical applications for type design changes that require an evaluation of the effect of the change on noise levels include:

a) increase in maximum takeoff weight without any change in engine or propeller installation;

b) change from a fixed pitch propeller to a variable pitch propeller;

c) change in propeller diameter;

d) change in number of blades;

e) increase in engine horsepower; and

f) modification that increases drag without any change in engine or propeller installations. Examples include installation of external cargo containers, larger tires on fixed gear, or advertising light arrays.

In many cases, changes in noise level introduced by these modifications can be determined analytically by using existing data for the unmodified airplane, or by supplementing the existing data with additional performance information when that performance is approved by the FAA. If that performance is “equal to” or “better” the applicant CANNOT take credit for “better” performance (e.g., shorter takeoff distance, increased rate of climb, etc.) when evaluating a modification for acoustical change unless the new performance is subsequently published in an approved Airplane Flight Manual Supplement (AFMS) or Supplemental Airplane Flight Manual (SAFM) for the modification. Most requests for supplemental type certificates (STC) are made by applicants that do not have access to manufacturer's data used to determine noise levels, even if these data exist. Since part 36 Appendix G applies to noise certification tests completed after December 1988, much of the existing fleet of small propeller airplanes do not have noise level data evaluated according to part 36 Appendix G. In order to obtain an STC, an applicant must demonstrate an NAC or conduct an entire Appendix G test. Several examples are given here of ways to substantiate a no acoustical change using the adjustment factors described previously.

There are, however, some design changes which an applicant may propose that Appendix G compliance is not required, based on similarity to previously approved type certificates (TC) or STCs. Examples of this are older airplanes in a series where the series has several different engine sizes certified in the same basic airframe. Converting an airplane from one engine power to higher engine power by an applicant for an STC will require the applicant to do a noise analysis, possibly including noise measurements, even though the same engine/airframe combination exists in a production series. The reason for this is that the manufacturer is very unlikely to have demonstrated part 36 Appendix G compliance with any of his production airplanes. Even if the manufacturer has demonstrated compliance and the certificated noise level is published in an FAA Advisory Circular, the data used to demonstrate compliance, including the 90 percent confidence level for the certificated noise level, is proprietary to the manufacturer.

Before the adoption of Appendix G, certain changes to an airplane were accepted as an NAC by the FAA without any analysis. Two examples are the replacement of a two-blade propeller with a three-blade propeller, and an increase of less than 2 percent takeoff weight. For the reasons described below, these two types of changes are no longer accepted as an NAC unless the it is substantiated by analysis and/or test data.

In the case of propeller replacements with increased number of blades, the change in noise generating mechanisms cannot be simply accounted for by tip Mach number and engine power corrections. Also, the increase in the number of propeller blades shifts the blade passage to higher frequency, which has a smaller A-weighing filter adjustment. In STC applications with propeller changes, the FAA may require a comprehensive NAC analysis to account for the modified noise generation mechanisms, and the A-weighing filter effects or flyover tests have to be conducted.

Increasing the maximum certificated takeoff weight over the base airplane (or aerodynamic changes which increase drag of the aircraft such that its takeoff performance deteriorates) would cause it to fly at a lower height over the noise measurement location, which results in a higher noise level. An increase in takeoff weight without any change in engine/propeller performance would be an acoustical change unless the noise increase is offset by performance gains or reduction in airplane noise generation, any of which must be substantiated by analysis and/or test data. It is possible to show an NAC condition analytically as given in Example 1 of this chapter, without actual flight or ground testing.

(4.1) *Increase in weight*

For a change in airplane takeoff weight without any change in engine/propeller installation, the following factors influence the noise level under part 36 Appendix G procedures.

a) As a reasonable first approximation, the takeoff distance to a height of 50 ft (15 m) is increased by a factor equal to the square of the ratio of the weight after the change to the weight before the change. However, the final determination must be done using the FAA approved takeoff distance from the Approved Airplane Flight Manual (AFM), AFMS, or SAFM.

b) The best-rate-of climb speed will increase essentially as the square root of the ratio of the weight before and after the change. However, the climb speed (and related performance) in the AFM may not be at the best rate of climb speed (V_y) for aircraft type certificated after February 9, 1996. As of this date the climb speed may be dependent on cooling or other airworthiness minimum requirements and not the best rate of climb for the airplane.

c) The climb angle at the increased weight will be lower.

The noise level produced at the higher weight will be greater than at the lower weight because these items combine to generate a lower reference height. The increase in airspeed can also cause a modest change in the reference helical tip Mach number, which may increase noise level.

The incremental change in noise level, if nothing else is done, can be shown by an example. Note that the subscript “P” (Parent) is used to denote the "before" conditions and the subscript “M” (Modified) is used to denote the "after" condition.

The following examples are provided to give applicants guidance for NAC analysis. The performance calculations used in the examples are for demonstration purposes only; they are not FAA approved performance calculation procedures. Any change in performance data (takeoff or climb) that is to be utilized in the determination of NAC must be published in the aircraft flight manual.

Example 1: Calculate the change in noise level expected if the weight of an airplane increases from 3000 lb to 3200 lb, without any other changes, given the following (note that all of the data given is readily available or is calculable from virtually all aircraft operations handbooks):

Step 1 Calculate the parent aircraft reference conditions:

From the AFM/AFMS/SAFM/POH:

D_{50}= 2220 ft

V_y = 90 kt

RC= 970 ft/min

D = 84 in.

rpm= 2600

Calculate:

γ_P = $\sin^{-1}(RC/V_y)$ = $\sin^{-1}[970/(60 \times$ /times $1.688 \times 90)] = 6.11°$ equation (1)

H_P = $\tan(\gamma)\,(8200 - D50) + 50$ = $\tan(6.11°)\,(8200 - 2220) + 50$ = 690 ft equation (2)

D_P = 84 in = propeller diameter

rpm = 2600 rpm

T_P = 59(°F) – lapse rate × H_P = 59(°F) – 0.003566 × 690 = 56.5°F equation (3)

c_P = $49.025 \times (T + 459.67)^{1/2}$ = 1113.8 ft/s equation (4)

δ_P = $(1 - 0.0000068753 \times H_P)^{5.2561}$ = 0.97532 equation (5)

θ_P = (T+459.67) / (59(°F) + 459.67) = 0.99518 equation (6)

σ_P = δ_P/θ_P = 0.98004 equation (7)

V_{TAS} = $V_y / \sigma_P^{1/2}$ = 90.9 knots (True airspeed of parent aircraft) equation (8)

M_{PA} = $V_{TAS}/c_P = 1.688 \times 90.9 / 1113.8 = 0.1378$ (Mach speed of parent aircraft) equation (9)

M_{PR} = $D_P \times rpm \times \pi / (60 \times 12 \times c_P) = 0.8556$ (Parent rotational Mach number) equation (10)

M_{Ph} = $(M_{PA}^2 + M_{PR}^2)^{1/2} = 0.8666$

Equation (11)

Step 2: Calculate the modified aircraft reference height for a weight of 3200 lb.

a) The takeoff distance before the change, D_{50P}, is 2220 ft. After the weight increase the takeoff distance is given by:

$$D_{50M} = 2220\ (3200 / 3000)^2 = 2526 \text{ ft} \qquad \text{equation (12)}$$

b) The new best rate-of-climb speed at sea level, standard day, V_{YM}, is given by:

$$V_{YM} = 90\ (3200 / 3000)^{1/2} = 93.0 \text{ kt} \qquad \text{equation (13)}$$

Note.— This is only a first approximation. Final determination of V_Y must be done using FAA approved methods. Unless approved and published in the AFMS/SAFM the applicant must use the V_Y value published in the original AFM/POH.

c) Calculating the climb angle at the increased weight can be done by several methods, depending upon the data available from the aircraft operations handbook or flight manual. Where handbook or flight manual data are not available, data such as climb rate or sink rate may be obtained by performing a limited amount of climb tests. Any such performance tests must be conducted with FAA approval.

Method 1:

A general equation for calculating climb performance can be obtained if best rate-of-climb data are available in the aircraft operations handbook for different airplane weights. These data can be used to calculate an effective thrust during takeoff, and the effective ratio of drag to lift. For stable climb conditions at moderate climb angles where the cosine of the climb angle may be assumed to be essentially equal to unity, the sine of the climb angle γ, which is also the ratio of rate-of-climb to climb speed, is determined from:

$$\sin(\gamma) = RC / (101.3 \times V_y) = F / W - C_D / C_L \qquad \text{equation (14)}$$

Note.— The published climb speed in the AFM/AFMS may not be the actual aircraft V_y. The applicant is responsible for determining what V_Y is. See previous note concerning the appropriate speed.

where F is the thrust developed by the propeller, and C_D/C_L is the ratio of drag to lift coefficients. Thrust is the product of propeller efficiency and engine power, divided by airspeed, with appropriate unit conversions. If it is assumed that the ratio of propeller efficiency to airspeed is approximately constant for airspeeds used for best-rate-of climb, then it can be assumed that thrust remains approximately constant for a given horsepower rating for takeoff. By obtaining RC and V_y for two different weights, two simultaneous equations are obtained using equation 14. These may then be solved for F and the ratio of C_D/C_L, since only the ratio is required.

In addition to the data for a weight of 3000 lb, the flight manual gives a rate-of-climb of 1140 ft/min at 2700 lb. The best rate-of-climb speed for a weight of 2700 lb will be the speed for 3000 lb times the square root of the ratio of the two weights, or 85.4 kt. Writing two equations with these values, and by subtracting one from the other, the effective thrust, F, is found to be 686 lb, and the drag/lift coefficient ratio is 0.1222.

Substituting the values for thrust, drag/lift ratio, and airspeed for the desired weight of 3200 lb yields climb angle of 5.29°. For a climb airspeed of 93.0 kt, the rate-of-climb is obtained as 868 ft/min.

Method 2:

Rate of climb, RC, in ft/min, is:

$$RC = (33000\ \eta\ P) / W - R_S \qquad \text{equation (15)}$$

where P is engine horsepower, η is propeller efficiency, W is airplane weight in pounds, and Rs is airplane power off sink rate in ft/min.

Some aircraft operations handbooks give a power off glide ratio and speed, from which a sink rate can be calculated. The sink rate calculated using these values is *not* the same as is obtained when operating at best rate-of-climb speed and propeller rpm. The best power off glide condition for an airplane with a variable pitch propeller is obtained with the propeller at low rpm (i.e., a blade pitch angle that provides minimum drag, and usually at an airspeed that is higher than that for best rate-of-climb). Note that in equation (14), if thrust is zero in glide, then the sine of the glide angle is just equal to the ratio of the drag to lift coefficients. For best glide distance this ratio will be lower than the ratio obtained during takeoff climb. For example, for the airplane in Example 1, the aircraft operations handbook states that the airplane will glide 1.7 nautical miles while losing 1000 ft in height, at an airspeed, $V\gamma$, of 105 knots. The glide angle, γ_g, is calculated by observing that its tangent is given by the ratio of the height lost to the distance traveled. Thus:

$$\gamma_g = -\tan^{-1}[1000 / (1.7 \times 6076.1)] = -5.53° \qquad \text{equation (16)}$$

In this mode of operation C_D/C_L is equal to the sine of 5.53°, or 0.0964. In the calculation above, it was found that C_D/C_L was 0.1222 for takeoff with the propeller operated at maximum rpm.

The rate of sink in takeoff configuration can be obtained by conducting glide tests at the speed for best rate-of-climb with the propeller at high rpm. The time required to lose a fixed altitude, 1000 ft or more, while holding constant airspeed, will give a sink rate that can be used in equation (15). At 90 kt and high rpm, the sink rate for the example airplane is approximately 1125 ft/m.

Propulsive efficiency, that is the product of propeller efficiency and installed power, can be calculated from equation (15) by using this sink rate, in conjunction with the flight manual value for climb rates at a given weight. Once these factors have been obtained, the climb rate at a different weight can be calculated, and this, coupled with the new climb speed, will allow the climb angle to be computed as in Example 1.

In Example 1 the best rate-of-climb was 970 ft/min at sea level at a weight of 3000 lb. Substituting these values into equation (15), along with the sink rate of 1125 ft/min, gives a product of propeller efficiency and horsepower, for this airplane, of 190. With no change in horsepower or propeller efficiency, substituting these values in equation (15) gives an equation for rate-of-climb at any weight, W:

$$RC = (6.285 \times 106 / W) - 1125 \text{ ft/m}$$

At a weight of 3200 lb, the rate-of-climb becomes 839 ft/m. At an airspeed of 93 kt, the climb angle γ is given by:

$$\gamma = \sin^{-1} [839 / (101.3 \times 93)] = 5.11°$$

Method 3:

An empirical expression for calculating the rate-of-climb, RC(2), at one weight, W(2), when the rate-of-climb, RC(1), at a different weight, W(1), is known is given by:

$$RC(2) = RC(1)\ [W(1) / W(2)]^{1.5} \qquad \text{equation (17)}$$

Substituting 3000 lb for W(1), 3200 lb for W(2), and 970 ft/m for RC(1), RC(2) is calculated to be 880 ft/m. In turn, climb angle γ by this method is given by:

$$\gamma = \sin^{-1} [880 / (101.3 \times 93)] = 5.36°$$

Reference height for the 3200 lb takeoff weight can now be calculated with each of the three rate-of-climb values by using the equation:

$$H_M = 50 + (8200 – D_{50M}) \times \tan (\gamma_M)$$

From the rate-of-climb of Method 1:

$$H_M = 50 + (8200 – 2526) \tan (5.29°) = 575 \text{ ft}$$

From the rate-of-climb of Method 2:

$$H_M = 50 + (8200 – 2526) \tan (5.11°) = 557 \text{ ft}$$

From the rate-of-climb of Method 3:

$$H_M = 50 + (8200 – 2526) \tan (5.36°) = 582 \text{ ft}$$

The modest discrepancies among the three calculated values are related to the erroneous assumption that the ratio of propeller efficiency to airspeed is essentially constant. To be conservative, the lower value for HM may be used in the analysis, or alternatively, the average of the three methods, 571 ft.

Step 2. Calculate reference Mach number.

Speed of sound at height h = 571 ft, from equations (3) and (4) is:

$$c_M = 1114.4 \text{ ft/s at 571 ft above sea level}$$

b) Air density ratio at 571 ft is given by equations (5-7):

$$\sigma_M = 0.97954 / 0.99614 = 0.98334$$

c) Best rate-of-climb speed of 93.0 kt at sea level becomes true airspeed at 571 ft of:

$$V_{TAS} = 93 / 0.98334^{1/2} = 93.8 \text{ kt}$$

d) Airplane Mach number at 93.8 kt is:

$$M_M = (1.688 \times 93.8) / 1114.4 = 0.1421$$

e) Propeller rotational Mach number is given by equation (10):

$$M_{RM} = 0.8551$$

f) Helical tip Mach number is given by the square root of the sum of the squares of the airplane and propeller rotational Mach numbers.

$$M_{hM} = [(0.1421)^2 + (0.8551)^2]^{1/2} = 0.8668$$

Step 3. Reference horsepower remains essentially constant.

Step 4. Calculate the increment in noise level under part 36 Appendix G operating conditions when the airplane is operated at a weight of 3200 lb instead of at 3000 lb, without further changes.

a) Increase in noise level due to decrease in height from 690 ft to 571 ft:

$$\Delta H = 22 \log (690 / 571) = 1.81 \text{ dB}$$

b) Increase in noise level due to increase in helical Mach number:

From Example 1, Mh = 0.8666.

$$\Delta M = 150 \log (0.8668 / 0.8666) = 0.02 \text{ dB}$$

Note.— Use of "150" for a "k" factor in the tip mach correction is restricted for use only when the Modified mach number is higher than the Parent mach number. Only an approved "k" determined experimentally for the particular propeller airplane combination may be used when the Modified configuration is lower than the Parent.

c) Change in noise level due to change of inflow angle:

In Example 1 the climb angle (γ_P) was 6.11° with an assumed pitch angle (α_P) of 4.25°. Using the average climb angle (γ_M) obtained from the three methods described above, 5.25° with an assumed pitch angle (α_M) of 3.00°. Tests conducted by FAA under controlled conditions in a wind tunnel show that for typical small propeller airplane, sound levels increase as climb angle increases due to the change in air-inflow angle to the propeller. On average an increase of 0.5 dB per degree increase of inflow angle was observed in the tests then, the change due to climb angle is given by

$$\Delta\alpha = 0.5\ (\alpha_M - \alpha_P) = 0.5\ (3.00° - 4.25°) = -0.63 \text{ dB} \qquad \text{equation (18)}$$

d) Total change in noise level:

The total change in noise level, ΔL, is the algebraic sum of the three adjustments.

$$\Delta L = 1.81 + 0.02 - 0.63 = 1.21 \text{ dB}$$

Clearly, a substantial acoustical change is created if the weight for this airplane is increased to 3200 lb without any other change to the engine/ propeller installation or other operating conditions. Once it has been determined that an acoustical change has occurred the applicant must develop new noise levels for the modified airplane. This may mean a full part 36 Appendix G noise test must be conducted. If the original data used to determine the aircraft noise levels is available to the applicant then additional adjustments might be made (if within limits) to create new noise levels. The noise levels published in the AFM (if available) CANNOT be adjusted using these calculations.

(4.2) *Change from fixed to variable pitch propeller*

If no other change is made to the airplane, such as increasing horsepower, the primary effect of changing from a fixed to variable pitch propeller of the same diameter is a change in Mach number. Typically, fixed pitch propellers are designed to operate optimally under cruise conditions where the propeller is designed to reach its maximum continuous rated rpm. During climb at the speed for best rate-of-climb the propeller cannot develop anywhere near its maximum rpm. Typically, takeoff rpm is approximately 85 percent of maximum rpm. For example a 150 hp engine having a maximum propeller rpm of 2700 will develop about 2300 rpm at takeoff. A 235 hp engine with a maximum rated rpm of 2575 typically develops about 2200 rpm in takeoff climb.

One of the primary reasons for changing from a fixed to variable pitch propeller is to shorten takeoff distance and to improve takeoff climb rate. An examination of aircraft operations handbooks for airplanes certified with both fixed and variable pitch propellers, at the same horsepower and takeoff weight, indicates the following nominal characteristics:

a) takeoff distances to a height of 50 ft with variable pitch propellers are approximately 88-90 percent of the distance required with a fixed pitch propeller; and

b) at the same takeoff weight and airspeed, the rate-of-climb with a variable pitch propeller is approximately 9-10 percent greater than with a fixed pitch propeller.

The incremental difference in noise level between an airplane equipped with a variable pitch propeller and a fixed pitch propeller can be estimated by using the same adjustment equations used before for height, Mach number, engine power, and climb angle.

Example 2: The aircraft operations handbook for a representative fixed gear airplane with a takeoff weight of 2900 lb has the following performance data with fixed and variable pitch propellers:

	Fixed	Variable
Takeoff distance, ft	1510	1350
Rate-of-climb, ft/min	825	900
Climb speed, V_y, kt	87	87
Propeller diameter, in.	80	80
Propeller rpm in climb	2200	2575

Using the equations provided in Section 4.1 above, the following calculated quantities are obtained:

Reference height, ft	679	753
Climb angle, degrees	5.37	5.86
Inflow angle (est.), degrees	5.25	6.15
Speed of sound, ft/s	1113.9	1113.6
True airspeed, kt	87.9	88.0
Airplane Mach number	0.1332	0.1334
Rotational Mach number	0.6894	0.8072
Helical Mach number	0.7021	0.8181

The difference in engine horsepower developed with the two propellers in climb can be calculated by using equation (15) to write two equations for the rate-of-climb in terms of horsepower and sink rate, since the sink rate is the same and thus the only difference in rate-of-climb in the two situations is the actual propulsive power. For the fixed pitch case:

$$825 = (33000\eta P_f) / 2900 - R_s$$

For the variable pitch case:

$$900 = (33000\eta P_v) / 2900 - R_s$$

Subtracting the first equation from the second results in a difference of about 7 horsepower. The nominal maximum continuous power for the engine is 235.

All the information necessary to calculate the difference in noise levels between the two propeller installations is now available. The difference in the noise levels for the two cases is the algebraic sum of the following adjustments:

a) Decrease in noise level due to increase in reference height:

$$\Delta H = 22 \log (679/753) = -0.99 \text{ dB}$$

b) Increase in noise level due to increase in helical Mach number:

$$\Delta M = 150 \log (0.8181 / 0.7021) = 9.96 \text{ dB}$$

c) Increase in noise level due to increase in engine power:

The rated maximum continuous power for the engine is 235 horsepower. The incremental change in noise level is approximately:

$$\Delta HP = 17 \log [(235+7)/(235)] = 0.22 \text{ dB}$$

d) Increase in noise level due to increase in inflow angle:

$$\Delta\alpha = 0.5 \times (4.15° - 3.25°) = 0.45 \text{ dB}$$

e) Total change in noise level:

$$\Delta L = -0.99 + 9.96 + 0.22 + 0.45 = 9.64 \text{ dB}$$

Clearly, an acoustical change exists between the fixed and variable pitch propeller installations unless some other changes are made to the airplane.

(4.3) *Change in propeller diameter*

Calculating the effect on Appendix G noise level of changing propeller diameter without any other change in power or performance is a straightforward application of the following equation:

$$\Delta M = k \log (M_M/M_P)$$

where k equals a constant dependent on the propeller design and Mach number range. A nominal value of 150 is permitted in G36.201 of part 36 if M_P is smaller than M_M (Parent and Modified respectively).

Although a change in propeller diameter will usually also change performance, if it can be shown that no degradation in takeoff distance or climb performance is created, the airplane performance before the change can be stipulated as the performance after the change. It is clear that an increase in diameter, considered alone, will increase the noise level. It is sometimes desirable to increase propeller diameter to improve climb performance, sometimes at the sacrifice of some cruise capability. The increased noise level caused by the greater diameter can be offset by a reduction in rpm, if the resulting airplane performance is satisfactory. Where this method is used to show "no acoustical change," it will be necessary to perform FAA approved takeoff and climb tests to verify performance. The following two examples illustrate the effect that changes in propeller diameter have on the noise level.

Example 3: The airplane in Examples 1 and 2 is normally equipped with a two-blade propeller having an 84 inch diameter. The same propulsive efficiency is claimed when using the same engine, same propeller rpm, if the propeller is replaced with a propeller of 86 inches diameter. For the same reference height and airplane speed, the difference in noise level between the two installations may be calculated as follows. In Examples 1 and 2, the airplane Mach number was 0.1378 and the propeller rotational Mach number was 0.8556 for an 84 inch diameter propeller. For the same altitude and rpm, the rotational Mach number is directly proportional to the propeller diameter, so the rotational Mach number for the 86 inch diameter propeller is 86/84 times 0.8556, or 0.8760. The corresponding Parent and Modified helical Mach numbers before the change and after the change become 0.8666 and 0.8868. The noise level difference is:

$$\Delta M = 150 \log (0.8868 / 0.8666) = 1.50 \text{ dB}$$

If the new propeller has three blades, which would cause a shift in the blade passage frequency, the above analysis would not be adequate to determine the entire effect of the change. The analysis would have to be extended to account for the noise delta caused by the ground reflections and A-weighing filter effects, or flyover tests would have to be conducted.

Example 4: An applicant wishes to replace an existing variable pitch propeller with a diameter of 76 inches for a different pitched propeller with a diameter of 80 inches. The new propeller is designed to provide a somewhat shorter takeoff distance and better rate-of-climb for the airplane. The applicant does not want to go to the trouble of determining the improvement in takeoff distance or climb rate, and is willing to use the existing handbook data to determine reference height.

The applicant has demonstrated to the FAA that, in flight during reference climb conditions, his existing propeller develops 2600 rpm. He believes that, even with a modest limitation on climb rpm to negate the increase in noise level that a larger diameter propeller would normally generate, the larger propeller will still be advantageous. The rpm limitation that would have to be imposed for "no acoustical change" to result, assuming the reference height of 700 ft and true airspeed of 74 kt do not change and the propeller tip shape and thickness are identical, is determined as follows.

Since the airplane climb speed remains the same, the helical Mach number will be the same if the rotational Mach numbers for the two propellers are held constant. The actual reference height and airspeeds are not relevant to this determination. It is not even necessary to calculate the actual Mach numbers, since the rotational Mach numbers will be the same if the products of propeller diameter and rpm remain constant for the two cases. For the original 76 inch propeller, the product is 76 times 2600 or 197,600. The rpm limitation with an 80 inch propeller is therefore 197,600 divided by 80, or 2470 rpm. If this rpm gives satisfactory takeoff and climb performance, limiting climb rpm to 2470 will result in no acoustical change when the larger propeller is installed. Other airworthiness considerations (e.g., engine cooling, stalling, etc.) may need further consideration.

(4.4) Change in engine power

Increasing the size of an engine without changing the takeoff weight of an airplane will change the Appendix G noise level. If no change in performance were involved, the level would increase by 17 times the logarithm of the ratio of the increased horsepower to the original horsepower. However, clearly a change in performance does take place. Takeoff distance is shortened, and climb rate is increased. Often, but not always, a propeller change is also made. If the increase in performance offsets the effect on noise level of the change in engine horsepower, no acoustical change occurs. The following example illustrates the required analysis.

Example 5: The airplane in Example 1 is originally equipped with an engine rated at 225 horsepower at 2600 rpm. The desired installation is for an engine rated at 250 horsepower at 2650 rpm. The same 84 inch two-blade propeller is used in each case. The acoustical effect of this change is evaluated as follows.

Step 1. If propeller efficiency remains the same, takeoff distance varies inversely with engine power and directly as the square of takeoff weight. The takeoff distance to 50 ft height after the increase in horsepower, D_{50M}, without any weight increase, is the original takeoff distance, D_{50P}, times the ratio of the original horsepower to the increased horsepower:

$$D_{50M} = D_{50P} \times (HP_P/HP_M) \text{ ft}$$

In this example:

$$D_{50M} = 2220\ (225) / (250) = 1998 \text{ ft}$$

Note.— This is an approximation and the final determination for no acoustical change must use FAA approved data from the AFM or the AFMS for the modified airplane. If the applicant chooses not to take credit for (and thus determine per FAA flight test guidelines) the improved takeoff distance, they cannot take credit for the decrease in distance in the acoustical change determination.

Step 2. From equation (15), rate-of-climb for a given airplane configuration is directly proportional to the ratio of engine power to airplane weight, minus the power off sink rate. The constant of proportionality is the unit conversion factor of 33,000 times the propeller efficiency. In Example 1, the product of propeller horsepower developed in climb is less than the rated horsepower due to installation effects and air density less than at sea level. It can be assumed that the same ratio of losses will apply to a slightly higher <u>rated</u> horsepower engine. Assuming these losses cancel each other out, the <u>apparent</u> propeller efficiency for Example 1 can be stated as the propulsive efficiency, 190, divided by the rated horsepower, 225, for an apparent efficiency of 0.844. Equation (15) can then be used to determine the rate-of-climb at the increased horsepower:

$$RC_M = (33000)\ (0.844)\ (250) / 3000 - 1125 = 1197 \text{ ft/m}$$

Step 3. Climb angle is given by:

$$\gamma = \sin^{-1} [RC / (1.688 \times 60 \times V_y)]$$

$$\gamma_M = \sin^{-1}[1197/(101.3)(90)] = 7.55°$$

Step 4. The reference height after the change, H_M, is:

$$H_M = 50 + (8200–1998) \tan (7.55) = 872 \text{ ft}$$

Step 5. Determine reference helical Mach number:

a) At 872 ft the speed of sound is:

$$c_P = 1113.2 \text{ ft/s}$$

True airspeed is calibrated airspeed divided by the square root of the density ratio:

$$\sigma_P = 0.97472$$

b) Best rate-of-climb speed of 90 kt at sea level becomes a true airspeed at 872 ft of:

$$V_{TAS} = 90 / 0.97472^{1/2} = 91.2 \text{ kt}$$

c) Airplane Mach number at 91.2 kt is:

$$M = (1.688 \times 91.2) / 1113.2 = 0.1383$$

d) Propeller rotational Mach number is:

$$M_R = 0.8725$$

e) Helical tip Mach number is:

$$M_h = [(0.1383)^2 + (0.8725)^2]^{1/2} = 0.8834$$

Step 6. Reference horsepower is now 250.

Step 7. Calculate the increment in noise level under part 36 Appendix G operating conditions:

a) Change in noise level due to increase in height:

From Example 1, H_P = 690 ft, and from above H_M = 872 ft.

$$\Delta H = 22 \log (690 / 872) = -2.24 \text{ dB}$$

b) Increase in noise level due to increase in helical Mach number:

From Example 2, M_h = 0.8666:

$$\Delta M = 150 \log (0.8834 / 0.8666) = 1.25 \text{ dB}$$

c) Increase in noise level due to increase in horsepower:

$$\Delta HP = 17 \log (250 / 225) = 0.78 \text{ dB}$$

d) Change in noise level due to change in inflow angle:

In Example 1 the inflow angle was 6.11 degrees with an assumed inflow angle of 4.25°. From equation (18):

$$\Delta\alpha = 0.5 \times (4.25° - 3.11°) = 0.57 \text{ dB}$$

e) Total change in noise level:

The total change in noise level, ΔL, is the algebraic sum of the four adjustments.

$$\Delta L = -2.24 + 1.25 + 0.78 + 0.57 = 0.36 \text{ dB}$$

The change in noise level due to an increase in horsepower, in this example, is not offset by the effect of improved takeoff performance, resulting in an "acoustical change" of 0.36 decibel. In order to become an NAC situation, some change in rating should take place. A small reduction in allowable takeoff rpm might be reasonable. Several iterations of the above calculations might be necessary to determine the optimum conditions. Any changes in performance where credit is being claimed must be FAA approved, determined using FAA approved methods, and published in the FAA approved AFM or AFMS (e.g., improved climb rates, shorter takeoff distances, change in V_y, etc.). Additional airworthiness criteria may need to be reestablished.

(4.5) *Increase in drag with no other changes*

Any modification to an airplane that increases its drag during takeoff and initial climb will increase the Appendix G noise level unless other changes are also introduced. If takeoff distance is increased, or rate-of-climb decreased, or both, the reference height will decrease. The change in level can be calculated from the adjustment equations provided previously if the change in performance can be determined. If an applicant wants to show compliance with the noise regulation via the NAC method, they will probably have to conduct takeoff distance and climb tests. If it looks as though the proposed modification will increase drag sufficiently to make a measurable performance change, then an offsetting change will be required. The amounts of increase or decrease in noise level involved can be calculated by the methods use in the previous examples.

(4.6) *Acoustical effects of combined changes*

Many proposed airplane modifications involve several changes. Examples are replacing an engine and fixed pitch propeller with a higher power engine and a variable pitch propeller, or increasing engine power and takeoff weight at the same time. The acoustical consequences of these combined effects can be calculated by combining the methods used in the examples. The sequence for calculating these effects is as follows:

a) Determine the effect changes in takeoff distance and rate-of-climb will have on reference height.

b) Determine the effect of helical Mach number caused by any changes in airplane speed, propeller rotational speed, or change in speed of sound because of change in reference height.

Note.— The default value of 150 for "k" in the correction equations is only valid when used to determine an increase in helical mach number. It CANNOT be used to reduce the noise level. The 150 factor is a generalized conservative value for simplified calculations where the true "k" value is not determined. Thus it is inherently inaccurate.

c) Determine the effect of any changes in engine power.

d) Determine any change in noise level due to change in airplane climb angle.

e) Obtain the algebraic sum of the four incremental changes in sound level.

f) If the sum is greater than zero, there are two choices:

— Conduct Appendix G tests as described in the regulation; or

— Evaluate different operating conditions to obtain an incremental noise level that is not greater than that of the original airplane. This may be accomplished by derating the engine, reducing fuel/payload, and/or limiting maximum takeoff rpm. One or a combination of these modifications may be iterated until a negative noise increment is obtained by the methods used in the examples. The cost of not performing an Appendix G noise test should be balanced against the loss of airplane performance or takeoff weight limitations during the lifetime of operation.

101(f) Acquisition of In-duct and/or Near-field Data for Demonstration of NAC

(1) *General*

The FAA has found it acceptable for applicants to conduct engine or component only noise tests to evaluate minor engine changes. Frequently the objective for these tests is to provide evidence that the changes involved produce negligible impact on EPNL noise values and may therefore be categorized as NACs relative to the certificated aircraft configuration. Such testing includes component tests, static engine tests in a test cell, near-field microphone measurements, and in-duct dynamic pressure measurements.

(2) *Guiding principles*

The overall guiding principles to be followed in providing acceptable evidence for substantiation of engine NACs are:

a) the measurements and analyses should adequately model the noise such that small changes in aircraft noise levels can be quantified; and

b) the noise measurement technique and the test environment should not introduce changes to the noise sources that invalidate the predicted small changes in aircraft noise levels.

These guiding principles should be applied in all cases, with details of the approach being justified on a case-by-case basis as appropriate.

Note 1.— It is important that the near-field or in-duct measurements enable a sufficiently accurate prediction of the changes to engine noise in the far field.

Note 2.— It is important that the noise-generating mechanisms of interest are not significantly affected by the test cell environment. The test cell should have an exhaust collector to minimize re-circulation. There should be insignificant inlet distortion or inflow turbulence, or a turbulence control screen or ICD should be employed to minimize such distortions or turbulence. Test cell measurements might not be appropriate for assessing jet noise changes because of the influence of the test cell on the jet development.

Note 3.— Care must be taken to ensure the noise source under investigation is not masked by other unrepresentative noise components. While a reduced acoustic standard of components not under investigation might be acceptable in many cases, there are examples where such differences might invalidate the premise of an NAC (e.g., noise from the intake being masked by a hard-walled bypass duct, or significant noise from an overboard air dump contaminating the measured noise).

(3) *Measurement systems*

Typical measurement systems used to acquire data for substantiation of an engine NAC include:

a) near-field microphones, either in test cells or outdoor facilities;

b) in-duct transducer measurements in the fan inlet or exhaust duct; and

c) core probes to assess combustor or low pressure turbine design changes.

4) Measurement and data analysis procedures

The measurement and data analysis process should be accomplished on the basis of the following criteria:

a) an adequate array of transducers should be used to ensure that the measurements adequately model the noise (To determine overall changes in sound pressure level, the measured noise levels will typically need to be averaged azimuthally, radially and/or axially in order to avoid false conclusions being drawn from anomalous readings from single transducers.);

b) environmental conditions in the test setup should be monitored to demonstrate that the local environment (e.g., test cell temperature) do not cause significant anomalies in the measured noise differences;

c) microphones should be mounted on the test cell wall or on the ground or floor but not in the shadow of any support structures or other test hardware;

d) in-duct transducers should be flush-mounted with minimal loss of area of acoustic treatment. Rake-mounted transducers in the flow path should be avoided if they shed wakes that impinge on downstream structures and thereby create significant noise;

e) core probes should be fixed securely to the pylon, boat-tail fairing or other support and not be excessively buffeted by the flow;

f) the specifications of the measurement system and calibration procedures for microphones, recording and reproducing systems should be in accordance with A36.3 of part 36 (Laboratory calibrations of in-duct transducers and core probes should be conducted before and, if possible, after each test. The dynamic range of the transducers should be sufficient to avoid overload.);

g) data should be acquired over the relevant engine operating speeds and for all relevant combinations of engine variables, as specified in the latest version of Reference T13;

h) the interpretation of in-duct measurements should take into account the possibility that decaying or cut-off acoustic waves may be present that may mask changes sensed in the far field of the propagating wave; and

i) two alternative methods could be used in the subsequent analysis of the measured noise levels to demonstrate an NAC:

   1) the measured component noise changes could be incorporated into a noise model that predicts the aircraft EPNL. This method has the added value of taking into account in-flight effects and the relative significance of the different noise sources; or

   2) in some circumstances, it might be possible to reach the conclusion of an NAC without the need to incorporate the measured component noise changes into a noise model that predicts aircraft EPNL. The measured noise changes could be examined to see if there is no increase in noise levels at any relevant frequency or engine condition.

Generally, noise models that predict the aircraft noise level expressed in EPNL are based on far-field static test data. Consequently, in either analysis it will be necessary to agree with the FAA on the method for calculating the impact on far-field static noise resulting from near-field microphone measurements or in-duct transducer measurements. This will normally require sound engineering judgment, seeking out patterns in the data and technical explanations for any observed differences.

Furthermore the statistical uncertainty in the data should be considered. For example if statistical analysis shows that the uncertainty in the data is large and the differences are small, then no conclusions can be drawn from the data. On the other hand if the tests show large decreases in noise levels that outweigh the uncertainty in the data it may be possible to conclude, with reasonable certainty, that the changed engine is indeed quieter than the original engine.

Chapter 2

NOISE STANDARDS: AIRCRAFT TYPE AND AIRWORTHINESS

CHAPTER TABLE OF CONTENTS

201 EXPLANATORY INFORMATION

201(a) Part 36 - Subpart A - General

201(a)(1) Applicability and definitions §36.1(a)

(1) *Applicable requirements*

Unless otherwise specified, the date to be used for determining the applicability of the appropriate part 36 standards for an aircraft type design is the date on which application for a type certificate was made. An application for type certification is effective for the time periods specified in §21.17(c) of part 21.

(2) *Noise related type certification requirements*

See paragraph 7-8 of Reference G4.

(3) *Supplemental type certificates*

See paragraph 7-8 of Reference G4.

(4) *Definitions of terms*

Section 4 of the preamble of this AC provides definitions of terms (see Table 2) related to the aircraft types and categories within Items (1) – (4) of §36.1(a).

Table 2. Aircraft terminology and categories

AIRCRAFT TERMINOLOGY	AIRCRAFT TERMINOLOGY
Aircraft	Large Aircraft
Airplane	Small Aircraft
Jet Airplane	
Turboprop Airplane (Note 3)	
Propeller	
AIRCRAFT CATEGORIES (Note 1)	**AIRCRAFT CATEGORIES (Note 1)**
Airplane	**Helicopter**
Acrobatic	Normal
Commuter	Transport
Normal	
Primary	
Restricted (Note 2)	
Transport	
Utility	

Note 1.— Airplane Categories and Aircraft Classes: Part 1 recognizes a distinction between Airplane Categories (e.g., acrobatic, commuter, normal, primary, restricted, transport and utility) and Aircraft Classes (e.g., Conventional Takeoff and Landing (CTOL), Vertical Takeoff and Landing (VTOL), Short Takeoff and Landing (STOL), Reduced Takeoff and Landing (RTOL), and Supersonic Transports (SST)). The noise certification requirements contained in part 36 are specified for several Airplane and Helicopter Categories but not for STOL, RTOL, SST (except for Concorde), or VTOL Aircraft Classes.

Note 2.— Restricted Category Propeller-Driven Large Airplanes: Propeller-driven large airplanes that have been type certificated in the restricted category (see §21.25 of part 21) are not required to demonstrate compliance with the requirements of part 36. In the absence of part 36 applicability, an Environmental Assessment is required (see paragraph 7-4 of Reference G4 for additional information).

Note 3.— Turboprop Airplanes: Turboprop-powered airplanes are included under the part 36 requirements applicable to propeller-driven airplanes (i.e., subsonic transport category large airplanes; propeller-driven small airplanes, including acrobatic, normal, restricted, and transport categories; or propeller-driven

201(a)(2) Aircraft configuration §36.1(b)

An applicant's proposal for an aircraft configuration to be certified under the requirements of part 36 must include any type design changes that may be a result of airworthiness standards testing and analysis, and which would result in acoustical changes. (See §36.1(c) for FAA criteria on when aircraft type design changes represent an acoustical change). If an applicant does not propose the appropriate aircraft configuration, additional noise certification testing and analysis may be required.

201(a)(3) Voluntary changes §36.1(c)

(1) *Examples of voluntary changes in type design*

A voluntary change in the configuration of an aircraft means a change in the type design of that aircraft. Examples of voluntary changes in aircraft type design that may affect part 36 certificated noise levels are as follows:

a) increased engine thrust (power) to improve aircraft performance;

b) maximum gross weight changes;

c) limitations on operational flap settings related to noise;

d) hardware revisions (e.g., vortex generators, flap configuration, wing tip stabilizers, wing tip fuel tanks, etc.);

e) engine modifications to improve engine performance, acceleration, deceleration, or surge margin protection;

f) addition of wing or body hardware to improve aerodynamics;

g) external nacelle changes to improve air flow patterns;

h) engine inlet changes to improve ice protection;

i) reduction of engine blade tip clearances to improve inlet flow characteristics, and;

j) modifications to engine/nacelle acoustic treatments.

(2) *Acoustical change criteria*

A voluntary change in the type design of an aircraft that may result in an increase in its certificated noise levels is defined as an "acoustical change." A type design change that does not result in an "acoustical change" as defined in section§21.93(b) of part 21 is referred to as a "no acoustical change" (NAC). The numerical criteria used by the FAA in defining an acoustical change for airplanes and helicopters are provided in 101(d) and (e) of this AC and are established to limit the cumulative effects of multiple small changes.

(3) NAC cumulative effects

When type design changes result in reduced noise levels, an applicant may elect not to provide the full part 36 substantiation, but instead provide FAA with data and/or information to substantiate an NAC. However subsequent type design changes may require full part 36 certification because of cumulative acoustical effects. Example: An applicant proposes a configuration change which will reduce the noise levels by approximately 2.1 dB for the flyover noise measurement point, 1.1 dB for the lateral noise measurement point, and with no change in noise level at the approach noise measurement point. FAA verifies that the noise levels were reduced, and the applicant accepts the pre-change configuration certificated noise levels as published in the AFM to apply to this change in type design. The applicant may not make another type design change as an NAC that increases the flyover noise level and the lateral noise level without providing substantiation of the cumulative effects of this type design change on AFM noise certificated levels. Multiple type design changes must be evaluated on a cumulative basis (as a combined single configuration) for each noise measurement point for the purposes of determining whether there is an acoustical change.

(4) NAC approvals

FAA may approve results of component laboratory demonstrations, back to-back noise comparisons from ground tests or flight tests of each configuration, acoustical analyses, etc as acceptable for substantiating that an applicant's proposed changes to an aircraft type design is an NAC. The results from these evaluations must be applicable to an aircraft's certificated noise levels at the part 36 reference noise measurement points.

(5) Non-standard jet airplane configurations

Sections 21.93(b)(2)(i) and (ii) specify exceptions under which certain changes in jet airplane type design are not subject to compliance with part 36 requirements because such configurations are not intended for normal operations, but are typically required for maintenance operations (e.g., ferry flights, transporting engines to aircraft that cannot be ferried, etc.).

(6) Time-limited changes

Time-Limited engine or nacelle changes on jet airplanes for periods of up to 90 days (as specified in §21.93(b)(2)(iii) of part 21) may be necessary for continued airplane operation until maintenance can be performed on the original engines or nacelles that were changed. These changes must comply with applicable airworthiness standards and the maintenance, preventative maintenance, rebuilding and alteration inspection requirements of part 43. Such changes do not require compliance with part 36 requirements even though they may result in an increase in airplane noise levels, relative to the certificated noise levels. FAA policy (see Federal Register Vol. 64, No. 225, Page 65655, dated November 23, 1999) permits the 90 day period allowed by §21.93(b)(2)(iii)of part 21 to continue to be used after December 31, 1999, but only for maintenance-related purposes. It cannot be used for meeting Stage 3 requirements due to lack of an adequate number of spare engines or nacelles, or insufficient number of engines or nacelles to operate a Stage 3 fleet at a given time. Section 21.93(b)(2)(iii) may only be used to intermix engines when maintenance is required and no conforming engine or nacelle for the configuration is available.

(7) Special purpose aircraft

Type design changes to propeller-driven small airplanes and helicopters do not need to comply with the provisions of part 36 when they are operated for special purposes as specified in §§21.93(b)(3)(i-iv) and §21.93(b)(4) of part 21.

(8) Applicant's responsibility

Pursuant to §21.93(b), an applicant must identify type design changes that affect an aircraft's certificated noise levels by aircraft serial number and must demonstrate part 36 compliance for those aircraft. The noise levels approved by the FAA for the modified aircraft must be documented in an FAA Approved AFM or RFM by either a revision to the AFM or RFM (typically an option only available to the aircraft manufacturer), an AFM or RFM Supplement (for Supplemental Type Certificates and Field Approvals), or a Supplemental AFM or RFM (for aircraft that do not have a FAA Approved AFM or RFM). Configurations and modifications for which noise approval is required must be found to comply with applicable airworthiness requirements specified in part 21 as well as the requirements of §36.3 of part 36.

201(a)(4) Airworthiness certificates
§36.1(d)

(1) Requirements for Issuance of Airworthiness Certificates

An airworthiness certificate is issued for each airplane produced, and is a means of distinguishing (by date of issuance) airplanes within a production run that comply with the noise certification requirements of part 36. Prior to the original issuance of a standard airworthiness certificate (see §21.183 of part 21) and regardless of the date of application for certification, compliance with the regulatory requirements of part 36 (including Appendix B) is required for a transport category large airplane, or for a jet airplane regardless of category (see paragraph 7-11(a) of Reference G4). The following table summarizes the requirements of §36.1(d) of part 36.

Table 3. Requirements of §36.1(d) of part 36

Maximum Airplane Weight	Airplane Type	Engine Configuration	Effective Date of Part 36	Compliance Date for Airplanes With Initial Flight Time on or After
75,000 pounds or less	Subsonic	All engines	December 1, 1969	December 31, 1974
Greater than 75,000	Subsonic	Without Pratt &Whitney JT3D engines	December 1, 1969	December 1, 1973
Greater than 75,000	Subsonic	With Pratt & Whitney JT3D engines	December 1, 1969	December 31, 1974
Concorde – all weights	Supersonic	All engines	October 13, 1977	January 1, 1980

(2) "Grandfathered" airplanes

Airplane types not identified above are "grandfathered" airplanes and are permitted to continue normal operations without showing compliance with the requirements of part 36. For example, the twin-engine propeller-driven Convair 580 or Douglas DC-3 airplanes that first logged flight time before December 31, 1974, did not have to comply with the noise provisions of part 36 and may have received a standard airworthiness certificate under the provisions of §21.183 of part 21, or may have received a standard airworthiness certificate under the provisions of the regulations in effect at the time of certification without compliance with part 36.

201(a)(5) Airworthiness certificates
§36.1(e)

(1) *Requirements for issuance of airworthiness certificates:*

An applicant must show compliance of individual airplanes with the requirements of part 36 prior to issuance of airworthiness certificates, as prescribed in §21.183 or 21.185 of part 21 (see paragraph 7-11 of Reference G4).

2) *Commuter category airplanes:*

Since airworthiness standards for commuter category airplanes became effective February 17, 1987, (under part 21, Amendment 21-59) there are no airplanes in this category with initial flight time before January 1, 1980. All commuter category airplanes are thus required to show compliance with the noise certification requirements of part 36.

201(a)(6) One-Stage limit
§36.1(g)

(1) In-flight configuration changes:

In-flight changes in an airplane configuration (including changes in maximum gross weight) that could result in multiple certificated noise levels for a given noise measurement point or stage classification are not permitted. They are changes in the airplane type design and therefore require a change in operating limitations. A change in maximum gross weight requires an applicant to remove an airplane from service, and comply with the approval procedures of part 43.5 and 43.7. The type design approval procedures under part 21 must be followed if the change does not have prior certification approval.

201(a)(7) Stage 1/ Stage 2 limits
§36.1(h)

(1) The Stage 1 noise limits apply to all helicopters for which application for a type certificate or a change in type design was made prior to March 6, 1986.

(2) The Stage 2 noise levels apply to all helicopters for which application for a type certificate or a change in type design is made on or after March 6, 1986, with the following exception. For helicopters for which application for issuance of an original type certificate in the normal, transport or restricted category is made on or after March 6, 1986, and which the FAA finds to be the first civil version of a helicopter which was designed and constructed for, and accepted for operational use by an Armed Force of the U.S. or the U.S. Coast Guard on or before March 6, 1986, it must be shown that the noise levels of the helicopter certificated under the provisions of Appendix H are no greater than Stage 2 levels plus 2 EPNdB at each measuring point. There is no corresponding provision under Appendix J. The tradeoff provision of H36.305(b) of part 36 may not be used to show compliance with Stage 2 levels plus 2 EPNdB, nor may they be used to increase any noise level beyond these limits. Subsequent civil versions (acoustical changes) must meet the Stage 2 requirements without the extra 2 EPNdB at each measuring point. The tradeoff provisions of H36.305(b) of part 36 may be used in showing stage 2 compliance for these subsequent versions.

(3) Helicopters excepted

Helicopters that are designated exclusively for agricultural aircraft operations, as defined in §137.3 of part 137, for dispensing firefighting materials, or for carrying external loads, as defined in §133.1(b) of part 133, are excluded from the noise certification requirements.

(4) Stage 1/Stage 2

A helicopter, with a maximum takeoff weight of 7000 lb (3175 kg) or less, that fails to comply with the Stage 2 noise limit prescribed in J36.305 of part 36 has the alternative to comply with the Stage 2 noise limit of H36.305 of part 36.

Note.— The Appendix J noise limit uses a sound exposure level (SEL) that was defined more stringent by approximately 2 dB than the corresponding average of the three Appendix H noise limits in EPNL. However, this is no guarantee that subsequent Appendix H noise certification testing will comply, especially for a military helicopter seeking civil certification.

201(a)(8) Date of application
§36.2

(1) Requirements

a) Section 36.2 specifies the applicable part 36 requirements to be those in effect on the date of application for the a) aircraft type certificate or b) change in type design. If the time interval between application for the type certificate (or change in type design) and the issuance of the type certificate (or amended or supplemental type certificate) exceeds 5 years, the applicable part 36 requirements are those in effect, on a date to be selected by the applicant, not earlier than 5 years before the date of issuance of the type certificate, amended type certificate, or supplemental type certificate.

b) Section 36.2(c) permits the applicant to elect to demonstrate compliance with a later part 36 standard than is required by §36.2(a) or (b). For the purposes of §36.2, "standard" refers to any of the requirements contained in part 36. As specified in §§36.2(c)(1) and (2), an applicant's election of a later standard is subject to FAA approval, and the election must include standards adopted between the date of application and the effective date of the standard that the applicant has elected to comply with. Thus, an applicant's election to demonstrate compliance with a particular later standard would also require that compliance be demonstrated with all other part 36 standards (applicable to the aircraft type) adopted between the date of application and the effective date of the standard that the applicant has elected to comply with. Further, in accordance with §36.2(c)(3), the FAA may require compliance with other standards that were adopted after the date of the elected standard. For the purposes of §36.2(c)(3), "other standards" refers to other part 36 standards. For example, if the compliance standard elected under §36.2(c)(3) had later been revised, the FAA may determine that it is appropriate for compliance to be demonstrated with the revised standard. Such a determination would also require that compliance be demonstrated with all other part 36 standards (applicable to the aircraft type) adopted between the date of application and the effective date of the standard that the FAA has determined to be the appropriate compliance basis.

201(a)(9) Airworthiness compatibility
§36.3

(1) Requirements

Aircraft certification tests and analyses must be conducted using configurations, procedures and information that are consistent with the airworthiness regulations applicable to that aircraft. For example, noise tests or analyses may not be conducted with landing flap settings that could not meet the applicable airworthiness regulation requirements.

201(a)(10) Limitations of part
§36.5

(1) Scope of part 36 regulation

Part 36 requires compliance with U.S. Government noise standards for aircraft type and airworthiness certification but does not include noise standards related to aircraft operations, such as is provided in part 91. Part 36 certificated noise levels are achieved using procedures that can be duplicated practicably in normal operations by flight crews with safe reserves of thrust (power) and speed. Public Law 103-272 (Reference G2), mandates that the Administrator of the FAA prescribe standards to measure and evaluate aircraft noise. Under this law, an original type certificate may be issued for an aircraft for which substantial noise abatement can be achieved only after the FAA Administrator prescribes standards and regulations that apply to that aircraft. Consideration must be given to relevant information on aircraft noise, consultations with appropriate US and State authorities, whether the standards or regulations are consistent with the highest degree of safety and are economically reasonable, technologically practical, and appropriate for the type of aircraft to which they apply.

(2) Compatability with ICAO Annex 16 Standards

Part 36 does not contain the Annex allowance to depart from the required reference procedures specified in Annex chapters. For example, §3.6.1.4 of Chapter 3 of Annex 16 permits the certificating authority to approve reference procedures that are different from those contained in §§ 3.6.2 and 3.6.3 of Annex 16, when design characteristics of an airplane would prevent flight from being conducted in accordance with §§ 3.6.2 and 3.6.3 of Annex 16. The FAA recognizes that there may be a need for changes to the specified reference procedures when part 36 may not be appropriate for a particular airplane when design characteristics of an airplane would prevent flight from being conducted in accordance with the reference procedures described in part 36. In cases where part 36 is not appropriate, the rulemaking process, which includes a public comment period, would be followed to develop an appropriate noise certification standard. Thus, the main difference between the U.S. and ICAO requirements is that under part 36, the reference procedures would be changed through the rulemaking process rather than solely at the discretion of the certificating authority.

201(a)(11) Configuration consistency
§36.7(c)

(1) Quietest airworthiness approved configuration

This requirement was established to show that an acoustical change resulting from an approved type design change must be determined consistently. The FAA policy does not require an applicant to determine the quietest airworthiness approved configuration at the flyover or lateral noise measurement points by noise measurement and evaluation. However, FAA requires consistent evaluations between derivative and originally certificated configurations. For example, an applicant might choose an approved takeoff flap setting of 5 degrees. Later a type design change may be requested that would increase the flyover and lateral noise levels (an acoustical change). The FAA may not require the applicant to measure and evaluate all airworthiness approved takeoff flap settings (e.g., 0, 1, 2, 5, 10 degrees) to determine the quietest configuration, but may, in this example, require appropriate evaluations for a flap setting of 5 degrees.

201(a)(12) Dual stage certification
§36.7(e)

(1) “Dual-Stage” certificated airplanes

Some older airplane models have been certificated to Stage 2 for one configuration and to Stage 3 for another configuration (e.g., airplane takeoff flap setting or maximum allowable gross weights). These airplanes are classified as “Dual-Stage” certificated airplanes. No new dual certifications will be considered.

201(a)(13) Exempt helicopter modifications
§36.11

Modifications excluded from compliance with part 36, as listed in part 21, §21.93(b)(4)(ii) “Classification of Changes in Type Design” include:

a) addition or removal of external equipment (This means any instrument, mechanism, part, apparatus, appurtenance, or accessory that is attached to or extends from the helicopter exterior but is not used nor is intended to be used in operating or controlling a helicopter in flight and is not part of an airframe or engine.);

b) changes in the airframe made to accommodate the addition or removal to facilitate the use of external equipment, to provide for an external load attaching means, to facilitate the safe operation of the helicopter with external equipment mounted to, or external loads carried by, the helicopter;

c) reconfiguration of the helicopter by the addition or removal of floats and skis;

d) flight with one or more doors and/or windows removed or in an open position; or

e) any changes in the operational limitations on the helicopter as a consequence of the addition or removal of external equipment, floats, and skis, or flight operations with doors and/or windows removed or in an open position.

201(a)(14) Helicopter compliance with part 36
§36.11(a)

(1) Equivalent procedures

Subject to prior approval by the FAA, equivalent procedures may be used to measure, evaluate and calculate noise levels (see 1(c) of the preamble of this AC). Some commonly used equivalent procedures relating to helicopter noise certification are included in Chapters 4 and 6 of this AC.

(2) Noise level tradeoffs

Tradeoffs between the adjusted noise levels for flyover, takeoff and approach defined in H36.305(b) of part 36 may be used to show compliance with the maximum noise levels (noise limits) of Appendix H of part 36. Since Appendix J of part 36 only includes a flyover procedure, no tradeoff is possible.

(3) Compliance

The procedure used to show compliance under Appendix H or Appendix J of part 36 must follow the applicable parts of the regulation. Compliance with the maximum noise levels (noise limits) prescribed in H36.305 or J36.305 of part 36 must be shown.

201(a)(15) Noise limits
§36.11(b)

(1) Stage 1 helicopters

The maximum noise levels (noise limits) associated with a Stage 1 helicopter certificated under Appendix H of part 36 after a change in type design are dependent on the noise levels of the original Stage 1 helicopter. Unless the Stage 1 helicopter after the change meets the Stage 2 maximum noise levels (noise limits), or Stage 2+ 2 EPNdB levels at each measurement point, it will be necessary to show that the helicopter has no increase in the noise levels at any of the measurement points. This will require determination of the noise levels associated with the original Stage 1 helicopter using Appendix H procedures. If this is not possible an applicant must obtain FAA approval for another procedure.

201(a)(16) Stage 2 helicopters
§36.11(c)

(1) Helicopter under 7000 lb (3175 kg)

If after a change in type design a helicopter previously certificated under Appendix J of part 36, fails to meet the Appendix J Stage 2 maximum noise levels (noise limits) prescribed in J36.305 of part 36 an applicant may attempt to show compliance by electing the use of Appendix H procedures and the Appendix H Stage 2 maximum noise levels (noise limits) specified in H36.305 of part 36.

(2) Noise levels

Section 36.11 requirements apply to helicopters certificated under both Appendix H and Appendix J of part 36.

201(b) Subpart B- Transport Category Large Airplanes and Jet Airplanes

201(b)(1) Noise measurement and evaluation
§36.101

(1) Appendix A

Appendix A prescribes methodologies for conducting airplane noise certification tests and for measurement and evaluation of noise data for comparison with maximum noise levels specified in Appendix B (see Note 1). Specific requirements include:

a) specifications of various physical and environmental conditions under which airplane noise certification measurements are permitted; these conditions are related to the noise test site, wind velocity/direction and atmospheric sound attenuation;

b) procedures for measurement of atmospheric parameters;

c) methods for synchronization of airplane position and performance measurements with noise measurements;

d) specifications for noise certification measurement and analysis systems (see Note 2);

e) methods to calculate atmospheric sound attenuation coefficients and effective perceived noise level (in units of EPNdB);

f) methods for adjustment of measured flight test data to reference conditions;

g) nomenclature for symbols and units; and

h) specification of data to be reported to FAA.

Note 1.— Part 36 Appendix A requirements are nearly identical to those of Appendix 2 of Annex 16 Volume 1, Amendment 7. Subsequent changes to Annex 16 Volume 1 after Amendment 7 have not created any significant differences between the requirements of part 36 Appendix A and Annex 16 Volume 1 Appendix 2 at the time of publication of this AC.

Note 2.— Some provisions of Appendix A may also apply to the noise certification of helicopters as prescribed in Appendix H of part 36.

(2) *Equivalent procedures*

Equivalent Procedures are described in 1(c) of the introductory purpose section of this AC. Section 402 of this AC identifies several potential applications of equivalent procedures for jet and heavy prop airplanes. The ICAO ETM (Reference G5) also provides general and technical guidance on equivalent procedures that have been accepted as a technical means for demonstrating compliance with the noise certification requirements of ICAO Annex 16, Volume 1. Equivalent procedures provided in the ICAO ETM are incorporated into this AC to the extent applicable to the U.S. regulations.. FAA has not approved these procedures for any current or future aircraft noise certification actions. (See Supplemental Information Items in Subpart O, §1501, regarding the FAA's approval process for equivalent procedures).

(3) *Applicant's responsibility*

Applicants must prepare noise compliance demonstration plans for FAA approval that include proposed methods for compliance with the requirements of B36.1 of part 36. Equivalent procedure proposals in these plans must include substantiation of their technical validity and feasibility of application to the airplane type for which noise certification is requested. (See Subpart O §1501, Supplemental Information, of part 36 for noise compliance demonstration plan documentation requirements.)

201(b)(2) Noise measurement constraints
§36.103(a)

(1) Noise measurement points

The locations of test noise measurement points frequently do not coincide with the reference noise measurement point locations specified in B36.3 of part 36. For example, locations of flyover noise measurement points may be subject to test site anomalies that would make it impractical to set up microphones at the reference locations. An applicant that has an approved equivalent procedure to measure airplane noise data for generation of NPD plots using the Flight Path Intercept procedure may select test noise measurement points (particularly the flyover point) so as to optimize the noise recording system signal-to-noise ratios.

(2) Equivalent procedures

The FAA does not consider equivalencies that modifies reference flight conditions (see 201(a)(10) paragraph 2 of this AC) without following public process.

(3) General approved flight test procedures, principles, methods and flight crew operational practices are included in AC 25-7A, Flight Test Guide (Reference G3).

201(b)(3) Flight manual statement of Chapter 4 or Chapter 5 equivalency §36.105, §36.106

The FAA is not authorized to approve aircraft compliance with Annex 16, Volume 1 Noise Standards. (Reference G7). This is the responsibility of the foreign airworthiness authority involved. FAA participation is limited to witnessing tests and reviewing data. For the cases where Stage 3 compliance has been demonstrated it is permissible, but not a requirement, to insert the statement in 201(d) section 36.1581(a)(8) of this AC. In those cases where Stage 4 compliance has been demonstrated, the following statement must be included in the AFM or operations manual:

> "Certification Noise Levels
>
> The following noise levels comply with part 36, Appendix B, Stage 4 maximum noise level requirements and were obtained by analysis of approved data from noise tests conducted under the provisions of part 36, Amendment 36-XX (insert part 36 amendment to which the airplane was certificated). The noise measurement and evaluation procedures used to obtain these noise levels are considered by the FAA to be equivalent to the Chapter 4 noise level required by the International Civil Aviation Organization (ICAO) in Annex 16, Volume I, Appendix 2, Amendment 7, effective March 21, 2002."

Similarly, if the compliance demonstration has been demonstarted for Stage 5, the following statement must be included in the AFM or operations manual:

> "Certification Noise Levels:
>
> The following noise levels comply with part 36, Appendix B, Stage 5 maximum noise level requirements and were obtained by analysis of approved data from noise tests conducted under the provisions of part 36, Amendment [insert part 36 amendment number to which the airplane was certificated]. The noise measurement and evaluation procedures used to obtain these noise levels are considered by the FAA to be equivalent to the Chapter 14 noise levels required by the International Civil Aviation Organization (ICAO) in Annex 16, Volume 1, Appendix 2, Amendment 11-B, applicable January 1, 2015." [Incorporated by reference, see § 36.6].

201(c) Subpart H – Helicopters

201(c)(1) Noise limits §36.805(c)

(1) Stage 1 helicopter

If §36.805(c) applies, then noise testing will lead to one of the following:

a) The helicopter is demonstrated to be a Stage 2 helicopter: the tradeoff provisions in H36.305(b) of part 36 may be used to demonstrate compliance with the Stage 2 noise level requirement. The certificated helicopter is not designated as a first civil version, instead the certificated helicopter is designated as a Stage 2 helicopter;

b) The helicopter is demonstrated to be a Stage 1 helicopter via the "Stage 2 + 2 EPNdB" noise limits specified in H36.305(a)(1)(ii) of part 36 and is consequently designated as the first civil version. The trade provisions in H36.305(b) of part 36 may not be used for a first civil version; or

c) The helicopter fails to demonstrate compliance with the (Stage 2 + 2) noise limits specified in H36.305(a)(1)(ii) of part 36: The helicopter will be denied a type certificate until such time that the helicopter, modified as necessary, successfully demonstrates compliance with at least the requirements for a first civil version outlined above in outcome (b). The helicopter fails to demonstrate compliance if one or more of the demonstrated Appendix H noise levels exceeds the corresponding noise level limit or that flight procedure and the helicopter does not otherwise meet the Stage 2 limits (note: a helicopter may exceed the Stage 1 limit for a given flight procedure and yet achieve Stage 2 compliance through the use of tradeoffs).

(2) Change in type design

If an applicant has substantiated that a proposed change in type design (as designated in §21.93) would be less noisy or no noisier than the (parent) first civil version helicopter, no additional demonstration of compliance with part 36 is required. The derivative helicopter remains a first civil version. The applicant may elect to:

a) carry forward the parent's noise numbers to the rotorcraft flight manual of the derived version; or

b) voluntarily noise test the derivative helicopter in order to substantiate lower noise certification levels.

However, if the derivative helicopter is found to be a Stage 2 helicopter as a result of the voluntary noise test, and if the applicant chooses to certify the derivative helicopter as a Stage 2 helicopter, that derivative helicopter is no longer classified as a first civil version.

(3) Subsequent civil version

The §36.805(c) requirement for a subsequent civil version applies only to a helicopter previously designated as a first civil version. A subsequent civil version (unless otherwise excepted under §21.93(b)(4) from the acoustical change requirements) is:

a) any change in type design of the first civil version that would result in one or more of the noise certification levels of the subsequent civil version that are greater than the corresponding noise certification levels of the first civil version; or

b) any change in the first civil version that is sufficient to require a new type certificate (as provided in §21.19).

As specified in §36.805(c), a subsequent civil version must comply with the Stage 2 noise limits.

201(d) Subpart 0 – Operating Limitations; and Information

201(d)(1) Procedures, noise levels, and other information §36.1501

The following types of documentation may be required in implementation of an aircraft (airplane or rotorcraft) noise certification process.

(1) Noise certification plans

Applicant noise certification plans should be provided to FAA in the early stages of an aircraft program and contain specific types of information including proposals for the methodology an applicant intends to use to certify a given type of aircraft. These plans, when approved, establish an aircraft's noise certification basis under part 36. When an aircraft program involves agreements between FAA and foreign certificating authorities, these plans may specify an aircraft's noise certification basis under both part 36 and the noise regulation used by the foreign authority (e.g., ICAO Annex 16, Volume 1).

Noise certification plans must include the following types of information:

a) an overview of the contents of a forthcoming noise compliance demonstration plan and noise certification report;

b) description of applicable noise certification regulations and the tests, reports, data submittals and flight manual pages planned to complete an aircraft noise certification process;

c) description of conformity requirements;

d) DERs and other cognizant personnel to be involved in the aircraft noise certification process;

e) milestone schedule of key events; and

f) miscellaneous information (e.g., acronyms, organizational codes, etc.).

2) Noise compliance demonstration plans (aircraft flight test)

Noise compliance demonstration plans contain the specific methodology (including equivalent procedures) by which an applicant proposes to establish compliance of a specific aircraft configuration with applicable part 36 requirements. These plans must define the information, data, and procedures that an applicant proposes in order to comply with the requirements of part 36. After approval by FAA, flight tests specified in this plan are included as a part of the Type Inspection Authorization (TIA) used to fulfill requirements for TC, STC, and amended TC certification.

Noise compliance demonstration plans must include the following types of information:

a) *introduction*: identify applicable part 36 requirements and aircraft noise certification basis, including part 36 amendment level;

b) *aircraft description*: type, model, engines, propellers/rotors, test aircraft serial numbers, engine ratings, engine nacelle acoustic treatments, aircraft gross dimensions (including propeller and/or rotor diameter), airplane engine and ILS antenna locations, aircraft/engine conformity);

c) *noise certification methodology*: test concepts and equivalent procedures, plans for determining airplane engine spooldown characteristics and airframe noise, aircraft/engine performance substantiation, estimated reference conditions including airspeeds, thrust (power) reduction distances, altitudes, thrust (power) settings, methods for determination of $EPNL_r$ values and 90% confidence limits, and flight manual format;

d) *test description*: test site location and characteristics (e.g., topography, ground cover and obstructions), location of noise measurement points, weather constraints, aircraft configuration including flap settings, airbrake and landing gear positions, APU Operation, conditions of pneumatic bleeds and power/takeoffs, test matrix, including weights, target altitudes, airspeeds, engine thrust (power), and test tolerances;

e) *measurement system components and procedures including calibration procedures*: acoustical, meteorological, time/space position, aircraft/engine performance;

f) *data evaluation procedures including calibration and data processing*: approval status of data processing software and version level, adjustment and normalization procedures (acoustical, meteorological, time/space position, and airplane engine performance);

g) *aircraft certification schedule, including noise certification and TC dates*: flight test plans should be submitted to FAA 60 days prior to start of testing. If new and novel equivalent procedures are proposed, or exemptions are required, then submittal of test plans earlier than 60 days prior to the start of testing may be necessary;

h) references;

i) *a listing of all equivalent procedures utilized*: for example, flight path intercept procedure;

(3) Noise compliance demonstration plans (airplane families)

Noise certification of airplane families (derived versions) often require FAA approval of equivalent procedures involving measurement and evaluation of static engine noise test data as described in Chapter 4 of this AC (402(a)(2) for jets and 402(b)(2) for heavy props), in addition to the information listed in Item (2), above. These procedures include projection of static engine noise test data for development of flyover, lateral, and approach NPD plots that define differences between the airplanes used for the original noise certification flight test and a derived version (see Note 1). When use of static engine noise data is proposed, test plans must also be submitted to FAA and either integrated into the basic noise compliance demonstration plan, or submitted to FAA as separate plans and referenced in the basic plan.

Static engine noise test plans must include the following information:

a) *engine description*: type, model, test engine serial numbers, nacelle acoustic treatments, engine conformity requirements;

b) *test description*: test facility, engine installation, turbulence control screen configuration, weather constraints, acoustical and meteorological measurement points, bleed schedules, test run matrix and sequence including thrust (power) settings and test tolerances;

c) *measurement system components and procedures including calibration procedures*: acoustical, meteorological, engine performance;

d) *data evaluation procedures including calibration, data processing, adjustment and normalization procedures*: acoustical, meteorological, engine performance;

e) *schedules*: static noise test, noise certification and TC dates;

f) references; and

g) a listing of all equivalent procedures utilized.

Note.— Applicants may also generate separate static test plans in cases where development of airplane families is anticipated but not yet formalized and there is opportunity to obtain static engine noise data (because of engine availability) for future noise certification applications.

(4) Noise compliance demonstration plans (analytical methods)

For certain aircraft type design changes (e.g., weight/thrust, airframe design changes and thrust (power) reduction distances or minor changes in engine components or acoustical treatments), applicants may propose using analytical equivalent procedures to derive noise increments to an aircraft's certificated noise levels (see 402(a)(2) of this AC for jets and 402(b)(2) of this AC for heavy props) as applicable to the type of aircraft being certificated) or to demonstrate a no acoustical change (NAC) between the original certificated aircraft and the derived version.

Noise compliance demonstration plans must include the following information:

a) *aircraft description*: type, model, , engines, propellers/rotors;

b) description of type design changes;

c) *noise certification methodology*: overall concepts, description/substantiation of analytical equivalent procedures or methods of assessment of NAC aircraft reference conditions, methods for determination of $EPNL_r$ and 90% confidence limit values;

d) aircraft certification schedules; and

e) references.

(5) DER "raw data" reports

FAA Order 8110.37E (Reference G6) specifies that Acoustical Designated Engineering Representatives (DERs) may, within the limits of their authority (defined in their letter of appointment) and with prior FAA approval, witness noise certification tests conducted in accordance with FAA approved noise compliance demonstration plans.

In cases where tests are witnessed by DERs, the FAA may require the following information to validate that tests are being conducted in accordance with approved plans.

a) *test event log*: includes event times and conditions, nominal engine thrusts (powers) and thrust (power) stability, atmospheric conditions, airspeeds and deviations relative to target speeds, valid and invalid test points (including reasons for invalid points);

b) test measurement system components (type/model) and measurement/calibration procedures;

c) measurement system calibration events and results;

d) measurement system failures, malfunctions, non-standard operations, spurious signals and corrective actions taken;

e) report of test condition compliance with part 36 test site requirements;

f) field data: samples of measured and corrected noise spectra, acoustical, meteorological, time/space position, aircraft performance field data and data adjustments, EPNdB estimates, and DER notes; and

g) summary of meetings.

(6) *Noise certification reports*

Noise certification reports must provide information, data, and procedures demonstrating compliance with the requirements of part 36 and FAA approved noise certification demonstration plans.

(7) *Noise certification reports (aircraft flight test)*

These reports must include the following:

a) *introduction*: identify applicable part 36 requirements and aircraft noise certification basis, including part 36 amendment level;

b) *aircraft description*: type, model, engines, propellers/rotors, test aircraft and part serial numbers, aircraft/engine conformity status, reference conditions (MTOW/MLW, thrust (power), altitudes, airspeeds, takeoff profiles;

c) *noise certification methodology*: noise certification methodology elements of a noise certification demonstration compliance plan approved by FAA for the aircraft configuration that is being certified and the specific report sections in which implementation of each element is addressed;

d) *test description*: test site location and characteristics (e.g., topography, ground cover, and obstructions), location of noise measurement points, test conditions for each noise measurement point (including weather), aircraft configuration (e.g., flap, airbrake, landing gear and CG positions, APU operation, conditions of pneumatic bleeds and power takeoffs, aircraft weights, altitudes, airspeeds, engine thrust (power)), engine spooldown measurement points and test conditions, airframe noise measurement points and test conditions, and valid and invalid measurements;

e) *measurement system components and procedures including calibration procedures*: acoustical, meteorological, time/space position, aircraft/engine performance equipment;

f) *data evaluation procedures including calibration, data processing and adjustment procedures*: acoustical, meteorological, time/space position, aircraft/engine performance;

g) *data analysis and normalization results*: analysis results for height of maximum lateral noise, thrust (power) reduction distance, airframe noise adjustments, engine spooldown characteristics, normalized aircraft data (e.g., noise, power, distance (NPD plots)), values of $EPNL_r$ and 90% confidence limits, and aircraft flight manual pages;

h) if test witnessing is delegated, then the witness log or notes specified in section 5 above must be included; and

i) references.

(8) Noise certification reports (airplane families)

Noise certification reports involving airplane family plan concepts must include additional information on noise certification methodology and, if applicable, results of static engine noise tests as follows:

a) *noise certification methodology*: identify approved equivalent procedures for projection of static engine noise data to flight conditions in NPD plot format and methods for defining:

NPD plot differences between flight datum (originally certified airplanes) and derived versions, and

"Residual" NPD plot differences between flight test data and projected flight data for the originally certified airplane;

b) static engine noise test results

c) *engine description*: type, model, serial numbers, nacelle acoustic treatments, engine conformity status]

d) *test description*: test facility, engine installation, turbulence control screen, acoustical and meteorological measurement points, bleed schedules, valid and invalid test points, test conditions for each test point (weather, engine thrust (power);

e) measurement systems and procedures including calibration procedures: acoustical, meteorological and engine performance;

f) *data evaluation procedures*: including calibration and data processing, and adjustment and normalization of acoustical, meteorological, and engine performance;

(9) *Equivalent* procedure applications, documentation and approval process

An applicant proposes to use equivalent procedures must be included in aircraft noise compliance demonstration plans (see Note 1). Such proposals may involve new procedures or procedures that have been used previously. However, applicants must be capable of implementing proposed procedures and such procedures must be applicable to the specific aircraft model for which a TC is requested (see Note 2). Equivalent procedures must be substantiated to yield the same noise levels as the procedures prescribed in part 36.

FAA Order 8110.4C (Reference G4), paragraph 7-5 specifies AEE as the FAA approving authority for Equivalent Procedures (see Note 3). However, as experience is gained with the application of a particular procedure, AEE may delegate approval of the procedure to ACO or NCS specialists (see Reference G8). For example, FAA policy currently permits NCS approval (or ACO approval when authority is delegated) of NPD equivalencies representing extensions of data used to demonstrate compliance with part 36 for original certified aircraft. NCS (or ACO) approval authority is limited to cases where either the NPD curve fit is linear and the proposed extension is not greater than 5 percent, or the NPD curve fit is 2nd order and the proposed extension is not greater than 2.5 percent. The NCS also has approval authority for use of existing NPD plots for amended type designs (excluding extrapolation and increments to NPD plots – see Note 4).

Although equivalent procedures may be submitted as proprietary property of an applicant, when several applicants propose closely related or similar procedures (e.g., Flight Path Intercepts), they may be considered to be common industry knowledge and may be described in this AC. Information on equivalent procedures is provided in this AC in Chapter 4, section 402 for subsonic jets, heavy props and helicopters, Chapter 5, section 502 for light props, and Chapter 6, section 602 or light helicopters.

Note 1.— Equivalent procedure proposals should be submitted to FAA early in an aircraft noise certification program because approval may require more than one year.

Note 2.— Prior to approving an equivalent procedure, the FAA must assess an applicant's capability to effectively implement the procedure as well as the appropriateness of the procedure for the specific type of aircraft for which certification is requested.

Note 3.— The FAA does not consider equivalencies that modifies reference flight conditions (see 201(a)(10) paragraph 2 of this AC) without following public process.

Note 4.— Data obtained during noise certification tests may support extrapolation of noise databases (e.g., for engine thrust (power) range extensions above and below what was tested). Guidance on extrapolation of NPD databases is provided in 402(a)(2)(B)) of this AC.

(10) No acoustical change (NAC) documentation

Aircraft type design changes that are categorized as NAC require FAA approval under the provisions of part 21 rather than part 36. Applicants' proposals for approval of NAC must be submitted to the FAA in writing. The written submittal must define the planned changes in aircraft type design, and must include information, data and analyses that will substantiate that the specified type design change will not result in an "acoustical change" (see Subpart A, §36.1(c)(2) of part 36).

NAC substantiation documentation must include:

a) introduction (concepts and requirements);

b) description of aircraft baseline and proposed type design changes;

c) methodology for substantiating an NAC;

d) description of tests and/or analyses performed; and

e) test and/or analyses results relating to compliance with FAA NAC criteria (see Subpart A, §36.1(c)(3) of part 36).

Note 1.— Section 21.93(b) of part 21 states that, "…any voluntary change in the type design of an aircraft that may increase the noise levels of that aircraft is an 'acoustical change'." Therefore NAC is determined on an aircraft by aircraft basis rather than just on the basis of the type certificate data sheet (TCDS) information for the aircraft model.

Note 2.— Section 183.29(i) of part 183 specifies that Acoustical DERs may not determine that a type design change is an NAC. As such, Acoustical DERs may not make recommendations for approval of NACs under Form 8110-3.

(11) Other noise-related documentation

FAA develops noise-related documentation other than that required of applicants under Subpart O, §1501 of part 36 as follows:

a) Findings required by public law 103-272 (Reference G2):

Compliance with Public Law 103-272 requires that FAA, before issuing an original TC for any aircraft of any category, regardless of whether part 36 applies to the aircraft, must make a finding to determine whether:

Substantial noise abatement cannot be achieved for that aircraft by prescribing standards and regulations consistent with the limitations of section 44715(b), or

Substantial noise abatement may be so achieved in which case the regulatory process must be used to determine the extent of noise reduction to be required before an original TC may be issued.

Note.— The specific process required for FAA to complete Noise Finding documentation is presented in paragraph 7-3 of FAA Order 8110.4C (Reference G4).

b) Environmental Assessments:

Compliance with the National Environmental Policy Act of 1969 may require that the FAA conduct an

Environmental Assessment (EA) as specified in Chapter 4 of FAA Order 1050.1F (Reference G1 xx). An EA is conducted when type certificate actions (New, Amended, or Supplemental) are initiated for aircraft types for which part 36 requirements do not exist (see Note 1). An Environmental Impact Statement (EIS) or Finding of No Significant Impact (FONSI) must be prepared by the FAA (see Note 2). The FAA may grant an interim aircraft noise certification upon completion of an EA while appropriate rulemaking is being completed.

Note 1.— Applicants may be requested to provide appropriate noise data to FAA to support the EA and/or rulemaking processes

Note 2.— Procedures for generation of an EA, EIS or FONSI are also found in FAA Order 1050.1E (Reference G1).

(12) Procedures

a) *Applicant's responsibility*: Applicants must generate and submit to FAA the following noise certification documentation:

- Noise certification plans;
- Noise compliance demonstration plans (including proposed equivalent procedures);
- Noise certification reports;
- NAC substantiation.

b) *DER's responsibility*: Acoustical DERs responsibilities are as defined in FAA Order 8110.37E (Reference G6).

201(d)(2) Non-flight test data
§36.1501(b)

(1) *Airplane families*

Chapter 4 of this AC, 402(a)(3) for jets, and 402(b)(3) for heavy props, present guidance on static engine noise tests and projection of static engine noise data to flight conditions. Comparisons of projections of static engine noise data from the engines of an originally certified airplane with those of modified configuration engines could enable certification of modified configurations without further expensive and time consuming flight tests (see §36.1501(b) of part 36). An originally certified airplane and its derived versions are known as an "Airplane Family".

(2) Tests for supplemental data:

An applicant should attempt to obtain static engine or flight test noise data at engine thrust (power) settings and ranges, and airplane flight configurations and conditions that may be needed in the foreseeable future. This may necessitate over-boosting of the engine thrust (power) (with the permission of the engine manufacturer), resetting of the engine idle thrust (power) to lower limits, testing to higher or lower range of airspeed and angles of attack, testing at higher or lower altitudes, etc.

201(d)(3) Manuals, markings and placards
§36.1581(a)

(1) *Aircraft flight manual*

An approved Airplane Flight Manual (AFM) or Rotorcraft Flight Manual (RFM) is required for certification of each aircraft type in compliance with §36.1581 of the Airworthiness Standards for parts 21.24 (Primary Category), 23, 25, 27, or 29. Section 36.1581 of part 36 requires that certificated noise level compliance information be included in an AFM or RFM. These levels must be contained in an FAA approved section of an AFM or RFM other than the limitations section. For example, the performance section is an appropriate place to include the certificated noise level compliance information. The certificated noise levels are to be reported to 0.1 dB in the AFM or RFM. Further, an AFM or RFM must specify the type certificate limitations if any, that are established as a result of part 36 compliance, combined with the airworthiness limitations.

(2) *Rotorcraft flight manual*

In addition to the requirements of §36.1581, §H36.3(e) and §J36.3(c)(1) of part 36 require that the values of V_H and V_{NE} defined for noise certification must be listed in the RFM. The value of V_{NE} is located in the limitations section of the RFM. The value of V_H should be listed in the section of the RFM containing the certificated noise level compliance information.

(3) Airplane flight manual limitation section

a) An AFM may be issued for a single airplane or a group of similar airplanes (including more than one series of a specific model). The AFM must clearly identify (by airplane serial number) the operating limitations, including the maximum weight limits that apply to an airplane.

b) The AFM may address a single configuration (hardware build) or multiple configurations. If an AFM includes information for more than one configuration (hardware build), the appropriate airplane operating limitations must be clearly identified for each configuration. Furthermore, if not all configurations are approved for the airplanes listed in the AFM, the AFM must clearly identify by serial number, the proper operating limitations for each airplane.

c) The operating limitations contained in the Limitations Section (including any noise-limited weights) must be expressed in mandatory language, not permissive language. The terminology used in the AFM must be consistent with the relevant regulatory language.

(4) Multiple airplane noise certifications

a) Multiple noise-limited gross weight pairs (takeoff and landing) for one airplane configuration are not permitted by Subpart A, §36.1(g) for compliance with part 36. Only one set of gross weight limits that pertain to a particular configuration (hardware build) may be established under part 36 for a particular airplane.

b) An airplane configuration (hardware build) may be certificated only to a single Stage as it qualifies under part 36 (Stage 1, Stage 2, Stage 3, Stage 4, or Stage 5). The limitations section of the AFM for an airplane configuration may not contain operating limitations that would result in noise levels exceeding part 36 noise limits. However, a Stage, 2 airplane may be recertificated as Stage 3, provided that it meets the noise limits for Stage 3 and the AFMs are revised and approved for configurations appropriate for compliance with Stage 3, and the Stage 2 approval is deleted.

(5) Landing flap restriction

a) An operating limitation preventing the use of an approved landing flap setting cannot be imposed under part 36 and must be established under the airworthiness requirements or through a voluntary type design change. If such a restriction is requested by an applicant in order to comply with part 36 certification requirements that flap setting limit must be incorporated into the design and operation of the airplane.

b) For some Stage 3 airplanes, a “softguard” (such as a crushable cover plate) or frangible device must be installed on the flap selection control to safeguard its use in instances other than emergency. This device makes obvious the flap settings that are not to be used for normal operation. Fracture or deformation of the softguard would indicate use of landing flap settings that have not been approved in demonstrating compliance with part 36. For airworthiness purposes, the design of these devices allows the flight crew use of airworthiness approved restricted flaps in emergencies (declared and undeclared). The device may not be resettable by the flight crew; a damaged softguard or frangible device must be repaired as a maintenance action accomplished in accordance with part 43 prior to the next flight.

(6) Procedures

a) Applicant responsibility:

An applicant must identify limiting configurations that may be required to satisfy airworthiness and/or noise regulatory requirements. The limiting configurations, including approved aircraft gross weights, are identified in the “Limitation Sections” of the approved aircraft AFM or RFM.

(7) Implementation of landing flap restrictions

FAA policy allows a choice of two options for an applicant to implement landing flap restrictions, where their approval is consistent with applicable airworthiness requirements:

a) where permitted and possible, remove the cockpit flap selection control and performance information from the Performance Section of the original AFM that is relevant to flap settings not considered in demonstrating compliance with part 36; and

b) if flap settings not considered in demonstrating compliance with part 36 are to remain selectable then, to prevent their use in normal operations:

— Restrictions against their use, except under emergency (declared and undeclared) operations, must be incorporated into the AFM Limitations Section.

— Operational information must be relocated to the Emergency Procedures Section.

— For Stage 3 airplanes, must install a “softguard” or frangible device over the flap selection control.

— Placards may be installed to provide appropriate information to the flight crew.

(8) *ICAO certifications*

The FAA is not authorized to approve aircraft compliance with Annex 16, Volume 1 Noise Standards. (Reference G7). This is the responsibility of the foreign airworthiness authority involved. FAA participation is limited to witnessing tests and reviewing data. If the Stage 4 or Stage 5 compliance has been demonstrated refer to §36.105 or §36.106 of part 36. In those cases where Stage 3 compliance has been demonstrated, it is permissible to insert the following statement in the AFM:

“Certification Noise Levels

The following noise levels comply with part 36, Appendix B, Stage 3 noise level requirements and were obtained by analysis of approved data from noise tests conducted under the provisions of part 36, Amendment 36-XX (Insert part 36 amendment to which airplane was certificated). The noise measurement and evaluation procedures used to obtain these noise levels are essentially equivalent to those required by the International Civil Aviation Organization (ICAO) in Annex 16, Volume I, Amendment 7, Chapter 3. ICAO Annex 16, Volume I, Chapter 3 approval is applicable only after endorsement by the Civil Aviation Authority of the country of airplane registration.”

201(d)(4) Supplemental information
§36.1581(b)

(1) Publication

The FAA allows publication of supplemental noise information in an approved AFM or RFM for configurations other than the maximum takeoff and landing weight configuration or noisiest approach configuration. Such information may be useful to airlines in conjunction with their selection of operational route structures and airport operational requirements.

(2) Applicant's responsibility

Applicants must identify supplemental noise levels as "Supplemental Information" when they are included in an AFM or RFM. Even though noise data used to provide "Supplemental Information" may have been obtained during certification noise testing and witnessed by the FAA, it must still be clearly marked to show that it is not intended to demonstrate compliance with part 36, and may be presented in a non-FAA approved section or page of the AFM or RFM.

201(d)(5) Index of acceptability
§36.1581(c)

(1) Certification vs. operational rule

Part 36 is a certification rule and not an operational rule. The certificated noise levels may or may not meet the operational noise requirements for any particular airport or operating rule. The aircraft noise certification provisions of part 36 do not place any operational permissibility or limitations on the operation of certificated aircraft at any airport.

(2) Applicant's responsibility

Applicants are responsible for developing an AFM or RFM and obtaining FAA approval prior to the aircraft entering service. The approved flight manual must list the certificated noise levels that have been shown to comply with part 36 maximum noise levels (noise limits) and contain the following statement as specified in §36.1581(c) and reprinted here:

> "No determination has been made by the Federal Aviation Administration that the noise levels of this aircraft are or should be acceptable or unacceptable for operation at, into, or out of, any airport."

201(d)(6) Airplane limitations
§36.1581(d)

(1) Airworthiness maximum gross weights

Transport category large airplanes and jet airplane gross weights are normally limited for structural, performance or economic reasons and demonstrated to the appropriate airworthiness standards for the airplane. Those airworthiness limited gross weights may constitute the maximum operational gross weights and are to be identified in the "Limitations Section" of an approved AFM.

(2) Approach noise limiting configurations

Applicants may need to limit the landing flaps or the approach gross weight in order to comply with the requirements of part 36. All noise limiting gross weights and configurations are to be included in the "Limitations Section" of an approved AFM.

(3) Takeoff noise limiting configurations

An applicant may establish takeoff limiting configurations (e.g., maximum takeoff gross weight, takeoff airspeed schedules, takeoff thrust (power) derate schedule, in-flight APU operation) that are more restrictive than the airworthiness limited configurations. These noise limited configurations must be furnished in the Limitations Section of an approved AFM.

(4) Optional engine thrust (power) ratings (derate and reduced thrust)

Compliance with part 36 is only required at full rated takeoff thrust (power). However, an airplane may be type certificated at derated/reduced thrust (power) that is less than full rated takeoff thrust (power). This is not an acoustical change as defined in §21.93(b) of part 21 provided that the full rated thrust (power) remains approved for a given airplane configuration. Airplane type certification at derated/reduced thrust (power) does not prohibit an applicant from employing thrust (power) reduction for noise certification as permitted by B36.7(b) of part 36.

201(d)(7) Non-complying agricultural and firefighting airplanes §36.1583(a)

(1) Fire fighting airplanes

Those small propeller-driven airplanes that are specifically designed for “dispensing of fire fighting materials" are exempt from the noise certification requirements of part 36.

(2) Agricultural airplane operations

Agricultural aircraft operation, as defined in §137.3 of part 137, means the operation of an aircraft for the purpose of:

a) dispensing any economic poison;

b) dispensing any other substance intended for plant nourishment, soil treatment, propagation of plant life, or pest control; or

c) engaging in dispensing activities directly affecting agriculture, horticulture, or forest preservation, but not including the dispensing of live insects.

(3) Economic poisons

Economic poisons, as defined in part §137.3 of part 137, means:

a) any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any insects, rodents, nematodes, fungi, weeds, and other forms of plant or animal life or viruses, except viruses on or in living man or other animals, which the Secretary of Agriculture declares to be a pest; or

b) any substance or mixture of substances intended for use as a plant regulator, defoliant or desiccant.

201(d)(8) Operating limitations §36.1583(b)

(1) Limitation on operations

No person may operate, in accordance with the restrictions of §91.815 of part 91, an airplane that complies with the noise certification exemptions of this section, except:

a) to accomplish the work activity directly associated with the purpose for which it is designed;

b) to provide flight crewmember training in the special purpose operation for which the airplane is designed; or

c) to conduct "nondispensing aerial work operations" related to agriculture, horticulture, or forest preservations.

Chapter 3

TECHNICAL PROCEDURES APPLICABLE FOR NOISE CERTIFICATION OF ALL AIRCRAFT TYPES

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301 NOISE MEASUREMENT PROCEDURES [ETM 3.1]

The applicant should submit to the FAA for its review and approval technical procedures for the measurement of aircraft noise certification levels that the applicant will use. The technical procedures described in the following sections of this chapter should be considered as generally appropriate for all aircraft types. See Chapter 4 for procedures specific to Appendices A and H. See Chapter 5 for procedures specific to Appendix G. See Chapter 6 for procedures specific to Appendix J.

301(a) Test Site Selection [ETM 3.1.1]

For airplanes, when the flight path intercept equivalent test procedure is used, and for helicopters, it may not be necessary for the test site to be located at an airport. Details of the proposed noise certification test-site locations should be submitted to the FAA for review and approval. Some test-site criteria that could support selection of a non-airport test site include level terrain, reduced air traffic, reduced ambient noise, improved weather conditions (temperature, humidity and wind), improved microphone placement, availability of field surveys, improved locations for aircraft position monitoring and improved pilot sight and handling.

301(a)(1) Terrain [ETM 3.1.1.1]

Uneven terrain having features such as mounds or furrows can result in reflections that could influence the measured sound levels. Vegetation can reduce the amount of sound that is reflected from the ground surface. In most cases this effect results in a reduced sound level, but under some circumstances the level may be higher. Testing over a smooth hard surface, such as a paved area, will generally result in a higher sound level.

301(a)(2) Grass
[ETM 3.1.1.2]

For noise measurement points under the flight path 25 ft (7.5 m) radius circles of mowed grass (not exceeding 3 in (8 cm) height) are acceptable. For noise measurement points located to the side of the flight path, the grass may be mowed in a semicircle of 25 ft (7.5 m) radius facing the line of flight.

301(a)(3) Snow
[ETM 3.1.1.3]

Snow in the area surrounding the noise measurement points may provide excessive absorption of aircraft sound reflected from the ground. Noise measurement points have been approved when snow within a 50 ft (15 m) radius of the noise measurement points has been removed. However, snow should not be piled at the borders facing the line of flight.

301(a)(4) Plowed fields
[ETM 3.1.1.4]

Earthen or sandy surfaces within a 25 ft (7.5 m) radius of the noise measurement points must be reasonably tamped down. Plowed furrows, silt or soft, powdered surfaces are unacceptable.

301(a)(5) Obstructions
[ETM 3.1.1.5]

Obstructions in the vicinity of the noise measurement points such as buildings, walls, trees, vehicles and test personnel, if close enough, may be unacceptable because of reflections that influence measured noise levels. There should be no obstructions that significantly influence the sound field from the aircraft within a conical space above a point on the ground vertically below the microphone at each noise measurement point. The cone is defined by an axis normal to the ground and by a half angle of 80º (75º for light propeller-driven airplanes) from the axis as illustrated in Table 2.

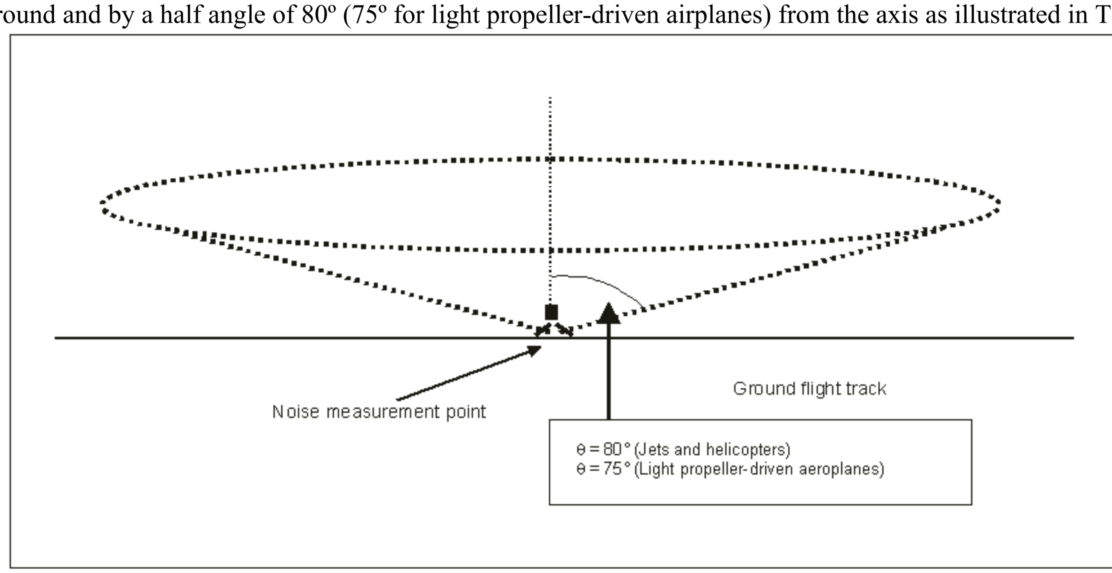

Figure 2. Obstruction-free cone defined from the base of the measurements microphone

301(a)(6) Anomalous meteorological conditions [ETM 3.1.1.6]

Certain geographical areas are more susceptible to anomalous meteorological conditions than others (i.e., large variations, or inversions, of temperature or humidity, excessive turbulence, or thermally induced vertical winds). The applicant may conduct certification testing only as approved by the FAA.

301(b) Precautions Regarding Effects of Precipitation [ETM 3.1.2]

301(b)(1) General precautions [ETM 3.1.2.1]

Fog, rain, drizzle and snow can have a number of adverse effects. Changes in sound generation and propagation under these conditions are not well documented. Most of the equipment used for measuring noise is not intended for use during conditions of precipitation, and the effects can range from changes in microphone and windscreen sensitivity or frequency response, to arcing of conventional condenser microphones, to possible failure of equipment because of electrical short circuits.

301(b)(2) Effect of moisture on microphones [ETM 3.1.2.2]

Most microphones that are used during noise certification testing are susceptible to moisture. Precipitation, including snow, drizzle and fog, or excessive humidity may induce electrical arcing of the microphone sensors, making measured noise data unacceptable. However, some pre-polarized microphones are less susceptible to electrical arcing during high-moisture conditions (consult the equipment manufacturer's specifications). Special care should be taken to ensure that any windscreens exposed to precipitation be thoroughly dry, inside and out, before use. Foam windscreens can trap water and wet foam windscreens should be avoided.

301(b)(3) Microphone internal heaters [ETM 3.1.2.3]

When internal heaters are provided, microphones are less likely to be affected by moisture in wet, humid, cold or freezing atmospheric conditions.

301(c) Calibration of Acoustical Measurement System [ETM 3.1.3]

301(c)(1) General calibration process [ETM 3.1.3.1]

The process for the calibration of an acoustical measurement system (see A36.3.1.1, A36.3.3.1, G36.103, and J36.109(c) of part 36 for definition of the "measurement system") for purposes of noise certification testing consists of two parts:

a) determination of system response corrections; and

b) sound pressure level calibrations and testing in the field.

Some of these calibrations must be conducted at the aircraft noise test site, with the measurement system configured and deployed for aircraft noise measurement. Note that additional calibrations and checks may be allowed, or required, by the FAA.

301(c)(2) Frequency-dependent system response corrections [ETM 3.1.3.2]

Corrections for system response may include consideration of some or all of the following frequency-dependent elements to account for variations in sensitivity differences relative to the calibration check frequency (see A36.3.9.1 of part 36).

Note.— To avoid confusion and to promote consistency, it is recommended that all response corrections be determined and presented in such a manner that the correction values are to be added to the measured aircraft noise levels to correctly adjust for the effects of system sensitivity differences. Example: The correction value for a microphone response at a frequency where the microphone is more sensitive to sound than at the calibration check frequency should be presented as a negative number which, when added to the measured aircraft noise levels in that frequency band, lowers them to what would have been measured if the microphone response were flat.

(1) *Microphone free-field frequency response*

Corrections for microphone free-field frequency response may be determined using electrostatic actuator testing in combination with manufacturer-provided corrections for free-field conditions, or alternately from anechoic free-field testing using a method approved by the FAA (see A36.3.9.2 of part 36).

(2) *Microphone incidence corrections*

Microphone incidence corrections may be required when the microphone is not set at nominally grazing incidence. The corrections may be determined using manufacturer's data, or alternately from anechoic free-field testing using a method approved by the FAA (see A36.3.9.3 of part 36).

(3) *Windscreen free-field insertion effects*

The windscreen free-field insertion effects may be determined using manufacturer's data, or alternately from anechoic free-field testing using a method approved by the FAA (see A36.3.9.10 of part 36).

Note.- If incidence corrections are required for microphone free-field response, then incidence corrections will likely also be required for the windscreen insertion effects.

(4) *System frequency response*

The frequency response corrections for the measurement system as deployed in the field for aircraft noise measurements (not including the microphone and windscreen, but including any cables, attenuators, gain stages, signal conditioners, etc.) should be determined using a method approved by the certificating authority. Acceptable methods may include the use of discrete- or swept- sine tones, or random or pseudo-random pink noise. The specific methods and techniques used should be submitted in advance to the FAA for approval. When using pink noise to determine system frequency response, there are additional specifications for noise generator performance and calibration specified in part 36. When using analog (direct or FM) magnetic tape recording, it is required that system frequency response be determined in the field while deployed for aircraft noise measurements (see A36.3.9.5 of part 36).

(5) *Effective bandwidth*

The effective bandwidth (also known as "bandwidth error" or "filter integrated response") for one-third octave band analyzer filters may be determined using manufacturer's data, or from tests using discrete or swept sine signals as described in IEC 61260 (Reference T2). Note that bandwidth corrections might be redundant, dependent on the specific testing methodology used, if the measurement system response, including the analyzer, is determined using pink noise or other broadband signal testing.

301(c)(3) Single-frequency level calibrations [ETM 3.1.3.3]

The following calibrations are typically performed at the calibration check frequency:

(1) *Sound calibrator output level*

The output level of the sound calibrator should be determined using means which are traceable to a national standards laboratory. This may include direct calibration by a certified metrology laboratory or comparison calibration methodology. Laboratory calibrations often include a certificate stating the sound pressure level, its tolerance, reference temperature and humidity, and the time period for which the calibration remains valid. This and other documentation may be required by the FAA for its approval. Sound calibrator output level corrections for barometric pressure, coupler volume, and other environmental effects may be determined according to the manufacturer's specifications.

(2) *Calibration of gain or attenuation settings*

The accuracy of gain or attenuation settings (range changes) for switchable components in signal conditioners, amplifiers, analyzers and sound level meters should be determined from manufacturer's specifications or by laboratory testing, as approved by the FAA.

(3) *Sound pressure level sensitivity of the acoustical measurement system*

Sensitivity calibrations of the entire system must be performed before and after each day's aircraft noise measurements using an approved sound calibrator. These calibrations should be performed in such a way that all system components, including cables, are accounted for.

301(c)(4) Field sound pressure level calibration considerations [ETM 3.1.3.4]

It is necessary to establish and monitor the overall sound pressure level sensitivity of the measurement system while it is deployed in the field. Considerations for such field sound pressure level calibrations include:

(1) *Schedule for sound pressure level calibrations*

For aircraft noise certification tests defined in Appendices A, G, H and J, an acoustic calibration signal of known amplitude and frequency should be applied to the entire measurement system, including the microphone, while deployed in the field. This calibration should be performed as a minimum at the start and end of each day of aircraft noise measurements. When analog (direct or FM) magnetic recording media are used, the signal from the sound calibrator should also be recorded at the beginning of each physical volume of recording media (e.g. each tape reel, cartridge, or cassette) as well as at the end of the last physical volume of recording media. In addition, sound pressure level calibrations should be considered at regular intervals throughout each day of aircraft noise measurements (see A36.3.9.8, A36.3.9, and J36.109(e)(i) of part 36). As an example, sound pressure level calibrations are sometimes scheduled to coincide with meteorological flights between noise measurement runs, or during test aircraft refueling for longer test programs. Applicants should include the scheduling of such calibrations in the noise measurement test plan.

(2) *Aircraft noise data validity*

Aircraft noise data that are not preceded and succeeded by valid sound pressure level calibrations are not acceptable for aircraft noise certification purposes. Part 36 specifies that the difference between pre- and post-calibrations must not be greater than 0.5 dB. Because of this limitation, frequent checks of system sensitivity and functionality are advised (see A36.3.9.8 and J36.109(e)(2)(ii)

(3) *Insert "checks"*

Depending upon the specific measurement system configuration, and with the approval of the FAA, level sensitivity checks (e.g. charge or voltage "insert" calibrations, which involve electrical signals injected into the microphone preamplifier) at frequent intervals (e.g. every two hours of aircraft noise measurement deployment) may be used to supplement the requirement for sound pressure level calibrations at the start and end of each day of aircraft noise measurement. Employing such a procedure can facilitate continuous testing activity, and provide supporting data to isolate and identify potential system failures. Insert checks should not be considered as substitutes for required sound pressure level calibrations.

(4) *System configuration during sound pressure level calibrations in the field*

During field sound pressure level calibration, all components of the measurement system including cables, attenuators, gain and signal-conditioning amplifiers, filters (including pre-emphasis, if used) and power supplies, but excluding the windscreen, should be in place. Where used, attenuators and gain stages should be set to prevent overload and to maintain the calibration signal level within the reference level range specified in A3.6.6 of part 36. If any switchable filters that could affect the calibration signal are utilized during measurements, then sound pressure level calibrations should be performed both with and without these filters enabled. Components of the electrical system should not be added, removed or replaced without re-calibrating any part of the system affected by that component immediately before and after making each change.

(5) *Adjustments for differences between pre- and post- calibrations*

Section A3.9.8 of part 36 requires that the arithmetic mean of the sound pressure level calibrations before and after a group of aircraft noise measurements must be used to represent the acoustical sensitivity level of the measurement system for those measurements. No such requirement is provided for in Appendices G or J of part 36. Nevertheless the FAA may approve such an adjustment to the system's acoustical sensitivity level. In all cases, and as an alternative to the arithmetic mean of the before and after sound pressure level calibrations, the FAA may accept that for a particular aircraft noise event the acoustical sensitivity level of the system be represented by a linear interpolation over time of the sound pressure level calibrations before and after the aircraft noise measurement to the time of the data acquisition for that aircraft event.

301(c)(5) Application of calibration corrections [ETM 3.1.3.5]

It is recommended that all calibration corrections be determined and presented in a manner such that they are to be added to the measured aircraft levels to properly correct for system instrumentation effects (see Note to 301(c)(2)).

All calibration corrections should be determined individually, reported with full documentation of the method of determination, and applied to the measured aircraft noise levels during data processing of analyzed one-third octave band sound pressure levels. This includes sound calibrator output adjustments for ambient conditions such as temperature and atmospheric pressure, coupler volume, etc. (see A36.3.9.7 of part 36), as well as any sensitivity "drift" corrections, or any system response corrections.

Note 1.— Such adjustments should not be applied by adjusting the calibration value in the analyzer or sound level meter.

Note 2.— In the event that the sound pressure level sensitivity of the analyzer or sound level meter needs to be reset after the initial calibration at the start of the test day, and after aircraft noise measurements have already been obtained, then prior to such reset, the sound pressure level calibration signal should be measured and recorded at the existing level sensitivity. In this way, a traceable record of the system sensitivity can be maintained.

301(c)(6) Calibration Traceability [ETM 3.1.3.6]

All sound calibrator output levels and performance testing of calibration instrumentation should be traceable to a national standards laboratory. The method of traceability may in some cases include documentation of any comparison calibration methods performed by the applicant, instrumentation manufacturer, or another third party. All methods of traceability must be approved by the FAA.

301(d) Windscreen Insertion Loss
[ETM 3.1.4]

The physical condition of a windscreen can significantly affect its performance due to insertion loss. Only new or clean, dry windscreens should be used.

Insertion loss data adjustments for windscreens used during aircraft noise evaluations under the provisions of Appendices A and H of part 36 may be obtained from manufacturer's data or by free-field calibration in an anechoic chamber (see 401(c)(14) of this AC).

For aircraft noise evaluations made under the provisions of Appendices G and J of part 36, windscreen insertion loss data adjustments may be required.

301(e) Wind Speed Limitations
[ETM 3.1.5]

The wind speed should be monitored against the specified wind speed limits. In cases where these limits are exceeded during an aircraft test run, that test run is invalid and might have to be repeated. No method has been approved for making data adjustments for wind speed or direction.

301(f) Measurement of Atmospheric Conditions
[ETM 3.1.6]

The temperature and relative humidity near the earth's surface can be affected by numerous factors including solar heating, surface winds, local heating or cooling, increased or decreased local humidity, etc. To avoid localized anomalous conditions that often occur near the ground, meteorological measurements are to be made 33 ft (10 m) above the surface for aircraft noise measurements made under the provisions of Appendices A and H of part 36 and between 4 ft (1.2 m) and 33 ft (10 m) for aircraft noise measurements made under the provisions of Appendices G and J of part 36. The meteorological conditions measured above the ground are assumed to be constant from the ground surface to the height at which they are measured.

301(g) Meteorological Measurement System
[ETM 3.1.7]

Atmospheric conditions should be measured within 6562 ft (2000 m) of the microphone locations and must be representative of the conditions existing over the geographical area in which noise measurements are conducted.

If an applicant can show that measurements from a fixed meteorological station, such as might be found at a nearby airport comply with these requirements, then subject to the approval of the FAA, this facility may be used. Approval will normally require the applicant to show that the measurement systems have been calibrated within 90 days prior to the tests.

In general, an approved portable system is preferred. This will be especially important when any of the meteorological conditions, in particular wind speed, are near their limits. Applicants should note that in order to determine the crosswind component an accurate measure of not only wind speed but also wind direction is required. Some wind direction indicators installed at airfields and airports have a slow response to rapid changes in wind direction and are not sufficiently accurate.

301(h) Aircraft Position Measurement [ETM 3.1.8]

Appendices A, G, H and J specify that the aircraft position must be determined by a method independent of normal flight instrumentation. For this purpose the FAA has approved differential global positioning systems (DGPS), radar tracking, theodolite triangulation or photographic scaling techniques (see 302).

301(i) Measurement System Specifications [ETM 3.1.9]

301(i)(1) Validity of measurent system configuration [ETM 3.1.9.1]

Each applicant should submit information to the FAA about the measurement system used. The FAA will determine whether any listed components require approval.

301(i)(2) Changes in measurement system configuration [ETM 3.1.9.2]

If an applicant makes changes to the approved measurement system configuration, the FAA should be notified before aircraft noise certification testing to determine whether additional evaluation and approval are required.

301(j) Noise Compliance Demonstration Plan [ETM 3.1.10]

An applicant should prepare a noise compliance demonstration plan (see 201(d)(1) of this AC), that specifies the proposed certification process, including the use of any equivalencies. This plan is to be submitted to the FAA allowing sufficient time to permit adequate review and possible revisions prior to the start of any noise certification testing.

302 FLIGHT PATH MEASUREMENT [ETM 3.2]

The criteria for the measurement of aircraft height and lateral position relative to the intended track are described in A36.2.3.1, F36.109(f)(6), G36.109(f), H36.101(d)(2), and J36.101(d)(2) of part 36. Examples of methods used include:

a) radar tracking system;

b) theodolite triangulation;

c) photographic scaling; and

d) differential global positioning system (DGPS)-based time-space-position information tracking systems.

Practical examples of aircraft tracking systems employing one or more of these techniques are described in subsequent sections. Other tracking systems such as inertial navigation systems (INS) and microwave systems, which have a high degree of accuracy, have been installed in aircraft and consequently have been accepted by several FAA for use during noise certification. These techniques may be used singly or in combination. This is not intended to be an exhaustive list and additional information will be included as more experience is acquired.

302(a) Radar or Microwave Tracking System [ETM 3.2.1]

One example of a radar position tracking system is shown in Figure 3. It operates on the principle of pulse radar with a radar interrogator (receiver/transmitter) located on the aircraft and a radar transponder (receiver/transmitter) positioned at each reference station. The elapsed time between the receiver/transmitter pulse and reception of the pulse returned from the reference station transponder is used as the basis for determining the range of each reference station. This range information, together with the known location of the reference stations, can be used to obtain a fix on the position of the aircraft in three dimensions.

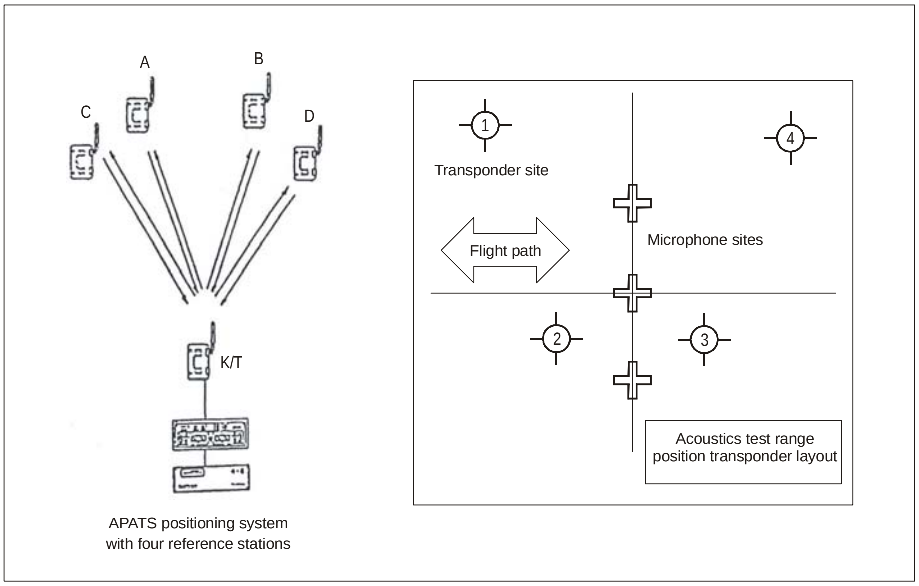

Figure 3. Example radar/microwave position tracking system

A pulse coding system is employed to minimize false returns caused by radar interference on reflected signals. The system performs the following basic functions during noise certification:

a) continuously measures the distance between the aircraft and four fixed ground sites;

b) correlates these ranges with Inter-Range Instrumentation Group Standard Serial Time Code Format B (IRIG B) time code and height information and outputs these data to a pulse code modulation (PCM) recorder;

c) converts the aircraft range and height information into X, Y and Z position coordinates in real time; and

d) uses the X, Y, Z data to drive a cockpit display providing the pilot with steering and position cueing.

The accuracy of the coordinate calculation depends on the flight path and transponder geometry. Errors are minimized when ranges intersect, and the recommended practice is to keep the intersection angle near to 90°. The four transponder arrangements shown in Figure 3 produce position uncertainties from ±3 ft to ±7 ft (±1.0 m to ±2.0 m).

At low aircraft heights some inaccuracies can be introduced with the use of microwave systems. The use of a radio-altimeter can reduce these errors. The height data are recorded and synchronized with the microwave system.

302(a)(1) Aircraft equipment
[ETM 3.2.1.1]

The distance measuring unit computer and transponder beacon are connected to a hemispherical antenna which is mounted under the fuselage, on the aircraft centerline, preferably as close to the aircraft center of gravity as possible.

302(a)(2) Ground equipment
[ETM 3.2.1.2]

The four beacons should be located on either side of the aircraft ground track to permit an optimum layout. For example, a helicopter should be covered with angles between 30° and 150° (90° being the ideal angle). Two beacons can be located on the axis of the noise measurement points at distances of ±1640 ft (±500 m) from the central microphone, while another two beacons can be located on the track at ±1969 ft (±600 m) from the central microphone.

302(b) Kine-theodolite System
[ETM 3.2.2]

It is possible to obtain aircraft position data with classical kine-theodolites, but it is also possible to make use of a system composed of two simplified theodolites including a motorized photo-camera on a moving platform, which reports azimuth and elevation. These parameters are synchronized with coded time and the identification number of every photograph recorded.

Each 0.1-second azimuth and elevation data measurement is sent to a central computer which calculates the aircraft position (X, Y and Z) versus time for each trajectory.

For example, for helicopter testing, photographic stations should be located at sideline positions about 984 ft (300 m) from the track, and at 656 ft (200 m) on either side of the three noise measurement points.

The accuracy of such a system can be ±4.9 ft (±1.5 m) in X, Y and Z over the working area.

302(c) Radar/theodolite Triangulation
[ETM 3.2.3]

The opto-electronic system shown diagrammatically in Figure 4 uses a single optical theodolite to provide azimuth and elevation while range data are obtained from a radar tracking system using a single transponder. Data from these two sources are transferred to a desktop calculator at a rate of 20 samples/second from which three-dimensional position fixes can be derived. The system also provides tape start and stop times to the measuring sites, synchronizing all tape-recording times. The accuracy of the system is approximately ±6.6 ft (±2.0 m), ±3.3 ft (±1.0 m) and ±6.6 ft (±2.0 m) for horizontal range (X), cross-track (Y) and height (Z) respectively. Uncertainties associated with the determination of the visual glide slope indicator and ground speed are ±0.1° and ±0.5 kt (±0.9 km/h)

302(d) Photographic Scaling
[ETM 3.2.4]

The flight path of an aircraft during a noise certification demonstration may be determined by using a combination of ground-based cameras and height data supplied as a function of time from the on-board radio or pressure altimeters. For example, using this method for a helicopter, three cameras are placed along the intended track, such that one is sited close to the center microphone position and the other two are sited close to each of the 10 dB-down points, typically 1640 ft (500 m) either side of the microphone, depending upon the flight procedure being used. The cameras are mounted vertically and are calibrated so that the image size, obtained as the helicopter passes overhead, can be used to determine the height of the aircraft. It is important that the time at which each camera fires is synchronized with the on-board data acquisition system so that the height of the aircraft as it passes over each of the cameras can be correlated with the heights obtained from the photographs. The flight path of the aircraft as a function of distance may be obtained by fitting the aircraft data to the camera heights.

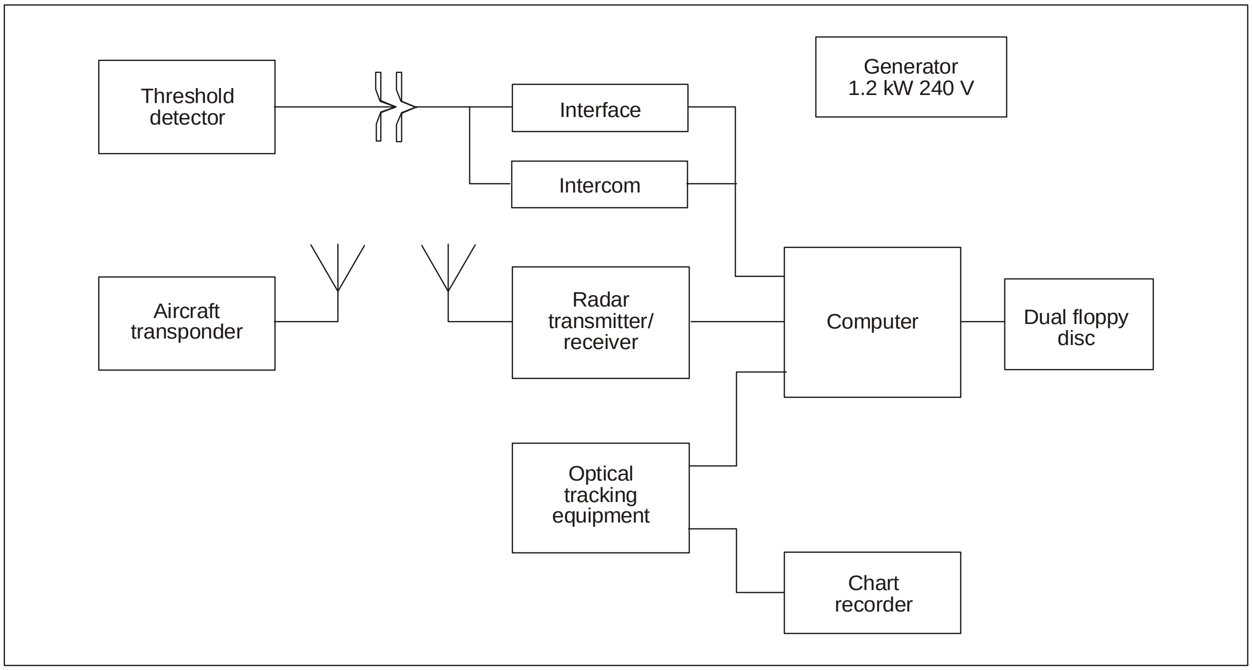

Figure 4. Radar/optical position tracking system

The aircraft reference dimension should be as large as possible in order to maximize photograph image size but should be chosen and used with care if errors in aircraft position are to be avoided. For a helicopter, foreshortening of the image due to factors such as main rotor coning (bending of the blades), disc tilt or fuselage pitch attitude, if not accounted for, will result in errors in the measurement of height and/or lateral and longitudinal position.

By erecting a line above each of the cameras at right angles to the intended track, at a sufficient height above the camera in order to provide a clear photographic image of both the line and the aircraft, the applicant may obtain the lateral offset of the aircraft as it passes over each of the cameras. This can be done by attaching marks to the line showing the angular distances from overhead at 5° intervals on either side of the vertical. For example, for helicopters, this method may be used to confirm that the helicopter follows a 6° ± 0.5° glide slope within 10° of the overhead of the center microphone as required by H36.107 of part 36.

Furthermore, from the synchronized times of the aircraft passing over the three camera positions, the ground speed can be determined for later use in the duration adjustment.

Overall accuracy of the system is ±1.0 percent of height and ±1.3 percent of longitudinal and lateral displacements. Mean approach/climb angles and mean ground speed can be determined within ±0.25° and ±0.7 percent respectively.

302(e) DGPS-based Time-Space-Position Information Tracking Systems [ETM 3.2.5]

302(e)(1) General [ETM 3.2.5.1]

The use of conventional global positioning system (GPS) receivers on-board aircraft to obtain time-space-position information (TSPI) is not considered to be accurate enough for noise certification testing. However, by using data from a second localized fixed-position GPS receiver, a substantial improvement in accuracy can be achieved. Such an arrangement is referred to as a differential GPS (DGPS) system.

FAA may approve the use of such DGPS systems, based on the particular characteristics of the hardware, related software, installation and operational specifics proposed by the applicant. This section summarizes recommended requirements for DGPS systems proposed for use during noise certification testing.

Typically the hardware components of these systems are GPS receivers and antennas on the ground and in the aircraft, the data link transmitter and antenna on the ground and the corresponding receiver and antenna in the aircraft, a laptop computer in the aircraft and batteries and electronic power supplies (see Figure 5). Software running on the laptop computer in the aircraft provides the user control/display function and performs data logging. A personal computer is generally needed to initialize the GPS receiver on the ground, but is not necessary for continuous operation.

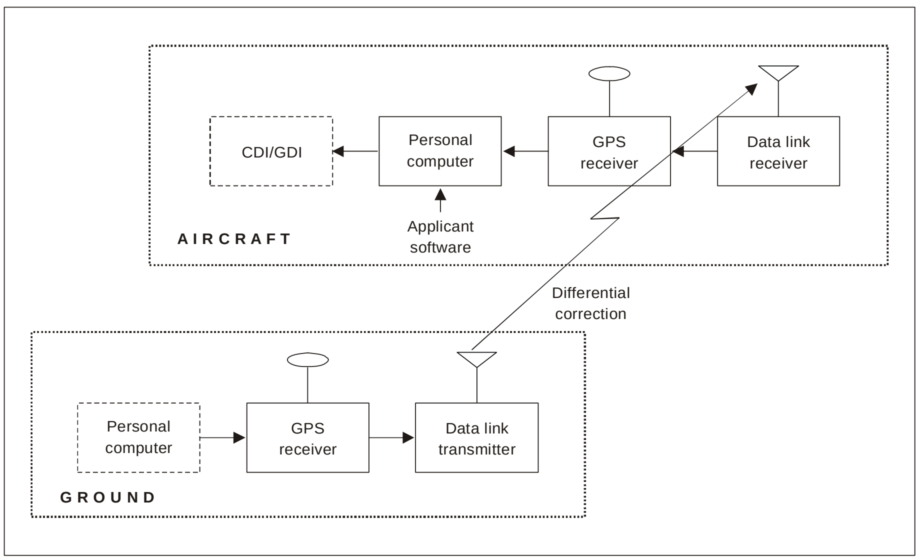

Figure 5. DGPS TSPI system basic architecture

In addition to generating flight reference data for post-processing, some applicants' systems provide the pilot with information to navigate the aircraft. Measured aircraft position is compared to a desired reference flight path, and steering commands are sent to a course/glide slope deviation indicator (CDI/GDI) installed specifically for use with the DGPS system.

Variations on the basic architecture shown in Figure 5 are possible. For example, it is possible to eliminate the data link elements by collecting and storing data from both GPS receivers during a flight and post-processing these data in a single computer after the flight is complete. However, without a data link, DGPS data cannot be used for aircraft guidance, nor can an aircraft-based operator obtain "quick-look" information regarding the DGPS solution quality. Another possible variation on the basic architecture in Figure 5 involves the use of a two-way data link. Typically, identical transceivers would be used on the ground and in the aircraft. This enables ground tracking of the aircraft during testing.

302(e)(2) System design issues
[ETM 3.2.5.2]

This section discusses DGPS system design issues including configuration, airport survey, DGPS receiver output data, and sources of error in DGPS systems.

302(e)(2)(A) Coordinate frames and waypoint navigation [ETM 3.2.5.2.1]

The native coordinate system for GPS (i.e., the one in which its computations are performed) is the World Geodetic Survey of 1984 (WGS-84). Most GPS receivers provide output position information (latitude, longitude and altitude) in a variety of geodetic coordinate systems by transforming the WGS-84 position data.

Aircraft noise certification tests typically involve the use of a rectangular coordinate frame whose definition is based upon the array of microphones or the centerline of an airport runway. Typically, the frame's x-axis is established from two points on the ground that are nominally aligned with the runway centerline; the y-axis is orthogonal to the x-axis and also level, and the z-axis is vertical. Some GPS receivers can furnish data in a rectangular coordinate system based on waypoints. These are user-defined reference points intended to facilitate navigation along a route or in a local area. If a receiver supports waypoint navigation then two such points, defined in terms of latitude, longitude and altitude, can be entered into the receiver.[1] The receiver will subsequently provide aircraft position relative to the coordinate frame implicitly defined by the points (i.e., the distance from the line connecting the two points and the distance to one point).

If waypoint navigation is to be used for noise testing, then the initial survey performed to determine the position of the two waypoints is critical to the accuracy of the TSPI results (see 302(e)(2)(b)). If waypoint navigation is not available, or is not to be used, then the geodetic position solution (i.e., latitude, longitude and altitude) must be transformed to a local coordinate system through post-processing by the applicant prior to noise data processing.

302(e)(2)(B) Test site survey [ETM 3.2.5.2.2]

A careful survey of the airport and nearby areas where noise testing is to be conducted is critical to the success of a measurement program. The following steps are involved in a survey:

a) An initial reference location, including numerical values for its latitude, longitude and altitude, is selected and its coordinates are stored in a permanent file for record keeping. Normally the initial reference location will be a surveyed monument on the airport upon which latitude and longitude are stamped. Often the monument will have been derived from a third-order survey, in which case geodetic position errors of the order of hundreds of meters are not uncommon. However, such errors have virtually no effect on the measurement of positions relative to that point or another point derived from it. The published airport reference altitude can be assigned to the monument. Although this altitude typically is applicable to the base of the tower, the altitude difference between the monument and tower will not degrade the accuracy of differential measurements relative to the reference location. Many GPS receivers have a "survey" mode whereby they average position measurements over a user-selected period of time (e.g., 24 hours) to generate a surveyed position estimate. Typical resulting absolute accuracies are 3 to 10 ft (0.9 to 3 m), which are more than adequate if the DGPS-based TSPI system measurements will not be related to measurements from another system.[2]

1. For noise certification testing it is recommended that the GPS receiver read the waypoints from a printable data file. Alternatively, the waypoints could be keyed into the receiver and then written to a data file.

2. Prior to the advent of satellite-based techniques in the 1990s, land surveys were performed using an optical theodolite (to measure angles) and a chain (to measure linear distance). Networks of interlocking triangles were surveyed, with measurements collected at each vertex. The accuracy of such a survey was classified by the amount that the sum of the interior angles of a triangle deviated from 180º (after accounting for the earth's curvature). A first-order survey was the most accurate; the vertices were typically 16 to 64 km (10 to 40 miles) apart, and the angular error 1 arc second or less. Also, for a first-order survey, the latitude/longitude of one point was measured by astronomical means (accuracy approximately 15 m (50 ft)). A second-order survey had vertices 8 to 16 km (5 to 10 miles) apart and maximum angular error of 5 arc minutes. A third-order survey had vertices 1.6 to 3.2 km (1 to 2 miles) apart and angular error not exceeding 15 arc minutes.

b) The DGPS-based TSPI system, with the ground-station antenna at the initial reference location, is used to measure the coordinates of the location where the ground-station antenna will be installed for the remainder of the test series. The latitude, longitude and altitude of this second location is stored in a permanent file for record keeping. If convenient, the ground-station antenna may be installed at the initial reference location for the duration of the test series.

c) If waypoint navigation is to be used for the measurement program, the DGPS-based TSPI system, with the ground station at the second (i.e., normal) location, is used to measure the latitude, longitude and altitude of the FROM and TO waypoints which will be used to establish the test program coordinate frame. At least three measurements should be made to guard against errors. The resulting locations should be stored in a permanent file for record keeping.

d) The DGPS-based TSPI system, with the ground station at its normal location, is used to measure the microphone positions. The measured positions are stored in a permanent file for record keeping. If waypoint navigation is to be used for the measurement program then microphone positions should be recorded in test coordinates; otherwise latitude, longitude and altitude should be used.

e) If it is not feasible to use the DGPS-based TSPI system to survey the microphone locations, then direct measurements of at least three common points should be performed in order that the relationship between the two surveys can be determined. For example, if the microphones are surveyed using classical techniques, then a DGPS-based TSPI survey of the two microphones at the ends of a microphone line and one other microphone, as far removed from the first two as possible, will be sufficient. The surveys should agree to within 1 ft (30 cm) at each common point. If they differ by more than 1 ft (30 cm) and the difference can be expressed in terms of an offset and a rotation, then it may be possible to adjust the results of one survey to agree with the other. Such adjustments should be approved by the FAA prior to testing.

The above tests should be performed, as a minimum, before and after each measurement program. Post-test data analysis should include a comparison of the two surveys.

302(e)(2)(C) Receiver output data
[ETM 3.2.5.2.3]

This section addresses the GPS receiver messages[3] (output data) which are of interest. All data are typically furnished via RS-232 serial ports (acceptable GPS receivers generally have multiple RS-232 ports).

Three kinds of GPS receiver output data are of interest:

a) data stored during flight testing for use during post-test processing of noise data, collected from either the aircraft receiver when a real-time data link is used or from both receivers when a real-time data link is not used;

b) differential correction data output by the ground-station receiver, transmitted to the aircraft via a real-time data link, and input to the aircraft receiver. These data are not stored, but directly influence the accuracy of the stored data addressed in a); and

c) data collected from the ground-station GPS receiver during multi-path verification tests prior to flight testing.

3. Standards organizations and manufacturers employ different terminology for pre-defined groups of data parameters available from receiver output ports. For example, in the United States, the National Marine Electronics Association (NMEA) uses the term “sentences,” the Radio Technical Commission for Maritime Services (RTCM) uses “messages,” Novatel Communications uses “logs” and Trimble Navigation Ltd. uses “cycle printouts.”

302(e)(2)(C)(i) Data stored during aircraft noise testing when a real-time data link is used [ETM 3.2.5.2.3.1]

GPS receivers provide TSPI data in a variety of formats, both industry-standard and proprietary. In the United States, the National Marine Electronics Association (NMEA) has issued standards (References T7 and T8) which are intended to facilitate user communications with GPS receivers and other navigation devices. Some GPS manufacturers have adopted NMEA standards, some use proprietary formats, and some use both. Manufacturers that provide NMEA outputs generally implement only a subset of the full set of messages set forth in the standards, and some follow the older Version 1.5 (Reference T7) rather than Version 2.0 (Reference T8), upon which this guidance was based.

GPS receiver manufacturers have chosen different parameters to indicate the quality or status of the TSPI data. DGPS-based TSPI systems considered for noise certification tests, using a real-time data link, should save data from the aircraft GPS receiver in the receiver's native raw format, in permanent files, for record keeping. Stored data should include time (e.g., Coordinated Universal Time (UTC) or GPS time with or without a local offset), aircraft latitude, longitude and altitude, or equivalently, aircraft position relative to a pre-defined waypoint, together with a status or quality flag indicating the reliability of the DGPS solution.

Typically the applicant will employ post-processing software which will read the raw data, parse and format these data, perform any necessary transformations, and generate a file which will be used for noise data processing. Storage of raw data allows the FAA to verify the validity of the post-processed results.

302(e)(2)(C)(ii) Data stored during aircraft noise testing when a real-time data link is not used [ETM 3.2.5.2.3.2]

DGPS-based TSPI systems considered for noise certification tests which do not use a real-time data link should save data from both the ground and aircraft GPS receivers in raw (i.e., the receiver's native) format, in permanent files, for record keeping. Manufacturers' proprietary formats should be used since NMEA standard messages do not support this application.

For post-processing, stored data should include time (e.g., UTC or GPS time) with or without a local offset, satellite ephemeris (see 302(e)(2)(F)(iv)) for a discussion of satellite ephemeris/clock data), pseudo-ranges,[4] signal-to-noise ratios,[5] and carrier phase.[6] Applicants using dual-frequency (L1/L2) receivers will typically also save L2 carrier phase data.[7] Typically, post-processing of the ground-based and airborne GPS data will be performed using manufacturer-supplied software. If this is not the case, then any applicant-developed software should be approved by the FAA.

302(e)(2)(C)(iii) Real-time DGPS messages [ETM 3.2.5.2.3.3]

GPS receiver manufacturers have implemented both industry-standard and proprietary messages for use on real-time DGPS data links. The Radio Technical Commission for Maritime Services (RTCM), Special Committee 104 (SC-104), has issued a standard (Reference T10) that is followed by most manufacturers. Manufacturers usually implement

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4. Pseudo-range is the receiver's measured distance to a satellite and is derived from the Coarse/Acquisition (C/A) code. It includes a receiver clock bias error and may be quantified in units of time or distance.

5. Signal-to-noise ratio (also called carrier-to-noise ratio) is derived from the receiver's tracking loop circuits and is a measure of the received signal strength. It is usually quantified in dB-Hz and varies from approximately 33 to 50.

6. Carrier phase is the amount of carrier cycles (at 1 575.42 MHz) which have accumulated since logging of this parameter was begun. It may be quantified in radians, degrees, cycles or feet (to convert to cycles, divide by the wavelength, 0.6247 ft).

7. The highest accuracy DGPS systems employ the signal carrier (L2 = 1 575.42 MHz), rather than the code (L1 = 1.023 MHz), which modulates the carrier, as the basic measurement observable. These techniques require that the number of full carrier cycles, i.e., 8-inch wavelengths, between the ground station and aircraft be determined once during a test. After the cycle count is established, the ground-station/aircraft separation is tracked to fractions of a wavelength, provided that the receiver carrier tracking loops (circuits) maintain phase lock.

only a subset of the RTCM/SC-104 messages, and some follow the older Version 2.0 of Reference T10 rather than Version 2.1, upon which this guidance was developed. Some manufacturers have also implemented proprietary DGPS messages which frequently bear a close resemblance to the RTCM/SC-104 messages.

For applicants implementing a real-time DGPS data link, it is preferred that RTCM/SC-104 messages be employed for this purpose. Type-1 or Type-9 messages, each of which contains the actual DGPS corrections, should be selected and transmitted at a rate of 0.5 Hz or higher. Other message types (e.g., Type-3 ground-station location and Type-5 satellite health) may be used but should be sent at a rate of once per minute or slower. There is no recommended requirement for storing real-time DGPS correction data. The data status or quality flag (see 302(e)(2)(C)(i)) should however provide an indication that the correction data have been properly received and processed by the aircraft.

302(e)(2)(C)(iv) Messages for multi-path testing [ETM 3.2.5.2.3.4]

Applicant-designed systems using code-based DGPS processing should collect and save data from dedicated multi-path tests to be conducted prior to aircraft noise testing (see 302(e)(2)(E)). Data collected during multi-path tests should include individual satellite pseudo-ranges and signal-to-noise ratios. These parameters are provided only by receiver manufacturers' proprietary messages. It is not necessary for applicants to conduct a dedicated test for systems using carrier-based DGPS processing.

302(e)(2)(D) System accuracy and sources of DGPS error [ETM 3.2.5.2.4]

If only divergence (spherical spreading) of the noise is considered, and atmospheric absorption mechanisms are ignored, then a 0.1 dB change in the noise level corresponds to a change of approximately 1.1 percent of the distance between the aircraft noise source and the measurement microphone. Thus, for an aircraft altitude of 400 ft (122 m), the approximate minimum altitude during noise certification tests, a position error of 4.3 ft (1.3 m) along the line-of-sight vector connecting the microphone and aircraft can be expected to introduce a 0.1 dB error in the processed noise data. A position error of 10 ft (3.0 m) along the line-of-sight vector can be expected to introduce a 0.23 dB error in the processed noise data.

For most DGPS systems, the most important error sources are, in decreasing order of importance, multi-path, correction latency and tropospheric delay. When these error sources are properly controlled, DGPS systems can provide accuracies between a few centimeters and approximately 15.1 ft (4.6 m) for an aircraft in low-dynamics flight regimes. Even the poorest of these accuracies is superior to that achieved by other conventional TSPI systems used for aircraft noise tests, including microwave and photo-scaling. The best accuracies are superior to those of a laser tracker.

DGPS systems suitable for consideration by noise certification applicants can be expected to achieve an accuracy of a few inches to 5 ft (1.5 m). The highest accuracy is achieved using carrier-based techniques and post-flight processing of data collected from both the aircraft and ground-station computers. Code-based solutions which use carrier smoothing (e.g., Novatel RT-20) achieve accuracies of 3.0 ft to 4.9 ft (0.9 m to 1.5 m), provided that the error sources discussed in this section are addressed properly. Consequently it is expected that the DGPS systems used for noise certification tests will introduce less than a 0.2 dB error into the noise data in a worst-case scenario (i.e., a noise certification approach measurement). Typical errors will be less than 0.1 dB for noise certification flyover and lateral measurements.

In addition to the three error sources cited above, increases in DGPS position errors can also occur when the manufacturer and model of the ground station and aircraft GPS receivers are not the same, or when the ground station and aircraft receivers use different satellite ephemeris/clock data to specify the satellite orbital parameters.

Sections 302(e)(2)(E)and 302(e)(2)(F) address all of the above errors and include methods for minimizing these errors or eliminating them entirely.

302(e)(2)(E) Multi-path errors [ETM 3.2.5.2.5]

302(e)(2)(E)(i) Characteristics [ETM 3.2.5.2.5.1]

Multi-path refers to signals from GPS satellites which are reflected from objects (e.g., the ground, buildings and aircraft structural elements) before reaching the GPS antenna. Multi-path signals add algebraically to the desired line-of-sight signal and thereby decrease the accuracy of measurements made with the latter. Multi-path conditions can occur independently at the aircraft and ground station antennas. Thus the differential correction data from the ground are not directly useful for correction for multi-path errors at the aircraft antenna. Rather, the broadcast corrections can contain ground-station multi-path errors which, in a statistical sense, add to those in the aircraft.

Measurements have consistently shown that the presence of multi-path conditions at the ground station is significantly more deleterious than at the aircraft. This is because ground-station multi-path conditions vary slowly, acting like a bias over a test run of a few minutes, whereas the more dynamic motion of the aircraft causes the effects of airborne multi-path conditions to behave like noise, which can be reduced somewhat by processing techniques such as filtering and averaging.

For code-based processing, ground station multi-path error is typically between 1.0 ft and 10 ft (0.3 m and 3 m). Under very adverse conditions (e.g., GPS antenna near the side of and well below the top of a large building) multi-path errors can be several hundred meters. Multi-path errors associated with carrier-based processing techniques are significantly less than those for code-based methods and are usually of the order of centimeters.

The extent of the multi-path error primarily depends on two factors: the capability of the ground station antenna and the location of the ground station antenna relative to reflecting objects such as paved runways, buildings and parked aircraft. Receiver processing (e.g., the use of narrow correlators available in most Novatel receivers) and/or carrier smoothing, available from several manufacturers, can reduce multi-path errors.

302(e)(2)(E)(ii) Code-based system ground station [ETM 3.2.5.2.5.2]

To mitigate the effects of multi-path conditions on DGPS-based TSPI performance, the applicant's ground station installation should meet the following requirements:

a) the ground station should employ a multi-path-limiting antenna, such as one with a choke ring or an absorbing ground plane; and

b) the ground station antenna should be mounted on a pole or tower, with unobstructed visibility of the sky. A minimum height of 10 ft (3 m) above ground level is recommended for the ground-station antenna.

Additionally, to ensure that significant undetected multi-path errors do not corrupt the TSPI data collected during aircraft noise testing, the applicant's ground-station installation should be tested for adequate multi-path condition performance prior to commencing the flight test. This can be done by collecting GPS receiver data during the same hours of the day that the system will be used for noise tests, with additional one-hour buffers on either side of this period. The data are then examined on a per-satellite basis, rather than navigation solution basis, for multi-path signatures. This examination should include at least pseudo-ranges and signal-to-noise ratios.

If multiple periods of significant multi-path errors (i.e., several feet) are found, then a new location for the ground-station antenna should be selected and tested. If only one or two isolated, brief multi-path incidents are found, then the antenna location can be retained but aircraft testing should not be conducted during these periods.

Note.— The satellite-user geometry repeats over a cycle of approximately 23 hours 56 minutes. Thus if a ground *station multi-path incident is observed one day, it is expected that a similar incident will occur 4 minutes earlier the following day.*

These procedures are similar to those utilized by the United States Coast Guard in checking out a marine DGPS station installation (References T10 and T19).[8] After establishing a ground-station antenna site/configuration that satisfies the multi-path conditions criterion, the ground-station antenna should not be moved without performing another multi-path test. The ground-station GPS receiver and any computer used in conjunction with the receiver may be removed and reinstalled without repeating the multi-path test. The multi-path verification test data should be saved as part of the permanent test-series data archive and should be made available for inspection by the FAA.

302(e)(2)(E)(iii) Carrier-based system ground station [ETM 3.2.5.2.5.3]

To mitigate the effects of multi-path conditions on DGPS-based TSPI performance, the applicant's ground-station installation should meet the following recommended specifications:

a) the ground station should employ a multi-path-limiting antenna, such as one with a choke ring or an absorbing ground plane; and

b) the ground station antenna should be mounted on a pole or tower, with unobstructed visibility of the sky. A minimum height of (9.8 ft (3.0 m) above ground level is recommended for the ground-station antenna.

There is no recommended requirement for collecting data to assess multi-path errors when carrier-based processing is employed.

302(e)(2)(E)(iv) Aircraft installation [ETM 3.2.5.2.5.4]

It is expected that aircraft manufacturers will select a location on each aircraft model that minimizes multi-path effects. In this regard no recommended specifications have been developed. For most smaller aircraft (e.g., 10 seats or fewer), it has been found that the roof area directly behind the windshield is most advantageous. Manufacturers of larger aircraft have found forward positions on the roof to be desirable, although some have mounted the GPS antenna on the tail structure. Selecting a location for the GPS antenna on a helicopter may be more challenging since the main rotor will momentarily obscure most areas on the airframe.

302(e)(2)(F) Other sources of DGPS error [ETM 3.2.5.2.6]

302(e)(2)(F)(i) Correction latency [ETM 3.2.5.2.6.1]

Correction latency, also called staleness, refers to the delay between the time of validity of a differential correction at the ground station and the time that the correction is applied in the aircraft. Delays in processing at both ends of the ground-to-air data link can cause stale corrections to introduce unacceptably large errors.

A second form of latency, solution latency, refers to the delay between the time at which a GPS receiver's measurement is valid and the time when it is available at the output of the receiver. Solution delays are inherently smaller than correction

8. Coast Guard DGPS ground stations employ two GPS receiver/antenna pairs. The "additional" receiver/antenna pair (termed the integrity monitor) provide a real-time continuous check on the validity of the differential corrections generated by the "basic" receiver/antenna pair (termed the reference station). DGPS ground-station architectures being investigated for the FAA LAAS program employ between 2 and 4 receiver/antenna pairs to verify the corrections sent to the aircraft. No requirement for redundant ground-station equipment is recommended for DGPS-based TSPI systems used in noise certification tests.

delays and, in this context, are of concern only for aircraft guidance.

For a system with a real-time data link which employs code-based DGPS solutions, it is strongly recommended that ground-to-aircraft messages conform to the RTCM/SC-104 standards used by the Coast Guard DGPS system.[9] These messages contain pseudo-range rates-of-change, as well as the correction at an identified time, to allow the user to correct for most of the latency-induced error. It is also preferred that the corrections be computed and transmitted at least at a 0.5 Hz rate.

302(e)(2)(F)(ii) Tropospheric delay [ETM 3.2.5.2.6.2]

The troposphere is that portion of the atmosphere between the earth's surface and an altitude of approximately 20 miles (32 km). Differences in meteorological conditions between the ground station and the aircraft can cause dissimilar changes in the propagation times of signals from a satellite to these two locations. The effect is most pronounced for low-elevation-angle satellites. Since these changes are not common to the two locations, they are not removed by differential corrections. Such tropospheric effects can contribute up to 66 ft (20 m) of ranging error on GPS signals, which can translate into as much as 33 ft to 39 ft (10 m to 12 m) of positioning error if not modeled and corrected. In differential mode this positioning error is typically less than 6.6 ft (2 m). Approximately 90 percent of these tropospheric propagation-related errors are due to the hydrostatic, or dry, component of tropospheric delay.

Experiments performed for the FAA LAAS program have found tropospheric differences to introduce DGPS errors between 1 ft and 3 ft (0.3 m and 0.9 m) when the aircraft was at 3000 ft (914 m) altitude, but only a few centimeters when the receiver antennas were at the same altitude. To reduce the effects of tropospheric errors on DGPS-based TSPI systems used in noise certification tests, it is recommended that use of these systems be limited to the aircraft being within a lateral distance of 20 nm (37 km) and a height of 5000 ft (1524 m) relative to the ground station.

If desired, the hydrostatic component of the tropospheric delay can be effectively removed with the application of the tropospheric delay model (Reference T9) developed by the Radio Technical Commission for Aeronautics (RTCA) as per ICAO Annex 10 Standards and Recommended Practices, along with local meteorological measurements at the ground station. The relevant portion of this model is driven by local barometric pressure and satellite geometry (i.e., elevation angle). Reference T18 provides a functional overview of the RTCA model, as well as comparisons with other tropospheric propagation delay models.

302(e)(2)(F)(iii) Mismatched GPS receivers [ETM 3.2.5.2.6.3]

Experiments have shown that DGPS errors are increased when the GPS receivers at the ground station and in the aircraft are not "matched" in terms of manufacturer and model. With mismatched receivers, errors are increased moderately (e.g., 1.5 to 3 times) compared to those when the receivers are matched and when the satellites are operating normally. When a rare, soft satellite-failure, or signal degradation, occurs, errors of several thousand feet have been observed.[10] It is required that applicants' systems have the same manufacturer/model GPS receiver on the ground and in the aircraft.

302(e)(2)(F)(iv) Mismatched satellite ephemeris/clock data [ETM 3.2.5.2.6.4]

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9. The United States Coast Guard DGPS system's broadcast messages (as well as marine systems of other nations) include the rate-of-change of each pseudo-range error, in addition to the pseudo-range error at a reference time. The user's receiver is required to apply an adjusted correction consisting of the broadcast pseudo-range error, plus its rate-of-change multiplied by the time elapsed between the time the adjusted correction is applied, and the validity time for the pseudo-range correction.
10. Beginning on or before 21 October 1993, some differential users with mismatched ground and aircraft receivers experienced position errors of thousands of feet. The GPS Joint Program Office (JPO) of the United States Department of Defense attributed the cause to a "deficiency" in Coarse/Acquisition code broadcast by satellite SVN19. It announced that the problem was corrected on 10 January 1994. Official statements are found in Notice Advisory to NAVSTAR User (NANU) 343-93294, 396-93337 and 006-94010.

GPS satellite broadcasts include a navigation message in the form of 50 bits per second modulation superimposed on the pseudo-random codes used for ranging. Within the navigation message are data sets that describe the satellite orbit (i.e., ephemeris information) and clock. These data sets are transmitted every 30 seconds. The GPS Control Segment uploads multiple ephemeris and clock data sets to the satellites, typically once per day.

Note.— The Control Segment is the ground-based portion of the total GPS system. It includes the Operational Control facility in Colorado Springs, Colorado, United States, where the satellite ephemeris and clock data are calculated, five worldwide sites which collect satellite broadcast signals and provide data to the operational control facility, and three locations from which new ephemeris/clock data are uploaded to the satellites.

Satellites typically change their broadcast ephemeris and clock message every four hours. The ephemeris/clock data sets are used by a receiver to compute its own position and, in the case of a reference station, differential corrections for use by other receivers. For a DGPS system to achieve full accuracy, both the ground station and aircraft receiver must use the same ephemeris and clock data sets. Internal receiver logic ensures that the ephemeris and clock data sets used by a given receiver are consistent for each satellite. However, occasionally the ground and aircraft receivers may use different ephemeris/clock data sets unless measures are taken by the user to ensure that the sets match. Mismatched ephemeris/clock data sets can occur for several reasons, e.g., a receiver is too busy performing other tasks when the data sets change, or a receiver encounters an error while decoding new data and continues to use an old data set.

The RTCM/SC-104 messages used by the Coast Guard DGPS system guard against mismatched ephemeris/clock data sets by including the issue of data (IOD), an eight-bit data set label broadcast by each satellite, in the broadcast messages (References T10 and T19). User receivers which conform to the RTCM/SC-104 standards will not apply differential corrections unless the IOD from the satellite and the DGPS correction message agree. The applicant should ensure that the ground station and aircraft use the same ephemeris and clock data sets during testing. One way is to purchase GPS receivers and select DGPS messages which cause this check to be performed automatically. Another way to ensure agreement between the ground and aircraft ephemeris/clock data sets is to store in a permanent file for record keeping, at a rate of once each 30 seconds, the IOD used by each receiver and compare the IODs during post-test processing.

302(e)(3) System approval recommendations [ETM 3.2.5.3]

This section summarizes approval recommendations for DGPS-based TSPI systems proposed for use during noise certification tests.

302(e)(3)(A) Design issues [ETM 3.2.5.3.1]

Each applicant's TSPI system design should address the issues identified in Table 4. The applicant's documentation (see 302(e)(3)(C)) should address each item in the table.

Table 4. TPSI systems design development issues

Number	*Issue*	*Major considerations*
1	Selection of processing method (real-time versus post-test)	Need for aircraft guidance, ability to check test-run quality
2	Selection of solution method (carrier versus code)	Accuracy (favors carrier), robustness (favors code), cost (favors code)
3	Use of geodetic or waypoint coordinates	Waypoints can simplify post-processing but are not available for all receivers
4	Selection of GPS receiver and antenna	Items 1, 2, 3 and others (antenna multi-path control, data messages, solution latency, matched air/ground receivers, and IOD capability)
5	Selection of data link equipment (if real-time system)	Assigned frequency, data rate, error detection/ correction, flexible interface

302(e)(3)(B) Data storage (logging) during noise testing [ETM 3.2.5.3.2]

302(e)(3)(B)(i) For a system with real-time data link [ETM 3.2.5.3.2.1]

For applicants employing a real-time data link, the ground-station GPS receiver should output RTCM/SC-104 Type-1 messages at a rate of 0.5 Hz or greater, which should be transmitted to and used by the aircraft GPS receiver. The applicant's aircraft computer should collect data from the aircraft GPS receiver and generate permanent data files containing:

a) the three-dimensional aircraft position copied directly from the receiver's data port (i.e., in raw/native form) and not processed;

b) if waypoint navigation is used, the waypoints (i.e., latitude, longitude and altitude) used to define the local coordinate frame;

c) the time (e.g., UTC or GPS time), with or without a local offset, associated with each sample of position data copied directly from the receiver's data port; and

d) the data quality/validity indication associated with each sample of position data.

If waypoints are used they should be included in the header of each data file. New waypoints should not be able to overwrite existing waypoints. If new waypoints are defined then a new data file should be created.

For consistency with the noise data collected during a certification test, it is recommended that the data associated with a), c) and d) above be saved in the GPS receiver's raw/native format at a rate greater or equal to 2 Hz, the rate associated with the noise data. However, if hardware limitations preclude following this recommendation, a sampling rate of 0.5 Hz or greater is acceptable.

302(e)(3)(B)(ii) For a system not using real-time data link [ETM 3.2.5.3.2.2]

TSPI systems which do not use a real-time data link should save data from both the ground and aircraft GPS receivers in raw/native format in a permanent file for record keeping. Manufacturers' proprietary formats should be used. NMEA standard messages do not support this application.

Stored data should include: time (e.g., UTC or GPS time) with or without a local offset, satellite ephemeris, pseudo-range, signal-to-noise ratio, and carrier phase. If tropospheric delay is being modeled, as described in 302(e)(2)(f) then local meteorological conditions should be measured and stored as well. It is recommended that applicants using dual-frequency (L1/L2) receivers also save L2 carrier phase data. Typically, post-processing of the ground-based and airborne GPS data will be performed using manufacturer-supplied software. If this is not the case then any applicant-developed software should be approved by the FAA.

302(e)(3)(C) Documentation
[ETM 3.2.5.3.3]

The applicant should prepare and submit documentation which includes:

a) *System description.* Identifies, at a minimum, the issues in Table 4.

b) *Hardware description.* Model and version number of all system components, including DGPS receivers, antennas, transceivers and computer.

c) *Software description.* Software functionality and capabilities, data file formats, hardware required and operating system.

d) *System setup and operation.* Ground and aircraft installation of the system including antennas, operating procedures, site survey procedures, power requirements and system limitations.

e) *Validating of the installation.* A method often used is to park the aircraft at a known surveyed location and to read its position from the DGPS system. From a comparison of the DGPS and surveyed positions the installation can be verified. This can be performed either at the test site or at another location, such as the aircraft home base. As a minimum this process should be performed at the start and end of each measurement program and preferably at the beginning and end of each measurement day.

302(e)(3)(D) Accuracy verification test
[ETM 3.2.5.3.4]

The applicant should perform a one-time verification of the system accuracy, based on a minimum of six aircraft flight-test runs which encompass the conditions (i.e., speed, altitude, range and maneuvers) for which the system will be later used as a reference. The accuracy verification test should involve a comparison of the DGPS-based TSPI system's position data with those from an accepted reference, such as a laser tracker or another approved DGPS system. This test should be performed on the complete DGPS-based TSPI system developed by the applicant. It is not adequate for an applicant seeking system approval to simply cite prior approval of another applicant's system designed around the same GPS receiver.

302(e)(3)(E) Software verification
[ETM 3.2.5.3.5]

Prior to using the system during a noise measurement program, any applicant-developed software for data logging and post-processing used to obtain data listed herein should be approved by the FAA. The approved software should be placed under version management.

302(e)(3)(F) Ground-station multi-path mitigation and verification
[ETM 3.2.5.3.6]

302(e)(3)(F)(i) All systems [ETM 3.2.5.6.1]

The ground-station GPS receiver antenna should have a choke ring, absorbing ground plane, or other multi-path-reducing technique. The antenna should be positioned on a pole or tower at a minimum height of 10 feet above ground level.

302(e)(3)(F)(ii) Code-based systems [ETM 3.2.5.3.6.2]

Prior to each measurement program, applicants using code-based DGPS systems should perform a multi-path investigation using the ground-station receiver and antenna, as described in 302(e)(2)(E)(ii). The results of the investigation should be saved as part of the permanent test-series data archive and be made available for inspection by the FAA.

302(e)(3)(G) Airport survey [ETM 3.2.5.3.7]

Additional information on survey requirements may be found in 302(e)(2)(B). Prior to and after completion of each measurement program, the applicant should use the DGPS-based TSPI system to survey the locations of:

a) if no other method of survey is used, all microphones and, if used, waypoints; or

b) if another method of survey is used, a recommended minimum of at least three points common to both methods.

Survey data should be stored as part of the measurement-program permanent archive. If two survey methods are used, the common points should be reconciled to an accuracy of 1 ft (0.3 m) and the adjustment procedure submitted to the FAA for approval.

303 ON-BOARD FLIGHT DATA ACQUISITION [ETM 3.3]

303(a) General [ETM 3.3.1]

It is necessary to obtain the values of a variety of flight and engine parameters during the noise measurement period in order to:

a) determine the acceptability of noise certification flight tests;

b) obtain data to adjust noise data; and

c) to synchronize flight, engine and noise data.

Typical parameters would include airspeed, climb angle, height/altitude, gross weight, flap position, landing gear position, jet-engine thrust (power) setting parameters (e.g., compressor rotor speed, engine pressure ratio and exhaust gas temperature), helicopter rotor speed, engine torque and propeller rotational speed.
A number of methods for collecting this information have been employed:

a) manual recording;

b) magnetic tape recording;

c) digital recording;

d) automatic still photographic recording;

e) cine recording; and

f) video recording.

Clearly, when a large number of parameters have to be collected at relatively short time intervals, it may not be practicable to manually record the data. Thus the use of one of the automatic systems listed in b) to f) becomes more appropriate. The choice of a particular system may be influenced by a number of factors such as the space available, cost and availability of equipment.

For systems which optically record the flight deck instruments, care must be taken to avoid strong lighting contrast such as would be caused by sunlight, deep shadow and reflections from the glass fronts of instruments, which would make data unreadable. To avoid this, it may be necessary to provide additional lighting to "fill in" the deep shadow regions. To prevent reflections from the front of instruments, it is recommended that light-colored equipment or clothing on the flight deck be avoided. Flight crews should be required to wear black or dark-colored clothing and gloves.

Furthermore, for systems which record the readings of dials it is important that the recording device be as near as possible, directly in front of the instruments to avoid parallax errors.

303(b) Magnetic Tape Recording
[ETM 3.3.2]

Multi-channel instrumentation tape recorders designed for airborne environments are employed for continuous recording of flight and engine performance parameters. Typical recorders are compact intermediate/wide band and can take both one-half-inch and one-inch magnetic tapes with a 24 to 28 volt DC power requirement. Six tape speeds as well as direct and FM recording are available in a tape recorder weighing about 60 lb (27) kg.

303(c) Automatic Still Photographic Recording
[ETM 3.3.3]

Photographs of the flight deck instrument panel can be taken by using a hand-held 35 mm single-lens reflex (SLR) camera with an 85 mm lens and high-speed slide film. The indications on the instruments can be read by projecting the slides onto a screen.

303(d) Cine Recording
[ETM 3.3.4]

Cine cameras with a one frame per second exposure rate have been used to acquire flight deck data. Care must be taken in mounting the camera to ensure that all the instruments that have to be photographed are within the field of view. Typical film cassettes containing about 2000 frames have been used with a frame counter to allow film changes to be anticipated.

303(e) Video recording
[ETM 3.3.5]

Flight and engine performance parameters can be recorded with a video camera, although as with cine cameras, care must be taken to ensure that all the instruments that have to be photographed are within the field of view. The recorded information is played back using freeze-frame features to obtain individual instrument readings.

304 TIME SYNCHRONIZATION OF MEASURED DATA [ETM 3.4]

304(a) General [ETM 3.4.1]

Sections A36.2.3.2 and H36.101(d)(3) of part 36 specifies that there be precise time synchronization between noise measurements and aircraft position. Several methods have been used, such as noting the synchronization time on a clock mounted on the instrument panel which itself is recorded by the data acquisition system. One such system uses a ground camera that operates a radio transmission which, when received by an aircraft, lights two high-intensity light emitting diodes (LEDs) mounted in an analog clock attached to the instrument panel. Other methods for acquiring and processing TSPI are described in subsequent sections.

A common time base should be used to synchronize noise, aircraft tracking and meteorological measurements. TSPI data should be determined at half-second intervals throughout the sound-measuring period (i.e., within 10 dB of maximum tone corrected perceived noise level (PNLTM)) by an approved method that is independent from systems installed aboard and normally used to control the aircraft. During processing, measured TSPI data should be interpolated, over time, to the time of sound emission of each half-second acoustic data record within the 10 dB-down period. Although the simplified procedure requires adjustment of only the PNLTM record to the reference flight path, sound emission coordinates should be determined for each half-second record for use in background noise adjustment procedures and for determination of incidence-dependent free-field microphone and windscreen corrections.

304(b) TSPI Equipment and Software Approval [ETM 3.4.2]

Some off-the-shelf TSPI equipment may require software enhancement to accommodate the specific installation. All TSPI equipment and software should be demonstrated to, and approved by, the FAA to ensure the system's operational accuracy.

304(c) Continuous Time-Dode Recording [ETM 3.4.3]

This method uses a time-code signal, such as IRIG B, which is a modulated audio-frequency signal used for encoding time-base data developed by the Inter-Range Instrumentation Group (IRIG). In this method, the time-code signals from individual generators that have been synchronized to a common time-base are continuously recorded by both the noise data recorder(s) and by the TSPI system during measurement test runs. Synchronization of multiple generators can be performed either physically, by interconnecting via cable, or by means of radio transmission. The transmitted continuous time-code signal can be recorded directly, or used either continuously or in bursts to maintain synchronization of an independent time-code generator which is being recorded directly. This method allows for high-quality continuous time-code recording when there are intermittent reception problems.

Note 1.— Synchronization should be accomplished at the start of each measurement day and checked at the end of each measurement day to minimize the effects of generator time drift. Any such drift should be documented and accounted for in processing.

Note 2.— GPS-based measurement systems are often used for acquisition of TSPI data. GPS receivers are capable of providing the user with precise time-base information broadcast from the GPS satellite system, in some cases eliminating the need for a separate time-keeping device in the TSPI system.

Note 3.— For noise data recording or for non-GPS-based TSPI systems, dedicated IRIG B time-code generators are available that use the GPS signal to constantly update and maintain time synchronization. Use of such a universal broadcast time-base can greatly simplify the logistics of time synchronization between measurement systems.

Note 4.— There are two available time-bases for GPS-based systems: GPS Time and Coordinated Universal Time

(UTC), whose values differ by more than 10 seconds at any given instant. Although the GPS signal includes both time-bases, not all GPS receivers give the user access to both. Therefore, the user should exercise caution in identifying which time-base is used by each instrument.

Note 5.— Many acoustical data recorders provide separate annotation channels in addition to the normal data channels. These channels are often not suitable for recording a modulated time-code signal because of limitations on dynamic range or bandwidth. In such cases a normal data channel of the recorder should be dedicated to recording the time-code signal.

Note 6.— When continuous time-code recording is used, analysis of the recorded acoustic data can be initiated by routing the time-code channel output into a time-code reader and triggering the analyzer based on readout time.

304(d) Recording of Single Time Marker [ETM 3.4.4]

This method involves transmittal and recording of a radio "hack", or tone, usually used to indicate the "recorders on" or "overhead" time instant. This method typically requires a dedicated channel on both the noise and the TSPI recording systems. When such a system is used, analysis can be triggered manually by an operator listening for the hack, or by a detector circuit responding to the tone. When the operator wishes to start analysis at a time other than that of the time marker, a stopwatch or delay circuit can be used to delay triggering of the analyzer. When manual triggering is employed, the operator should use extreme care to perform the triggering as accurately as possible. Accuracy to within one-tenth of a second can be expected from a conscientious human operator.

304(e) Measurement of the Interval Between Recorder Start and Overhead [ETM 3.4.5]

This method of synchronization involves use of a stopwatch or elapsed-time indicator to measure the interval between start-up of the noise data recorder and the instant that the aircraft position is overhead the centerline noise measurement point. This method can be employed successfully as long as the operator exercises care in timing, the determination of the overhead instant is performed accurately, and the start-up characteristics of the recorder (in both record and playback modes) are known and repeatable. Some recorders have variable start-up times that cannot be predicted. Such recorders are not suitable for this method of synchronization.

304(f) Setting of Internal Time-Stamp Clock [ETM 3.4.6]

Many digital recorders maintain a continuous internal time-of-day function by encoding time data in the recorded data stream. This method uses a digital recorder's sub-code time, synchronized to the time-base used for the TSPI data. As with the continuous time-code recording method, synchronization by this method should be checked at the beginning and end of each measurement day and any drift accounted for in processing.

Unfortunately, the time-setting function on many recorders does not provide for the necessary precision. The "second" digits cannot be made to "tick" in synchrony with an external clock. Such recorders are unsuitable for this method of synchronization.

304(g) Additional Time-Synchronization Considerations [ETM 3.4.7]

Regardless of the synchronization method used, all elements affecting time synchronization, such as analyzer start-up delay, head displacement between normal and annotation data channels on analog recorders, and delays in automated triggering circuits, should be identified, quantified and accounted for in analysis and processing. Whenever human response to a timing event is required, errors cannot be accurately predicted, and conscientious operation is required to minimize such errors. The use of automated methods is preferred. Other methods, or variants of the listed methods, may be appropriate, but the use of all methods and instrumentation is subject to prior approval by the FAA.

305 CALCULATION OF CONFIDENCE INTERVALS [ETM 3.5]

305(a) Introduction [ETM 3.5.1]

The use of NPD curves requires that confidence intervals be determined by using a more general formulation than is used for a cluster of data points. For this more general case, confidence intervals may have to be calculated about a regression line for:

a) flight test data;

b) a combination of flight test and static test data;

c) analytical results; or

d) a combination thereof.

Items b) and c) are of particular significance for noise certification of an aircraft model range and require special care when pooling the different sources of sampling variability.

Sections 305(b) to 305(e) provide an insight into the theory of confidence interval evaluation. Application of this theory and some worked examples are provided in 305(f). A suggested bibliography is provided in Appendix 3 to this AC for those wishing to gain a greater understanding.

305(b) Confidence Interval for the Mean of Flight Test Data [ETM 3.5.2]

305(b)(1) Confidence Interval for the Sample Estimate of the Mean of Clustered Measurements [ETM 3.5.2.1]

If *n* measurements of EPNLs $y_1, y_2, \ldots, y_n$ are obtained under approximately the same conditions and it can be assumed that they constitute a random sample from a normal population with true population mean, μ, and true standard deviation, σ, then the following statistics can be derived:

$\bar{y}$ = estimate of the mean $= \frac{1}{n}\left\{\sum_{i=1}^{i=n} y_{(i)}\right\}$

s = estimate of the standard deviation of the mean

$= \sqrt{\frac{\sum_{i=1}^{i=n}(y_1-\bar{y})^2}{n-1}}$.

From these and the Student's t-distribution, the confidence interval, CI*,* for the estimate of the mean, $\bar{y}$, can be determined as:

$$CI = \bar{y} \pm t_{(1-\frac{\alpha}{2},\delta)} \frac{s}{\sqrt{n}},$$

Where $t_{(1-\frac{\alpha}{2},\delta)}$ denotes the $(1-\frac{\alpha}{2})$ percentile of the single-sided Student's t-test with δ degrees of freedom (for a clustered data set $\delta = n-1$ and where $\alpha$is defined such that $100(1-\alpha)$ percent is the desired confidence level for the confidence interval. In other words it denotes the probability with which the interval will contain the unknown mean, μ. For noise certification purposes, 90 percent confidence intervals are generally desired and thus f $t_{95,\delta}$ is used (see Table 5 for a listing of values of $t_{95,\delta}$ for different values of δ).

305(b)(2) Confidence interval for mean line obtained by regression [ETM 3.5.2.2]

If *n* measurements of EPNL ($y_1, y_2, \ldots, y_n$) are obtained under significantly varying values of engine-related parameter ($x_1, x_2, \ldots, x_n$) respectively, then a polynomial can be fitted to the data by the method of least squares. For determining the mean EPNL, μ, the following polynomial regression model is assumed to apply:

$$\mu = B_0 + B_1 x + B_2 x^2 + \cdots + B_k x^k.$$

The estimate of the mean line through the data of the EPNL is given by:

$$y = b_0 + b_1 x + b_2 x^2 + \cdots + b_k x^k.$$

Each regression coefficient (B_i) is estimated by b_i from the sample data using the method of least squares in a process summarized as follows.

Each observation (x_i, y_i) satisfies the equations:

$$y_i = B_0 + B_1 x_i + B_2 x_i^2 + \cdots . + B_k x_i^k + \varepsilon_i = b_0 + b_1 x_i + b_2 x_i^2 + \cdots . + b_k x_i^k + e_i,$$

Where ε_i and e_i are, respectively, the random error and residual associated with the EPNL. The random error ε_i is assumed to be a random sample from a normal population with mean zero and standard deviation σ. The residual (e_i) is the difference between the measured value and the estimate of the value using the estimates of the regression coefficients and x_i . Its root mean square value (*s*) is the sample estimate for σ. These equations are often referred to as the normal equations.

Table 5. Student's t-distribution (for 90 percent confidence) for various degrees of freedom

Degrees of freedom (ζ)	$t_{.95,\zeta}$
1	6.314
2	2.920
3	2.353
4	2.132
5	2.015
6	1.943
7	1.895
8	1.860
9	1.833
10	1.812
12	1.782
14	1.761
16	1.746
18	1.734
20	1.725
24	1.711
30	1.697
60	1.671
>60	1.645

The *n* data points of measurements (x_i, y_i) are processed as follows:

Each elemental vector ($\underline{x_i}$) and its transpose ($\underline{x_i'}$) are formed such that:

$$\underline{x_i} = (1\ x_i\ \ x_i^2 \ldots x_i^k)\text{, a row vector; and}$$

$$\underline{x_i'} = \begin{pmatrix} 1 \\ x_i \\ x_i^2 \\ : \\ . \\ x_i^k \end{pmatrix}\text{, a column vector.}$$

A matrix $\underline{X}$ is formed from all the elemental vectors $\underline{x_i}$ for i = 1, ….., n. $\underline{X'}$ is the transpose of $\underline{X}$. A matrix $\underline{A}$ is defined such that $\underline{A} = X'\underline{X}$ and a matrix $\underline{A^{-1}}$ is the inverse of $\underline{A}$ In addition, $\underline{y} = (y_1 y_2 \ldots y_n)$, and $\underline{b} = (b_0 b_1 \ldots b_k)$, with $\underline{b}$ determined as the solution of the normal equations:

$$\underline{y} = \underline{Xb} \text{ and } \underline{X'y} = \underline{X'Xb} = \underline{Ab},$$

to give

$$\underline{b} = \underline{A^{-1}}\underline{X'y}.$$

The 90 percent confidence interval CI_{90} for the mean value of the EPNL estimated with the associated value of the engine-related parameter x_0 is then defined as:

$$CI_{90} = \overline{y}(x_0) \pm t_{95,\delta} s v(x_0),$$

where $v(x_0) = \underline{\sqrt{x_0 A^{-1} x_0'}}$.

Thus $CI_{90} = \overline{y}(x_0) \pm t_{.95,\delta} s \underline{\sqrt{x_0 A^{-1} x_0'}}$,

where:

- $\underline{x_0} = (1 x_0 x_0^2 \ldots x_0^k)$;
- x_0' is the transpose of $\underline{x_0}$;
- $\overline{y}(x_0)$ is the estimate of the mean value of the EPNL at the associated value of the engine-related parameter;
- $t_{.95,\zeta}$ is obtained for ζ degrees of freedom. For the general case of a multiple regression analysis involving K independent variables (i.e., $K + 1$ coefficients) ζ is defined as $\zeta = n\text{-}K\text{-}1$ (for the specific case of a polynomial regression analysis, for which k is the order of curve fit, there are k variables independent of the dependent variable, and so $\zeta = n\text{-}K\text{-}1$); and
- $s = \sqrt{\frac{\sum_{i=1}^{i=n}(y_i - \overline{y}(x_i))^2}{n-K-1}}$, the estimate of σ the true standard deviation.

305(c) Confidence Interval for Static-Test-Derived NPD Curves [ETM 3.5.3]

When static test data are used in family certifications, NPD curves are formed by the linear combination of baseline flight regressions, baseline projected static regressions and derivative projected static regressions in the form:

$$EPNL_{DF} = EPNL_{BF} - EPNL_{BS} + EPNL_{DS},$$

or using the notation adopted above:

$$\overline{y_{DF}}(x_0) = \overline{y_{BF}}(x_0) - \overline{y_{BS}}(x_0) + \overline{y_{DS}}(x_0),$$

where:

DF denotes derivative flight;

BF denotes baseline flight;

BS denotes baseline static; and

DS denotes derivative static.

Confidence intervals for the derivative flight NPD curves are obtained by pooling the three data sets, each with their own polynomial regression. The confidence interval for the mean derived EPNL at engine-related parameter x_0, i.e., for $\mu_{DF}(x_0)$, is given by:

$$CI_{90}(x_0) = \overline{y_{DF}}(x_0) \pm t' v_{DF}(x_0)$$

where:

$$v_{DF}(x_0) = \sqrt{(s_{BF} v_{BF}(x_0))^2 + (s_{BS} v_{BS}(x_0))^2 + (s_{DS} v_{DS}(x_0))^2}$$

with s_{BF}, s_{BS}, s_{DS}, $v_{BF}(x_0)$, $v_{BS}(x_0)$, $v_{DS}(x_0)$ computed as explained in 3.5.2.2 for the respective data sets indicated by the subscripts BF, BS and DS, and

$$t' = \frac{(s_{BF} v_{BF}(x_0))^2 t_{BF} + (s_{BS} v_{BS}(x_0))^2 t_{BS} + (s_{DS} v_{DS}(x_0))^2 t_{DS}}{(s_{BF} v_{BF}(x_0))^2 + (s_{BS} v_{BS}(x_0))^2 + (s_{DS} v_{DS}(x_0))^2}$$

where t_{BF}, t_{BS}, t_{DS} are the $t_{95,\zeta}$ values each evaluated with the respective degrees of freedom ζ_{BF}, ζ_{BS}, ζ_{DS} as they arise in the corresponding regressions.

305(d) Confidence Interval for Analytically Derived NPD Curves [ETM 3.5.4]

Analysis may be used to determine the effect of changes in noise source components on certificated levels. This is accomplished by analytically determining the effect of hardware change on the noise component it generates. The resultant delta (Δ) is applied to the original configuration, and new noise levels are computed. The changes may occur on the baseline configuration or on subsequent derivative configurations. The confidence intervals for this case are computed using the appropriate method from 305(b) and 305(c).

If $\hat{\Delta}$ represents the analytically determined change and if it is assumed that it may deviate from the true unknown Δ by some random amount, *d,* such that:

$$\hat{\Delta} = \Delta + d,$$

Where d is assumed to be normally distributed with mean zero and known variance τ^2, then the confidence interval for $\mu(x_0) + \Delta$ is given by:

$$(\overline{y}(x_0) + \hat{\Delta}) \pm t' v'(x_0),$$

Where $v'(x_0) = \sqrt{v(x_0)^2 + \tau^2}$ and *t'* is as above without change.

305(e) Adequacy of the Model [ETM 3.5.5]

305(e)(1) Choice of engine-related parameter [ETM 3.5.5.1]

Every effort should be made to determine the most appropriate engine-related parameter, *x*, which may be a combination of various simpler parameters.

305(e)(2) Choice of regression model [ETM 3.5.5.2]

It is not recommended in any case that polynomials of greater complexity than a simple quadratic be used for certification purposes, unless there is a clear basis for using a higher order polynomial.

Standard texts on multiple regression should be consulted, and the data available should be examined to show the adequacy of the model chosen.

305(f) Worked Example of the Determination of 90 percent Confidence Intervals from the Pooling of Three Data Sets [ETM 3.5.6]

305(f)(1) Introduction [ETM 3.5.6.1]

This section presents an example of the derivation of the 90 percent confidence intervals arising from the pooling of three data sets. Worked examples and guidance material are presented for the calculation of confidence intervals for a clustered data set as well as for first order (i.e., straight line) and second order (i.e., quadratic) regression curves. In addition this section also shows how the confidence interval must be established for the pooling together of several data sets.

Consider the theoretical evaluation of the certification noise levels for an aircraft retrofitted with silenced engines. The approach noise level for the "flight datum" aircraft was derived from a clustered data set of noise levels measured at nominally reference conditions, to which were added source noise corrections derived from a quadratic least-squares curve fit through a series of data points made at different engine thrusts. In order to evaluate the noise levels for the aircraft fitted with acoustically treated engines, a further source noise curve, assumed to be a straight least-squares regression line, was established from a series of measurements of the silenced aircraft. Each of the three databases is assumed to be made up of data unique to each base.

The clustered data set consists of six EPNL levels for the nominal datum hard wall condition. These levels have been derived from measurements which have been fully corrected to the hard wall approach reference condition.

The two curves which determine the acoustical changes are the regression curves (in this example quadratic and straight-line least-squares fit curves) for the plots of EPNL against normalized thrust for the hard wall and silenced conditions. These are presented in Figure 6 where the dotted lines plotted about each line represent the boundaries of 90 percent confidence.

Each of the two curves is made up of the full set of data points obtained for each condition during a series of back-to-back tests. The least-squares fits therefore have associated with them all the uncertainties contained within each data set. It is maintained that the number of data points in each of the three sets is large enough to constitute a statistical sample.

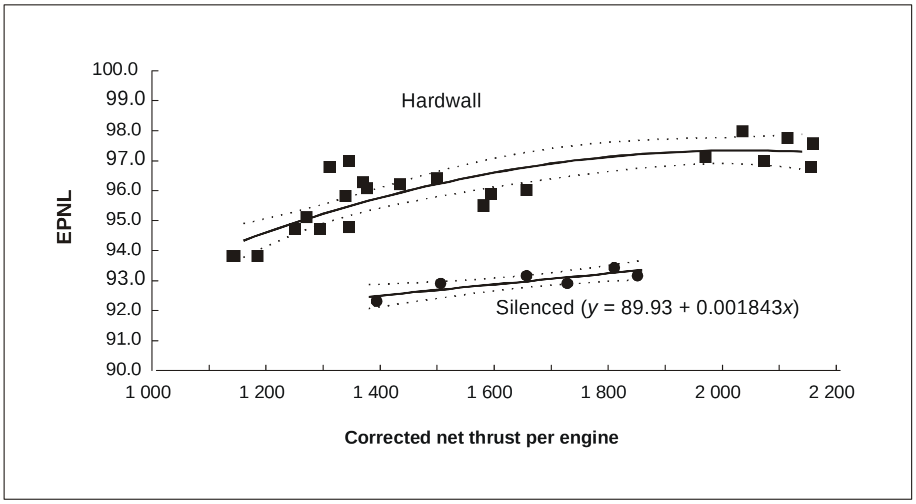

Figure 6. Regression curves for plots of EPNL against normalized thrust for hard wall and silenced conditions

305(f)(2) Confidence interval for a clustered data set [ETM 3.5.6.2]

The confidence interval for the clustered data set is defined as follows:

Let $EPNL_i$ be the individual values of EPNL,

n = number of data points; and

t = Student's t-distribution for (n-1) degrees of freedom (i.e., the number of degrees of freedom associated with a clustered data set).

Then the confidence interval $CI = \overline{EPNL} \pm t\frac{s}{\sqrt{n}}$, where s, the estimate of the standard deviation, is defined as:

$$s = \sqrt{\frac{\sum_{i=1}^{i=n}(EPNL_i - \overline{EPNL})^2}{n-1}}, \text{ and}$$

$$\overline{EPNL} = \frac{\sum_{i=1}^{i=n} EPNL_i}{n}.$$

Suppose that the clustered set of EPNL values consists of the following:

Run number	*EPNL*
1	95.8
2	94.8
3	95.7
4	95.1
5	95.6
6	95.3

Then the number of data points (*n*) = 6, the degrees of freedom (*n*-1) = 5, and the Student's t-distribution for 5 degrees of freedom = 2.015 (see Table 5), and so:

$$\overline{EPNL} = \frac{\sum_{i=1}^{i=n} EPNL_i}{n} = 95.38,$$

$$s = \sqrt{\frac{\sum_{i=1}^{i=n}(EPNL_i - \overline{EPNL})^2}{n-1}} = 0.3869,$$

and the confidence interval (CI) is calculated as follows:

$$CI = \overline{EPNL} \pm t\frac{s}{\sqrt{n}} = 95.38 \pm 2.015\frac{0.3869}{\sqrt{6}} = 95.38 \pm \underline{0.3183}$$

305(f)(3) Confidence interval for a first order regression curve [ETM 3.5.6.3]

Suppose that the regression curve for one of the source noise data sets, the silenced case, can best be represented by a straight line least-squares fit curve (i.e., a first order polynomial).

The equation for this regression line is of the general form:

$$Y = a + bX$$

where *Y* represents the dependent variable EPNL, and *X* represents the independent variable, in this case normalized thrust $\frac{F_N}{\delta}$.

Although for higher order polynomial least-squares curves a regression line's coefficients (i.e., the solutions to the "normal equations") are best established through computer matrix solutions, the two coefficients for a straight-line fit, *a* and *b,* can be determined from the following two simple formulae for the measured values of *X* and *Y*, X_i and Δ_i :

$$a = \frac{\sum_{i=1}^{i=n} Y_i - b\sum_{i=1}^{i=n} X_i}{n}\text{; and}$$

$$b = \frac{Covariance}{Variance} = \frac{S_{xy}^2}{S_x^2}\text{, where:}$$

$$Sxy^2 = \frac{\sum_{i=1}^{i=n} X_i Y_i}{n} - \frac{\sum_{i=1}^{i=n} X_i \sum_{i=1}^{i=n} Y_i}{n^2}\text{ ;and}$$

$$S_x^2 = \frac{\sum_{i=1}^{i=n} X_i^2}{n} - (\frac{\sum_{i=1}^{i-n} X_i}{n})^2.$$

The 90 percent confidence interval about this regression line for X = x_0 is then defined by:

$$CI_{90} = \overline{Y} \pm ts\sqrt{x_0 A^{-1} x_0'}$$

where:

t = Student's t-distribution for 90 percent confidence corresponding to (*n* – *k* - *1*) degrees of freedom, where *k* is the order of the polynomial regression line and *n* is the number of data points;

$$\underline{x_0} = (1 x_0);$$

$$\underline{x_0'} = (\begin{matrix}1\\ x_0\end{matrix});$$

$\underline{A^{-1}}$ is the inverse of $\underline{A}$ where $\underline{A} = \underline{X'X}$, with $\underline{X}$ and X' defined as in 305(b)(2) from the elemental vectors formed from the measured values of the independent variable X_i; and

$$s = \sqrt{\frac{i=1}{n-k-1}}$$

Where $(\Delta Y)_i$ = the difference between the measured value of Y_i at its associated value of X_i, and the value of Y derived from the straight line least-squares fit curve for X = X_i, and *n* and *k* are defined as the number of data points and the order of the polynomial regression line, respectively.

Suppose that the data set consists of the following set of six EPNL values, together with their associated values of engine-related parameter (see Table 6). Note that it would be usual to have more than six data points making up a source noise curve, but in order to limit the size of the matrices in this example, the number of data points has been restricted.

By plotting this data (see Figure 6) it can be seen by examination that a linear relationship between EPNL (the dependent variable *Y*) and $\frac{F_N}{\delta}$ (the independent variable *X*) is suggested with the following general form:

$$Y = a + bX.$$

The coefficients *a* and *b* of the linear equation are defined as above and may be calculated as follows:

X	*Y*	*XY*	*X*²
1 395	92.3	128 759	1 946 025
1 505	92.9	139 815	2 265 025
1 655	93.2	154 246	2 739 025
1 730	92.9	160 717	2 992 900
1 810	93.4	169 054	3 276 100
1 850	93.2	172 420	3 422 500
∑X	∑Y	∑XY	∑X²
9 945	557.9	925 010	16 641 575

$$a = \frac{\sum_{i=1}^{i=n} Y_i - b\sum_{i=1}^{i=n} X_i}{n} = \frac{557.9-(0\ 001843)(9945)}{6} = 89.93$$ and

$$b = \frac{Covariance}{Variance} = \frac{S_{xy}^2}{S_x^2}$$, where:

$$Sxy^2 = \frac{\sum_{i=1}^{i=n} X_iY_i}{n} - \frac{\sum_{i=1}^{i=n} X_i \sum_{i=1}^{i=n} Y_i}{n^2} = \frac{925010}{6} - \frac{(9945)(557.9)}{36} = 48.46$$; and

$$S_x^2 = \frac{\sum_{i=1}^{i=n} X_i^2}{n} - \left(\frac{\sum_{i=1}^{i-n} X_i}{n}\right)^2 = \frac{16641575}{6} - \left(\frac{9945}{6}\right)^2 = 26.289.6$$, to give:

$$b = \frac{48.46}{26289.6} = 0.001843.$$

The 90 percent confidence interval about this regression line is defined as:

$$CI_{90} = \overline{Y} \pm ts\sqrt{x_0 A^{-1} x_0'}$$

and is calculated as follows. From the single set of measured independent variables tabulated in Table 6, the matrix, $\underline{X}$, is formed from the elemental row vectors such that:

$$\underline{X} = \begin{pmatrix} 1 & 1395 \\ 1 & 1505 \\ 1 & 1655 \\ 1 & 1730 \\ 1 & 1810 \\ 1 & 1850 \end{pmatrix}$$

and $\underline{X'}$, the transpose of $\underline{X}$, where

$$\underline{X'} = \begin{pmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ 1395 & 1505 & 1655 & 1730 & 1810 & 1850 \end{pmatrix}.$$

The matrix $\underline{A}$ is now formed, defined such that $\underline{A} = \underline{X'X}$ and so:

$$\underline{A} = \begin{pmatrix} 6 & 9945 \\ 9945 & 16641575 \end{pmatrix},$$

and its inverse $\underline{A}^{-1}$ such that:

$$\underline{A^{-1}} = \begin{pmatrix} 17.5836 & -0.01051 \\ -0.01051 & 6.3396 * 10^{-6} \end{pmatrix}.$$

Note.— The manipulation of matrices (i.e., their multiplication and inversion) is best performed by computers via standard routines. Such routines are possible using standard functions contained within many commonly used spreadsheets.

Table 6. Values of sample data set

Run number	$\frac{F_N}{\delta}$	*EPNL*
1	1 395	92.3
2	1 505	92.9
3	1 655	93.2
4	1 730	92.9
5	1 810	93.4
6	1 850	93.2

To find the 90 percent confidence interval about the regression line for a value of $\frac{F_N}{\delta}$ (i.e., x_0) of 1 600, the row vector ($\underline{x_0}$) and its transpose ($\underline{x'_0}$), a column vector, are formed such that:

$$\underline{x_0} = (1 \;\; 1600),$$

and

$$\underline{x'_0} = \begin{pmatrix} 1 \\ 1600 \end{pmatrix}.$$

From the calculation of $\underline{A^{-1}}$ one obtains:

$$\underline{x_0 A^{-1}} = (1 \;\; 1600)\begin{pmatrix} 17.5836 & -0.01051 \\ -0.01051 & 6.3396 * 10^{-6} \end{pmatrix} = (0.7709 \;\; -3.6453 * 10^{-4}),$$

and so:

$$x_0 A^{-1} \underline{x'_0} = (0.7709 \;\; -3.6453 * 10^{-4})\begin{pmatrix} 1 \\ 1600 \end{pmatrix} = 0.1876.$$

The equation for confidence interval also requires the value of standard deviation for the measured data set to be evaluated. From Table 6 and the regression equation for the least-squares best fit straight line, from which is calculated the predicted value of EPNL at each of the six measured values of $\frac{F_N}{\delta}$ one proceeds as follows:

Run number	$\frac{F_N}{\delta}$	EPNL *(Measured)*
1	1 395	92.3
2	1 505	92.9
3	1 655	93.2
4	1 730	92.9
5	1 810	93.4
6	1 850	93.2

Run number	EPNL *(Predicted)*	$(\Delta EPNL)^2$
1	92.50	0.03979
2	92.70	0.03911
3	92.98	0.04896
4	93.12	0.04708
5	93.26	0.01838
6	93.34	0.01909

$$s = \sqrt{\frac{\sum_{i=1}^{i=n}(\Delta EPNL)_i^2}{n-k-1}} = \sqrt{\frac{0.21241}{6-1-1}} = 0.2304$$

for $n = 6$ and $k = 1$.

Taking the value of Student's t-distribution from Table 5 for $(n - k - 1)$ degrees of freedom (i.e., 4) to be 2.132, the confidence interval about the regression line at $\frac{F_N}{\delta} = 1600$ is defined as follows:

$$CI_{90} = \overline{EPNL} + ts\sqrt{x_0 A^{-1} x'_0} = 92.88 \pm (2.132)(0.2304)\sqrt{0.1876} = 92.88 \pm 0.2128$$

In order to establish the lines of 90 percent confidence intervals about a regression line, the values of CI_{90} for a range of values of independent variable(s) should be calculated, through which a line can be drawn. These lines are shown as the dotted lines in Figure 6.

305(f)(4) Confidence interval for a second order regression curve [ETM 3.5.6.4]

The confidence intervals for a second order regression curve are derived in a similar manner to those for a straight line detailed in 305(f)(3). A detailed example of their calculation is not discussed here. However the following points should be borne in mind.

The coefficients of the least-squares regression quadratic line are best determined via computer matrix solutions. Regression analysis functions are a common feature of many proprietary software packages.

The matrices $\underline{x_0}, \underline{x'_0}, \underline{X}, and\ \underline{X'}$ formed during the computation of the confidence interval according to the formula:

$$CI_{90} = \overline{Y} \pm ts\sqrt{x_0 A^{-1} x'_0}$$

are formed from 1 × 3 and 3 × 1 row and column vectors respectively, made up from the values of independent variable *X* according to the following general form:

$$\underline{x} = (1 \;\; x \;\; x^2) and\ x' = \begin{pmatrix} 1 \\ x \\ x^2 \end{pmatrix}.$$

The number of degrees of freedom associated with a multiple regression analysis involving *K* variables independent of the dependent variable (i.e., with (*K+1*) coefficients, including the constant term) is defined as (*n – K - 1*) . For a second order regression curve, there are two independent variables and so the number of degrees of freedom is (*n-3*) .

305(f)(5) Confidence interval for the pooled data set [ETM 3.5.6.5]

The confidence interval associated with the pooling of three data sets is defined as follows:

$$CI = \overline{Y} \pm T\sqrt{\textstyle\sum_{i=1}^{i=3} Z_i^2},$$

where:

$$Z_i = \frac{CI_i}{t_i},$$

With CI_i = confidence interval for the *i*-th data set,

t_i = the value of Student's t-distribution for the *i*-th data set, and

$$T = \frac{\sum_{i=1}^{i=3} Z_i^2 t_i}{\sum_{i=1}^{i=3} Z_i^2}.$$

The different stages in the calculation of the confidence interval at the reference thrust of $\frac{F_N}{\delta} = 1600$ for the pooling of the three data sets are summarized in

Table 7.

305(g) Student's t-distribution (for 90 percent Confidence) for Various Degrees of Freedom [ETM 3.5.7]

The values in the Student's t-distribution to give a probability of 0.95 that the population mean value (μ) is such that:

$$\mu \leq \overline{y} + t_{.95,\delta}\frac{s}{\sqrt{n}}$$

and thus a probability of 90 percent that

$$\overline{y} - t_{.95,\delta}\frac{s}{\sqrt{n}} \leq \mu \leq \overline{y} + t_{.95,\delta}\frac{s}{\sqrt{n}}$$

are tabulated in Table 5.

Table 7. Example of confidence interval calculation

Description	*Function*	*Datum*	*Hard wall*	*Silenced*
Reference thrust	$\frac{F_N}{\delta}$		1 600	1 600
90% confidence interval about the mean	CI_{90}	0.3183	0.4817	0.2128
Number of data points	*n*	6	23	6
Degree of curve fit	*k*	0	2	1
Number of independent variables	*K*	0	2	1
Number of degrees of freedom	$N – K - 1$	5	20	4
Student's t-distribution	*t*	2.015	1.725	2.132
Z	$\frac{CI_{90}}{t}$	0.1580	0.2792	0.09981
Z^2	$(\frac{CI_{90}}{t})^2$	2.4953×10^{-2}	7.7979×10^{-2}	9.9625×10^{-3}
Z^2t	$(\frac{CI_{90}}{t})^2 t$	5.0280×10^{-2}	0.1345	2.1240×10^{-2}
$\sum Z^2$			0.1129	
$\sum(Z^2 t)$			0.2060	
T	$\frac{\sum(Z^2 t)}{\sum Z^2}$		1.8248	
$\sqrt{\sum Z^2}$			0.3360	
CI	$T\sqrt{\sum Z^2}$		0.6131	

306 ADJUSTMENT OF AIRCRAFT NOISE LEVELS FOR THE EFFECTS OF BACKGROUND NOISE [ETM 3.6]

306(a) Introduction [ETM 3.6.1]

The following is provided as guidance material on procedures for adjusting measured aircraft noise levels for the effects of background noise.

The presence of background noise during aircraft noise certification tests can influence measured aircraft sound levels and, in some cases, obscure portions of the spectral time history used to obtain EPNL values. Adjustment procedures should include the following components:

a) testing to determine which portions of the spectral time history, if any, are obscured;

b) adjustment of unobscured levels to determine the aircraft sound levels that would have been measured in the absence of background noise; and

c) replacement or reconstruction of obscured levels by frequency extrapolation, time extrapolation or other means.

Definitions of the terms used in this section are provided in 306(b). Although some of the terms have generally accepted meanings, the specific meanings as defined apply herein.

A detailed step-by-step procedure is presented in 306(c) including equations and descriptions of time and frequency extrapolation methods (see 306(c)(2)(J)). Other procedures may be used provided that they have been approved by the FAA.

General considerations that apply to any background noise adjustment procedure are listed in 306(d), including limitations and requirements (see 306(d)(1)) and other special considerations (see 306(d)(2) through 306(d)(4)).

306(b) Definitions
[ETM 3.6.2]

For the purposes of 306, the following definitions apply:

Adjusted level. A valid one-third octave band level which has been adjusted for measurement conditions, including:

a) the energy contribution of pre-detection noise; and

b) frequency-dependent adjustments such as system frequency response, microphone pressure response and free-field response, and windscreen incidence-dependent insertion loss.

Ambient noise. The acoustical noise from sources other than the test aircraft present at the microphone site during aircraft noise measurements. Ambient noise is one component of background noise.

Background noise. The combined noise present in a measurement system from sources other than the test aircraft, which can influence or obscure the aircraft noise levels being measured. Typical elements of background noise include, but are not limited to, ambient noise from sources around the microphone site, thermal electrical noise generated by components in the measurement system, magnetic flux noise ("tape hiss") from analog tape recorders and digitization noise caused by quantization error in digital converters. Some elements of background noise, such as digitization noise, can obscure the aircraft noise signal, while others, such as ambient noise, can also contribute energy to the measured aircraft noise signal.

Energy-subtraction. Subtraction of one sound pressure level from another, on an energy basis, in the form of the following:

$$10log_{10}[10^{(\frac{L_A}{10})} - 10^{(\frac{L_B}{10})}]$$

where L_A and L_B are two sound pressure levels in decibels, with L_B being the value subtracted from L_A.

Frequency extrapolation. A method for reconstruction of high frequency masked data, based on unmasked data in a lower-frequency one-third octave band from the same spectrum.

High frequency bands. The twelve bands from 800 Hz through 10 kHz inclusive (also see "low frequency bands").

Last good band (LGB). In the adjustment methodology presented in 3.6.3, for any aircraft one-third band spectrum, the LGB is the highest frequency unmasked band within the range of 630 Hz to 10 kHz inclusive, below which there are no masked high frequency bands.

Low frequency bands. The twelve bands from 50 Hz through 630 Hz inclusive (also see “high frequency bands”).

Masked band. Within a single spectrum, any one-third octave band containing a masked level.

Masked level. Any one-third octave band level which is less than or equal to the masking criterion for that band. When a level is identified as being masked, the actual level of aircraft noise in that band has been obscured by background noise and cannot be determined. Masked levels can be reconstructed using frequency extrapolation, time extrapolation or other methods.

Masking criteria. The spectrum of one-third octave band levels below which measured aircraft sound pressure levels are considered to be masked or obscured by background noise. Masking criteria levels are defined as the greater of:

a) pre-detection noise + 3 dB; or

b) post-detection noise + 1 dB.

Post-detection noise. The minimum levels below which measured noise levels are not considered valid. Usually determined by the baseline of an analysis “window” or by the amplitude non-linearity characteristics of components in the measurement and analysis system. Post-detection noise levels are non-additive (i.e., they do not contribute energy to measured aircraft noise levels).

Pre-detection noise. Any noise which can contribute energy to the measured levels of sound produced by the aircraft, including ambient noise present at the microphone site and active instrumentation noise present in the measurement, record/playback and analysis systems.

Reconstructed level. A level, calculated by frequency extrapolation, time extrapolation, or by other means, which replaces the measured value for a masked band.

Sound attenuation coefficient. The reduction in level of sound within a one-third octave band, in dB per 100 meters, due to the effects of atmospheric absorption of sound.

Time extrapolation. A method for reconstruction of high frequency masked data, based on unmasked data in the same one-third octave band, from a different spectrum in the time history.

Valid or unmasked band. Within a single spectrum, any one-third octave band containing a valid level.

Valid or unmasked level. Any one-third octave band level which exceeds the masking criterion for that band.

306(c) Background Noise Adjustment Procedure [ETM 3.6.3]

306(c)(1) Assumptions [ETM 3.6.3.1]

a) A typical aircraft spectrum measured on the ground contains one-third octave band levels which decrease in amplitude with increasing frequency. This characteristic high frequency roll-off is due primarily to the effects of atmospheric absorption.

b) A typical electronic instrumentation floor spectrum contains one-third octave band levels which increase in amplitude with increasing frequency.

c) Due to the assumptions cited in a) and b), as the observed frequency is increased within a one-third octave band aircraft spectrum and once a band becomes masked, all subsequent higher frequency bands will also be masked. This allows the implementation of a Last Good Band (LGB) label to identify the frequency band above which the bands in a spectrum are masked.

d) If, on occasion, a valid level occurs in a band with higher center frequency than the LGB, its presence will most likely be due to small variations in the pre-detection levels and/or due to levels of the measured aircraft one-third octave band spectrum being close to the levels of the background noise in general, so its energy contribution will not be significant. Note that this assumption is valid only in the absence of significant aircraft-generated tones in the region of masking. Therefore, the possibility of a level being valid in a band with higher center frequency than the LGB may be ignored. Applicants who prefer to implement algorithms for identifying and handling such situations may do so, but no procedure may be used without prior approval by the FAA.

306(c)(2) Step-by step description [ETM 3.6.3.2]

306(c)(2)(A) Determination of pre-detection noise [ETM 3.6.3.2.1]

A time-averaged one-third octave band spectrum of pre-detection noise levels for each test run, or group of runs occurring during a short time period, should be obtained by recording and analyzing ambient noise over a representative period of time (30 seconds or more). Care should be taken to ensure that this “ambient” noise sample reasonably represents that which is present during measured aircraft runs. In recording ambient noise, all gain stages and attenuators should be set as they would be during the aircraft runs in order to ensure that the instrumentation noise is also representative. If multiple gain settings are required for aircraft noise measurements, a separate ambient sample should be recorded at each of the settings used.

306(c)(2)(B) Determination of post-detection noise [ETM 3.6.3.2.2]

A one-third octave band spectrum of post-detection noise levels should be determined as a result of testing, or from manufacturer’s specifications, for each measurement/analysis configuration used, including different gain and/or sensitivity settings. These minimum valid levels may be determined on the basis of display limitations (e.g., blanking of the displayed indication when levels fall below a certain value), amplitude non-linearity or other non-additive limitations. In cases where more than one component or stage of the measurement/analysis system imposes a set of minimum valid levels, the most restrictive in each one-third octave band should be used.

306(c)(2)(C) Testing of pre-detection noise versus post-detection noise [ETM 3.5.3.2.3]

The validity of pre-detection noise levels must be established before these levels can be used to adjust valid aircraft noise levels. Any pre-detection noise level that is equal to or less than the post-detection noise level in a particular one-third octave band should be identified as invalid and therefore should not be used in the adjustment procedure.

306(c)(2)(D) Determination of masking criteria [ETM 3.6.3.2.4]

Once the pre-detection noise and post-detection noise spectra are established, the masking criteria can be identified. For each one-third octave band, compare the valid pre-detection noise level + 3 dB with the post-detection noise level + 1 dB. The highest of these levels is used as the masking criterion for that band. If there is no valid pre-detection noise level for a particular one-third octave band, then the post-detection noise level + 1 dB is used as the masking criterion for that band. The 3 dB window above pre-detection levels allows for the doubling of energy which could occur if an aircraft noise level were equal to the pre-detection level. The 1 dB window above the post-detection levels allows for a reasonable amount of error in the determination of those levels.

306(c)(2)(E) Identification of masked levels [ETM 3.6.3.2.5]

Each spectrum in the aircraft noise time history can be evaluated for masking by comparing the one-third octave band levels against the masking criteria levels. Whenever the aircraft level in a particular band is less than or equal to the associated masking criterion, that aircraft level is considered masked. A record must be kept of which bands in each spectrum are masked.

306(c)(2)(F) Determination of Last Good Band [ETM 3.6.3.2.6]

For each half-second spectral record, determine the highest frequency unmasked one-third octave band ("Last Good Band " or "LGB") by starting at the 630 Hz band and incrementing the band number (i.e., increasing frequency) until a masked band is found. At that point, set LGB for that spectral record equal to the band below the masked band. The lowest frequency band that can be identified as LGB is the 630 Hz band. In other words, if both the 630 Hz band and the 800 Hz band are masked, no reconstruction of masked levels may be performed for that spectrum, and the thirteen bands between 630 Hz and 10 kHz inclusive should be left as is and identified as masked. According to the masking limits specified in 306(d)(2), such a spectrum is not valid for calculation of EPNL.

306(c)(2)(G) Adjustment of valid levels for background noise [ETM 3.6.3.2.7]

In each half-second spectrum, for each valid band up to and including LGB, perform an energy-subtraction of the valid pre-detection level from the valid measured level in the aircraft noise time history using:

$$10log_{10}[10^{(\frac{L_{Aircraft}}{10})} - 10^{(\frac{L_{Predetection}}{10})}]$$

Energy-subtraction should be performed on all valid one-third octave band noise levels. For any one-third octave band where there is no valid pre-detection noise level, no energy-subtraction may be performed (i.e., this adjustment cannot be applied when either the measured aircraft noise time-history level or the pre-detection noise level is masked).

306(c)(2)(H) Adjustment of valid levels for measurement conditions [ETM 3.6.3.2.8]

Before any reconstruction can be done for masked levels, valid levels which have been adjusted for the presence of pre-detection noise must also then be adjusted for frequency-dependent adjustments such as system frequency response, microphone pressure response and free-field response, and windscreen incidence-dependent insertion loss. These adjustments cannot be applied to masked levels.

306(c)(2)(I) Reconstruction of low frequency masked bands [ETM 36.3.2.9]

In cases where a single masked low frequency one-third octave band occurs between two adjacent valid bands, the masked level can be retained, or the arithmetic average of the adjusted levels of the adjacent valid bands may be used in place of the masked level. If the average is used, the level should be categorized as reconstructed. However, if masked low frequency bands are found adjacent to other masked low frequency bands, these masked levels should be retained and remain categorized as masked. The procedure presented in this 306(c) does not provide for any other form of reconstruction for masked low frequency bands.

306(c)(2)(J) Reconstruction of levels for masked high frequency bands [ETM 3.6.3.2.10]

Frequency extrapolation and time extrapolation are the methods used to reconstruct masked one-third octave band levels for bands at frequencies higher than LGB for each spectral record. One-third octave band sound attenuation coefficients (either in dB per 100 m or in dB per 1000 ft) must be determined before such reconstruction of masked band levels can be performed. Note that sound emission coordinates must also be calculated for each record before reconstruction is performed since the procedure is dependent on propagation distance.

306(c)(2)(J)(i) Frequency extrapolation method [ETM 3.6.3.2.10.1]

For a spectrum where the LGB is located at or above the 2 kHz one-third octave band, the frequency extrapolation method is used. This method reconstructs masked high frequency bands starting with the level associated with LGB in the same spectrum. The levels for all bands at higher frequencies than LGB must be reconstructed using this method. Any frequency-extrapolated levels should be categorized as reconstructed. Reconstruct the level for the masked bands using the following equation:

$$L_{i,k} = L_{j,k} + \alpha_j \frac{SR_k}{100} - \alpha_{jREF} \frac{60}{100} + 20log_{10} \frac{SR_k}{60} + \alpha_{jREF} \frac{60}{100} - \alpha_j \frac{SR_k}{100} + 20log_{10} \frac{SR_k}{60}$$

which can be reduced to:

$$Lx_{i,k} = L_{j,k} + [\alpha_j - \alpha_i] \frac{SR_k}{100} + [\alpha_{iREF} - \alpha_{jREF}] \frac{60}{100},$$

where:

- i is the masked band to be extrapolated;
- k is the record of interest;
- j is the LGB in record k;
- $Lx_{i,k}$ is the frequency-extrapolated level in dB for masked band i and spectral record k;
- $L_{j,k}$ is the level for LGB in record k after all test-day adjustments have been applied, including pre-detection noise energy-subtraction, system and microphone adjustments, etc.;
- α_j is the test-day sound attenuation coefficient (dB per 100 m) for LGB;

α_i is the test-day sound attenuation coefficient (dB per 100 m) for band i;

α_{jREF} is the reference 77°F (25°C), 70 percent relative humidity (RH) sound attenuation coefficient (dB per 100 m) for LGB;

α_{iREF} is the reference 77°F (25°C), 70 percent RH) sound attenuation coefficient (dB per 100 m) for masked band i; and

SR_k is the slant range or acoustic propagation distance in meters at the time of sound emission for spectral record k, between the aircraft and the microphone.

This procedure is based on the assumption that the aircraft spectrum is “flat” (i.e., all high frequency band levels are equal) at a distance of 197 ft (60 m) under reference conditions 77°F (25°C), 70 percent RH). The process can be conceptualized by means of the following steps:

a) the level for band *j,* the highest frequency unmasked band in spectral record *k*, which has already been adjusted for measurement conditions, is adjusted for test-day propagation effects to obtain the source level and then adjusted using reference propagation effects to the197 ft (60 m) distance from the source;

b) this level is then assigned as the level for all high frequency masked bands (i.e., band *i*, band *i* + 1, etc.) at a distance of 197 ft (60 m);

c) a new source level is determined for each masked high frequency band by removing the associated reference-day propagation effects; and

d) the extrapolated level that would have been measured on the ground, in the absence of background noise, is determined for each masked high frequency band by adding the test-day propagation effects to each of the source levels determined in c) above.

306(c)(2)(J)(ii) Time extrapolation method [ETM 3.6.3.2.10.2]

For a spectrum where LGB occurs at or between the 630 Hz one-third octave band and the 1.6 kHz band, use the time extrapolation method. This method reconstructs a masked band in a spectrum from the closest spectral record (i.e., closest in time) for which that band is valid. The levels for all one-third octave bands with frequencies greater than that of LGB must be reconstructed using this time extrapolation method. Any time-extrapolated levels should be categorized as reconstructed. Reconstruct the levels for the masked bands by using the following equation:

$$L_{i,k} = L_{i,m} + \alpha_j [\frac{SR_m}{100} - \frac{SR_k}{100}] + 20log_{10}[\frac{SR_m}{SR_k}]$$

where:

— $Lx_{i,k}$ is the time-extrapolated level in dB for masked band *i* and spectral record *k*;

— $L_{i,m}$ is the adjusted level in dB for band *i* in spectral record *m*, which is the nearest record in time to record *k* in which band *i* contains a valid level;

— SR_m is the slant range or acoustic propagation distance in meters at the time of sound emission for spectral record *m*, between the aircraft and the microphone;

— SR_k is the slant range or acoustic propagation distance in meters at the time of sound emission for spectral record *k*, between the aircraft and the microphone; and

— $\alpha_i$is the test-day sound attenuation coefficient (dB per 100 m) for band *i*.

This procedure is based on the assumption that the aircraft spectrum is omnidirectional during the aircraft pass-by.

306(c)(2)(K) Handling of spectra after reconstruction of masked bands [ETM 3.6.3.2.11]

After reconstruction of masked data has been performed, the background noise adjustment procedure is complete. The adjusted as-measured data set, comprised of adjusted levels, reconstructed levels, and possibly some masked levels, is next used to obtain the test-day PNLT time history described in A36.4.3 of part 36. The identification of masked data should be kept accessible for use during the tone correction procedure, since any tone correction which results from the adjustment for background noise may be eliminated from the process of identifying the maximum tone within a spectrum. When this background noise adjustment procedure is used, the band identified as LGB should be treated as the last band of the tone correction calculation in the manner prescribed for the 10 kHz band in A36.4.3.1 of part 36, including the calculation of a new slope for band LGB + 1 that equals the slope at LGB (i.e., $s'(LGB + 1,k) = s'(LGB,k)$) in Step 5 of the tone correction procedure.

306(d) General Considerations [ETM 3.6.4]

306(d)(1) Limitations and requirements for any background noise adjustment procedure [ETM 3.6.4.1]

Any method of adjusting for the effects of background noise must be approved by the FAA before it is used. The adjustment procedure presented in 306(c)(2) includes applicable limitations and requirements. Those limitations and requirements which apply to all methodologies are described as follows.

The applicant must be able to demonstrate by means of narrow-band analysis or other methods that no significant aircraft-generated tones occur in the masked one-third octave bands during the EPNL duration.

Neither frequency-dependent adjustments nor energy-subtraction of pre-detection levels can be applied to masked data.

When consecutive one-third octave bands in the range of 2.5 kHz to 10 kHz inclusive are masked, and when no consecutive bands are masked in the region of 800 Hz to 2 kHz inclusive, frequency extrapolation, as described in 306(c)(2)(J)(i), must be performed on all consecutive masked bands with nominal frequencies greater than 2 kHz.

When consecutive one-third octave bands in the range of 800 Hz to 2 kHz inclusive are masked, time extrapolation, as described in 306(c)(2)(J)(ii), must be performed on all consecutive masked bands with nominal frequencies greater than 630 Hz.

In cases where a single masked one-third octave band occurs between two adjacent valid bands, the levels of the adjacent adjusted bands may be arithmetically averaged and the averaged level used in place of the masked level. If the masked level is retained it must be included when counting the masked levels in the procedure described in 306(d)(2)

306(d)(2) Rejection of spectra due to masking [ETM 3.6.4.2]

A spectrum becomes invalid if the following conditions prevail:

a) if, after any reconstruction of masked bands, more than four one-third octave bands retain masked values;

b) for records within one second of the record associated with the $PNLT_{max}$ spectrum (i.e., five half-second data records) if:

1) more than four high frequency bands require reconstruction; or

2) the LGB is located at or below the 3150 Hz one-third octave band when the example background noise adjustment procedure presented in 306(c)(2) is used.

Note.— If an invalid spectrum occurs within the 10 dB-down period, the aircraft test run is invalid and cannot be used for aircraft noise certification purposes.

305(d)(3) Special tone correction considerations due to masking [ETM 3.6.4.3]

When the maximum tone correction for a one-third octave band spectrum occurs at a masked or reconstructed band, the tone correction for that spectrum cannot simply be set to zero. The maximum tone correction for the spectrum must be computed, taking masked or reconstructed levels into consideration. Any tone correction resulting from the adjustment for background noise may be eliminated by either one of the following two methods, as appropriate:

a) when the example background noise adjustment procedure presented in 306(c)(2) is used or, specifically, when all of the high frequency bands in a spectrum are masked for frequencies beyond a certain band (i.e., “LGB”) the band labeled as LGB should be treated as the last band of the tone correction calculation, in the manner prescribed for the 10 kHz band (band number 24) in A36.4.3.1 of part 36, including calculation of a new slope for the band above LGB that equals the slope of the band at LGB (i.e., $s'(LGB + 1,k) = s'(LGB,k)$) in Step 5 of the tone correction procedure; or

b) for tone corrections that occur at one-third octave bands that are masked or reconstructed, set F equal to zero in Step 9 of the tone correction procedure, and recalculate the maximum tone correction for that spectrum.

Note.— All band levels within a spectrum, whether adjusted, reconstructed or masked, must be included in the computation of the PNL value for that spectrum.

306(d)(4) Handling of masked data in reference conditions data sets [ETM 3.6.4.4]

For any one-third octave band spectrum adjusted to reference conditions, all bands, including those containing masked levels or reconstructed levels, including values less than 0 dB, must be adjusted for differences between test and reference conditions (i.e., atmospheric absorption and spherical spreading). The special tone correction considerations listed in 306(c)(2) apply both to test and reference data sets.

307 Noise Reduction Systems [ETM 3.7]

An aircraft can employ noise reduction systems that change its configuration or operating condition to reduce noise, or implement devices or subsystems that directly reduce or counteract noise emissions. Two categories, variable noise reduction systems (VNRS) and selectable noise reduction systems (SNRS), have been defined to address differences in activation/actuation for these systems. General guidance on noise certification of aircraft equipped with these systems is provided below.

307(a) Variable Noise Reduction Systems [ETM 3.7.1]

A VNRS is an integral design feature, or subsystem, of an aircraft that automatically changes the configuration or operating condition of the aircraft to reduce noise.

Note 1.— If pilot action is necessary to activate, i.e., select the use of, an automatically controlled noise reduction system or if a pilot can deactivate (deselect) an automatically controlled noise reduction system, such a system is not considered a VNRS.

Note 2.— Aircraft can incorporate variable systems, primarily intended to improve performance, reduce engine emissions and/or increase safety, that may also affect noise. Such aircraft can be noise certificated using the guidance provided for aircraft with VNRS. For such changes to existing type designs, the guidelines provided in 101(d) for “no acoustical change” are applicable.

For a VNRS-equipped aircraft, the VNRS characteristics may prevent flight from being conducted in accordance with the associated reference procedure(s) in part 36. In such cases, the reference procedures for noise certification of an aircraft with a VNRS should depart from those specified in part 36 only to the extent required by those design characteristics that cause the departure and should be approved by the FAA after the rulemaking process for an deviation from part 36 is completed (see 201(a)(10) paragraph 2 of this AC).

The impact of a VNRS on noise certification of an aircraft can extend beyond deviations from the part 36 reference procedures. A plan for noise certification of a VNRS-equipped aircraft should take into consideration three key elements, namely:

a) the necessity, if any, to depart from the part 36 procedures;

b) the adaptation/modification of test procedures to ensure compliance with part 36; and

c) the applicability of existing procedures in part 36 for adjusting the measured data to reference conditions.

Experience to date has shown that one or more of these elements may be interrelated, requiring detailed consideration of all three elements in devising an acceptable plan for noise certification.

307(a)(1) Reference procedures [ETM 3.7.1.1]

The part 36 reference procedures typically utilize constant flight path and operational parameters. A VNRS can, however, result in non-constant reference flight paths and/or non-constant operational parameters such as non-constant rates of climb and/or non-constant engine/propeller/rotor speeds, respectively, that compel departure from the reference procedures. In addition to reducing noise emissions, a VNRS may, and typically does, impact aircraft performance during a noise certification reference procedure. In some cases, this impact can be indirect via another affected performance parameter. Both direct and indirect impacts on aircraft performance should be addressed in defining any departure necessary from the reference procedures in part 36 to accommodate a VNRS.

Actuation of a VNRS can be a function of one or more operational conditions such as airspeed, ground speed, height above ground level, density altitude, pressure altitude and ambient temperature. Beginning and end points on the reference flight path for any transition triggered by a VNRS should be determined using the reference test and meteorological conditions.

307(a)(2) Test conditions and procedures [ETM 3.7.1.2]

When a VNRS results in a non-constant reference flight path for the aircraft, the flight path tolerances (height and lateral deviation limits) specified in part 36 for the corresponding constant reference procedure should be applied, subject to approval by the FAA. Similarly, when a VNRS results in a non-constant operational parameter for the aircraft, a reference schedule for the affected operating parameter should be defined along the reference flight path, and the test tolerances permitted by part 36 for that parameter should be applied to the reference schedule, subject to approval by the FAA.

307(a)(3) Adjustments to measured noise data [ETM 3.7.1.3]

Adjustments to measured data in part 36 are based on constant reference procedures. A VNRS can, however, result in a non-constant reference procedure(s) that in turn impacts the adjustments to measured data that account for test deviations from reference flight profiles and test conditions. The adjustments to measured data specified in part 36 should be modified only as necessary to account for any departures from the reference procedures in part 36. In many cases, only minor changes to data-processing software that do not affect the adjustment procedures will be needed. Any modifications, including software revisions, of the adjustments to measured data specified in part 36 are subject to approval by the FAA.

307(a)(4) Guidance for specific VNRS
[ETM 3.7.1.4]

Specific guidance for VNRS technologies will typically be developed as these technologies are developed and implemented in aircraft designs. Cross references to the appropriate sections of this Advisory Circular for the VNRS technologies for which specific guidance has been generally accepted by FAA are provided in Table 8.

Table 8. Cross references to specific guidelines in this ACfor VNRS

Variable noise reduction system (VNRS)	*Specific guidelines provided in this AC*
Variable rotor speed helicopters	Chapter 4, 401(h), H36.3: H36.103(b) [Takeoff flight test procedures], paragraph 8)

307(b) Selectable Noise Reduction Systems
[ETM 3.7.2]

(Reserved)

Note.— The guidance provided in 307 addresses VNRS only and, by inference, defines as selectable all noise reduction systems that do not satisfy the requirements for classification as VNRS. Guidance specific to SNRS, including a definition specific to SNRS, is not yet provided.

308 CALCULATION OF THE SPEED OF SOUND
[ETM 3.8]

For the purposes of noise certification the value of the speed of sound, c, is calculated from the equation taken from ISO 9613-1:1993(E):

$$c = 1125.9\ (T/T_0)^{1/2}\ \text{ft/s, or}$$

$$c = 343.2\ (T/T_0)^{1/2}\ \text{m/s}$$

where T_0 = 293.15 K and T is the absolute ambient air temperature in kelvins.

Note.— At the noise certification reference temperature of 25°C, T = 298.15 K, and c *therefore equals 1135.5 ft/s (346.1 m/s).*

309 REFERENCE TABLES USED IN THE MANUAL CALCULATION OF OF EFFECTIVE PERCEIVED NOISE LEVEL
[ETM 3.9]

Table 9 and Table 10 and Figure 7 contain information useful for the manual calculation of EPNL. Such manual calculations are often used to verify the accuracy of computer programs used for calculating certification noise levels.

Table 9. Perceived noisiness (noys) as a function of sound pressure level (One-third octave band center frequencies (Hz))

SPL	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
4																			0.10					
5																		0.10	0.11	0.10				
6																		0.11	0.12	0.11	0.10			
7																		0.12	0.14	0.13	0.11			
8																		0.14	0.16	0.14	0.13			
9																	0.10	0.16	0.17	0.16	0.14			
10																	0.11	0.17	0.19	0.18	0.16	0.10		
11																	0.13	0.19	0.22	0.21	0.18	0.12		
12																0.10	0.14	0.22	0.24	0.24	0.21	0.14		
13																0.11	0.16	0.24	0.27	0.27	0.24	0.16		
14																0.13	0.18	0.27	0.30	0.30	0.27	0.19		
15															0.10	0.14	0.21	0.30	0.33	0.33	0.30	0.22		
16										0.10	0.10	0.10	0.10	0.10	0.11	0.16	0.24	0.33	0.35	0.35	0.33	0.26		
17										0.11	0.11	0.11	0.11	0.11	0.13	0.18	0.27	0.35	0.38	0.38	0.35	0.30	0.10	
18									0.10	0.13	0.13	0.13	0.13	0.13	0.15	0.21	0.30	0.38	0.41	0.41	0.38	0.33	0.12	
19									0.11	0.14	0.14	0.14	0.14	0.14	0.17	0.24	0.33	0.41	0.45	0.45	0.41	0.36	0.14	
20									0.13	0.16	0.16	0.16	0.16	0.16	0.20	0.27	0.36	0.45	0.49	0.49	0.45	0.39	0.17	
21								0.10	0.14	0.18	0.18	0.18	0.18	0.18	0.23	0.30	0.39	0.49	0.53	0.53	0.49	0.42	0.21	0.10
22								0.11	0.16	0.21	0.21	0.21	0.21	0.21	0.26	0.33	0.42	0.53	0.57	0.57	0.53	0.46	0.25	0.11
23								0.13	0.18	0.24	0.24	0.24	0.24	0.24	0.30	0.36	0.46	0.57	0.62	0.62	0.57	0.50	0.30	0.13
24							0.10	0.14	0.21	0.27	0.27	0.27	0.27	0.27	0.33	0.40	0.50	0.62	0.67	0.67	0.62	0.55	0.33	0.15
25							0.11	0.16	0.24	0.30	0.30	0.30	0.30	0.30	0.35	0.43	0.55	0.67	0.73	0.73	0.67	0.60	0.36	0.17
26							0.13	0.18	0.27	0.33	0.33	0.33	0.33	0.33	0.38	0.48	0.60	0.73	0.79	0.79	0.73	0.65	0.39	0.20
27						0.10	0.14	0.21	0.30	0.35	0.35	0.35	0.35	0.35	0.41	0.52	0.65	0.79	0.85	0.85	0.79	0.71	0.42	0.23
28						0.11	0.16	0.24	0.33	0.38	0.38	0.38	0.38	0.38	0.45	0.57	0.71	0.85	0.92	0.92	0.85	0.77	0.46	0.26
29						0.13	0.18	0.27	0.35	0.41	0.41	0.41	0.41	0.41	0.49	0.63	0.77	0.92	1.00	1.00	0.92	0.84	0.50	0.30
30					0.10	0.14	0.21	0.30	0.38	0.45	0.45	0.45	0.45	0.45	0.53	0.69	0.84	1.00	1.07	1.07	1.00	0.92	0.55	0.33
31					0.11	0.16	0.24	0.33	0.41	0.49	0.49	0.49	0.49	0.49	0.57	0.76	0.93	1.07	1.15	1.15	1.07	1.00	0.60	0.37
32					0.13	0.18	0.27	0.36	0.45	0.53	0.53	0.53	0.53	0.53	0.62	0.83	1.00	1.15	1.23	1.23	1.15	1.07	0.65	0.41
33					0.14	0.21	0.30	0.39	0.49	0.57	0.57	0.57	0.57	0.57	0.67	0.91	1.07	1.23	1.32	1.32	1.23	1.15	0.71	0.45
34				0.10	0.16	0.24	0.33	0.42	0.53	0.62	0.62	0.62	0.62	0.62	0.73	1.00	1.15	1.32	1.41	1.41	1.32	1.23	0.77	0.50
35				0.11	0.18	0.27	0.36	0.46	0.57	0.67	0.67	0.67	0.67	0.67	0.79	1.07	1.23	1.41	1.51	1.51	1.41	1.32	0.84	0.55
36				0.13	0.21	0.30	0.40	0.50	0.62	0.73	0.73	0.73	0.73	0.73	0.85	1.15	1.32	1.51	1.62	1.62	1.51	1.41	0.92	0.61
37				0.15	0.24	0.33	0.43	0.55	0.67	0.79	0.79	0.79	0.79	0.79	0.92	1.23	1.41	1.62	1.74	1.74	1.62	1.51	1.00	0.67
38				0.17	0.27	0.37	0.48	0.60	0.73	0.85	0.85	0.85	0.85	0.85	1.00	1.32	1.51	1.74	1.86	1.86	1.74	1.62	1.10	0.74
39			0.10	0.20	0.30	0.41	0.52	0.65	0.79	0.92	0.92	0.92	0.92	0.92	1.07	1.41	1.62	1.86	1.99	1.99	1.86	1.74	1.21	0.82
40			0.12	0.23	0.33	0.45	0.57	0.71	0.85	1.00	1.00	1.00	1.00	1.00	1.15	1.51	1.74	1.99	2.14	2.14	1.99	1.86	1.34	0.90
41			0.14	0.26	0.37	0.50	0.63	0.77	0.92	1.07	1.07	1.07	1.07	1.07	1.23	1.62	1.86	2.14	2.29	2.29	2.14	1.99	1.48	1.00
42			0.16	0.30	0.41	0.55	0.69	0.84	1.00	1.15	1.15	1.15	1.15	1.15	1.32	1.74	1.99	2.29	2.45	2.45	2.29	2.14	1.63	1.10
43			0.19	0.33	0.45	0.61	0.76	0.92	1.07	1.23	1.23	1.23	1.23	1.23	1.41	1.86	2.14	2.45	2.63	2.63	2.45	2.29	1.79	1.21
44		0.10	0.22	0.37	0.50	0.67	0.83	1.00	1.15	1.32	1.32	1.32	1.32	1.32	1.52	1.99	2.29	2.63	2.81	2.81	2.63	2.45	1.99	1.34
45		0.12	0.26	0.42	0.55	0.74	0.91	1.08	1.24	1.41	1.41	1.41	1.41	1.41	1.62	2.14	2.45	2.81	3.02	3.02	2.81	2.63	2.14	1.48
46		0.14	0.30	0.46	0.61	0.82	1.00	1.16	1.33	1.52	1.52	1.52	1.52	1.52	1.74	2.29	2.63	3.02	3.23	3.23	3.02	2.81	2.29	1.63
47		0.16	0.34	0.52	0.67	0.90	1.08	1.25	1.42	1.62	1.62	1.62	1.62	1.62	1.87	2.45	2.81	3.23	3.46	3.46	3.23	3.02	2.45	1.79
48		0.19	0.38	0.58	0.74	1.00	1.17	1.34	1.53	1.74	1.74	1.74	1.74	1.74	2.00	2.63	3.02	3.46	3.71	3.71	3.46	3.23	2.63	1.98
49	0.10	0.22	0.43	0.65	0.82	1.08	1.26	1.45	1.64	1.87	1.87	1.87	1.87	1.87	2.14	2.81	3.23	3.71	3.97	3.97	3.71	3.46	2.81	2.18
50	0.12	0.26	0.49	0.72	0.90	1.17	1.36	1.56	1.76	2.00	2.00	2.00	2.00	2.00	2.30	3.02	3.46	3.97	4.26	4.26	3.97	3.71	3.02	2.40
51	0.14	0.30	0.55	0.80	1.00	1.26	1.47	1.68	1.89	2.14	2.14	2.14	2.14	2.14	2.46	3.23	3.71	4.26	4.56	4.56	4.26	3.97	3.23	2.63
52	0.17	0.34	0.62	0.90	1.08	1.36	1.58	1.80	2.03	2.30	2.30	2.30	2.30	2.30	2.64	3.46	3.97	4.56	4.89	4.89	4.56	4.26	3.46	2.81
53	0.21	0.39	0.70	1.00	1.18	1.47	1.71	1.94	2.17	2.46	2.46	2.46	2.46	2.46	2.83	3.71	4.26	4.89	5.24	5.24	4.89	4.56	3.71	3.02
54	0.25	0.45	0.79	1.09	1.28	1.58	1.85	2.09	2.33	2.64	2.64	2.64	2.64	2.64	3.03	3.97	4.56	5.24	5.61	5.61	5.24	4.89	3.97	3.23
55	0.30	0.51	0.89	1.15	1.35	1.71	2.00	2.25	2.50	2.83	2.83	2.83	2.83	2.83	3.25	4.26	4.89	5.61	6.01	6.01	5.61	5.24	4.26	3.46
56	0.34	0.59	1.00	1.29	1.50	1.85	2.15	2.42	2.69	3.03	3.03	3.03	3.03	3.03	3.48	4.56	5.24	6.01	6.44	6.44	6.01	5.61	4.56	3.71
57	0.39	0.67	1.09	1.40	1.63	2.00	2.33	2.61	2.88	3.25	3.25	3.25	3.25	3.25	3.73	4.89	5.61	6.44	6.90	6.90	6.44	6.01	4.89	3.97
58	0.45	0.77	1.18	1.53	1.77	2.15	2.51	2.81	3.10	3.48	3.48	3.48	3.48	3.48	4.00	5.24	6.01	6.90	7.39	7.39	6.90	6.44	5.24	4.26
59	0.51	0.87	1.29	1.66	1.92	2.33	2.71	3.03	3.32	3.73	3.73	3.73	3.73	3.73	4.29	5.61	6.44	7.39	7.92	7.92	7.39	6.90	5.61	4.56

SPL	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
60	0.59	1.00	1.40	1.81	2.08	2.51	2.93	3.26	3.57	4.00	4.00	4.00	4.00	4.00	4.59	6.01	6.90	7.92	8.49	8.49	7.92	7.39	6.01	4.89
61	0.67	1.10	1.53	1.97	2.26	2.71	3.16	3.51	3.83	4.29	4.29	4.29	4.29	4.29	4.92	6.44	7.39	8.49	9.09	9.09	8.49	7.92	6.44	5.24
62	0.77	1.21	1.66	2.15	2.45	2.93	3.41	3.78	4.11	4.59	4.59	4.59	4.59	4.59	5.28	6.90	7.92	9.09	9.74	9.74	9.09	8.49	6.90	5.61
63	0.87	1.32	1.81	2.34	2.65	3.16	3.69	4.06	4.41	4.92	4.92	4.92	4.92	4.92	5.66	7.39	8.49	9.74	10.4	10.4	9.74	9.09	7.39	6.01
64	1.00	1.45	1.97	2.54	2.88	3.41	3.98	4.38	4.73	5.28	5.28	5.28	5.28	5.28	6.06	7.92	9.09	10.4	11.2	11.2	10.4	9.74	7.92	6.44
65	1.11	1.60	2.15	2.77	3.12	3.69	4.30	4.71	5.08	5.66	5.66	5.66	5.66	5.66	6.50	8.49	9.74	11.2	12.0	12.0	11.2	10.4	8.49	6.90
66	1.22	1.75	2.34	3.01	3.39	3.98	4.64	5.07	5.45	6.06	6.06	6.06	6.06	6.06	6.96	9.09	10.4	12.0	12.8	12.8	12.0	11.2	9.09	7.39
67	1.35	1.92	2.54	3.28	3.68	4.30	5.01	5.46	5.85	6.50	6.50	6.50	6.50	6.50	7.46	9.74	11.2	12.8	13.8	13.8	12.8	12.0	9.74	7.92
68	1.49	2.11	2.77	3.57	3.99	4.64	5.41	5.88	6.27	6.96	6.96	6.96	6.96	6.96	8.00	10.4	12.0	13.8	14.7	14.7	13.8	12.8	10.4	8.49
69	1.65	2.32	3.01	3.88	4.33	5.01	5.84	6.33	6.73	7.46	7.46	7.46	7.46	7.46	8.57	11.2	12.8	14.7	15.8	15.8	14.7	13.8	11.2	9.09
70	1.82	2.55	3.28	4.23	4.69	5.41	6.31	6.81	7.23	8.00	8.00	8.00	8.00	8.00	9.19	12.0	13.8	15.8	16.9	16.9	15.8	14.7	12.0	9.74
71	2.02	2.79	3.57	4.60	5.09	5.84	6.81	7.33	7.75	8.57	8.57	8.57	8.57	8.57	9.85	12.8	14.7	16.9	18.1	18.1	16.9	15.8	12.8	10.4
72	2.23	3.07	3.88	5.01	5.52	6.31	7.36	7.90	8.32	9.19	9.19	9.19	9.19	9.19	10.6	13.8	15.8	18.1	19.4	19.4	18.1	16.9	13.8	11.2
73	2.46	3.37	4.23	5.45	5.99	6.81	7.94	8.50	8.93	9.85	9.85	9.85	9.85	9.85	11.3	14.7	16.9	19.4	20.8	20.8	19.4	18.1	14.7	12.0
74	2.72	3.70	4.60	5.94	6.50	7.36	8.57	9.15	9.59	10.6	10.6	10.6	10.6	10.6	12.1	15.8	18.1	20.8	22.3	22.3	20.8	19.4	15.8	12.8
75	3.01	4.06	5.01	6.46	7.05	7.94	9.19	9.85	10.3	11.3	11.3	11.3	11.3	11.3	13.0	16.9	19.4	22.3	23.9	23.9	22.3	20.8	16.9	13.8
76	3.32	4.46	5.45	7.03	7.65	8.57	9.85	10.6	11.0	12.1	12.1	12.1	12.1	12.1	13.9	18.1	20.8	23.9	25.6	25.6	23.9	22.3	18.1	14.7
77	3.67	4.89	5.94	7.66	8.29	9.19	10.6	11.3	11.8	13.0	13.0	13.0	13.0	13.0	14.9	19.4	22.3	25.6	27.4	27.4	25.6	23.9	19.4	15.8
78	4.06	5.37	6.46	8.33	9.00	9.85	11.3	12.1	12.7	13.9	13.9	13.9	13.9	13.9	16.0	20.8	23.9	27.4	29.4	29.4	27.4	25.6	20.8	16.9
79	4.49	5.90	7.03	9.07	9.76	10.6	12.1	13.0	13.6	14.9	14.9	14.9	14.9	14.9	17.1	22.3	25.6	29.4	31.5	31.5	29.4	27.4	22.3	18.1
80	4.96	6.48	7.66	9.85	10.6	11.3	13.0	13.9	14.6	16.0	16.0	16.0	16.0	16.0	18.4	23.9	27.4	31.5	33.7	33.7	31.5	29.4	23.9	19.4
81	5.48	7.11	8.33	10.6	11.3	12.1	13.9	14.9	15.7	17.1	17.1	17.1	17.1	17.1	19.7	25.6	29.4	33.7	36.1	36.1	33.7	31.5	25.6	20.8
82	6.06	7.81	9.07	11.3	12.1	13.0	14.9	16.0	16.9	18.4	18.4	18.4	18.4	18.4	21.1	27.4	31.5	36.1	38.7	38.7	36.1	33.7	27.4	22.3
83	6.70	8.57	9.87	12.1	13.0	13.9	16.0	17.1	18.1	19.7	19.7	19.7	19.7	19.7	22.6	29.4	33.7	38.7	41.5	41.5	38.7	36.1	29.4	23.9
84	7.41	9.41	10.7	13.0	13.9	14.9	17.1	18.4	19.4	21.1	21.1	21.1	21.1	21.1	24.3	31.5	36.1	41.5	44.4	44.4	41.5	38.7	31.5	25.6
85	8.19	10.3	11.7	13.9	14.9	16.0	18.4	19.7	20.8	22.6	22.6	22.6	22.6	22.6	26.0	33.7	38.7	44.4	47.6	47.6	44.4	41.5	33.7	27.4
86	9.95	11.3	12.7	14.9	16.0	17.1	19.7	21.1	22.4	24.3	24.3	24.3	24.3	24.3	27.9	36.1	41.5	47.6	51.0	51.0	47.6	44.4	36.1	29.4
87	10.0	12.1	13.9	16.0	17.1	18.4	21.1	22.6	24.0	26.0	26.0	26.0	26.0	26.0	29.0	38.7	44.4	51.0	54.7	54.7	51.0	47.6	38.7	31.5
88	11.1	13.0	14.9	17.1	18.4	19.7	22.6	24.3	25.8	27.9	27.9	27.9	27.9	27.9	32.0	41.5	47.6	54.7	58.6	58.6	54.7	51.0	41.5	33.7
89	12.2	13.9	16.0	18.4	19.7	21.1	24.3	26.0	27.7	29.9	29.9	29.9	29.9	29.9	34.3	44.4	51.0	58.6	62.7	62.7	58.6	54.7	44.4	36.1
90	13.5	14.9	17.1	19.7	21.1	22.6	26.0	27.9	29.7	32.0	32.0	32.0	32.0	32.0	36.8	47.6	54.7	62.7	67.2	67.2	62.7	58.6	47.6	38.7
91	14.9	16.0	18.4	21.1	22.6	24.3	27.9	29.9	31.8	34.3	34.3	34.3	34.3	34.3	39.4	51.0	58.6	67.2	72.0	72.0	67.2	62.7	51.0	41.5
92	16.0	17.1	19.7	22.6	24.3	26.0	29.9	32.0	34.2	36.8	36.8	36.8	36.8	36.8	42.2	54.7	62.7	72.0	77.2	77.2	72.0	67.2	54.7	44.4
93	17.1	18.4	21.1	24.3	26.0	27.9	32.0	34.3	36.7	39.4	39.4	39.4	39.4	39.4	45.3	58.6	67.2	77.2	82.7	82.7	77.2	72.0	58.6	47.6
94	18.4	19.7	22.6	26.0	27.9	29.9	34.3	36.8	39.4	42.2	42.2	42.2	42.2	42.2	48.5	62.7	72.0	82.7	88.6	88.6	82.7	77.2	62.7	51.0
95	19.7	21.1	24.3	27.9	29.9	32.0	36.8	39.4	42.2	45.3	45.3	45.3	45.3	45.3	52.0	67.2	77.2	88.6	94.9	94.9	88.6	82.7	67.2	54.7
96	21.1	22.6	26.0	29.9	32.0	34.3	39.4	42.2	45.3	48.5	48.5	48.5	48.5	48.5	55.7	72.0	82.7	94.9	102	102	94.9	88.6	72.0	58.6
97	22.6	24.3	27.9	32.0	34.3	36.8	42.2	45.3	48.5	52.0	52.0	52.0	52.0	52.0	59.7	77.2	88.6	102	109	109	102	94.9	77.2	62.7
98	24.3	26.0	29.9	34.3	36.8	39.4	45.3	48.5	52.0	55.7	55.7	55.7	55.7	55.7	64.0	82.7	94.9	109	117	117	109	102	82.7	67.2
99	26.0	27.9	32.0	36.8	39.4	42.2	48.5	52.0	55.7	59.7	59.7	59.7	59.7	59.7	68.6	88.6	102	117	125	125	117	109	88.6	72.0
100	27.9	29.9	34.3	39.4	42.2	45.3	52.0	55.7	59.7	64.0	64.0	64.0	64.0	64.0	73.5	94.9	109	125	134	134	125	117	94.9	77.2
101	29.9	32.0	36.8	42.2	45.3	48.5	55.7	59.7	64.0	68.6	68.6	68.6	68.6	68.6	78.8	102	117	134	144	144	134	125	102	82.7
102	32.0	34.3	39.4	45.3	48.5	52.0	59.7	64.0	68.6	73.5	73.5	73.5	73.5	73.5	84.4	109	125	144	154	154	144	134	109	88.6
103	34.3	36.8	42.2	48.5	52.0	55.7	64.0	68.6	73.5	78.8	78.8	78.8	78.8	78.8	90.5	117	134	154	165	165	154	144	117	94.9
104	36.8	39.4	45.3	52.0	55.7	59.7	68.6	73.5	78.8	84.4	84.4	84.4	84.4	84.4	97.0	125	144	165	177	177	165	154	125	102
105	39.4	42.2	48.5	55.7	59.7	64.0	73.5	78.8	84.4	90.5	90.5	90.5	90.5	90.5	104	134	154	177	189	189	177	165	134	109
106	42.2	45.3	52.0	59.7	64.0	68.6	78.8	84.4	90.5	97.0	97.0	97.0	97.0	97.0	111	144	165	189	203	203	189	177	144	117
107	45.3	48.5	55.7	64.0	68.6	73.5	84.4	90.5	97.0	104	104	104	104	104	119	154	177	203	217	217	203	189	154	125
108	48.5	52.0	59.7	68.6	73.5	78.8	90.5	97.0	104	111	111	111	111	111	128	165	189	217	233	233	217	203	165	134
109	52.0	55.7	64.0	73.5	78.8	84.4	97.0	104	111	119	119	119	119	119	137	177	203	233	249	249	233	217	177	144
110	55.7	59.7	68.6	78.8	84.4	90.5	104	111	119	128	128	128	128	128	147	189	217	249	267	267	249	233	189	154
111	59.7	64.0	73.5	84.4	90.5	97.0	111	119	128	137	137	137	137	137	158	203	233	267	286	286	267	249	203	165
112	64.0	68.6	78.8	90.5	97.0	104	119	128	137	147	147	147	147	147	169	217	249	286	307	307	286	267	217	177
113	68.6	73.5	84.4	97.0	104	111	128	137	147	158	158	158	158	158	181	233	267	307	329	329	307	286	233	189
114	73.5	78.8	90.5	104	111	119	137	147	158	169	169	169	169	169	194	249	286	329	352	352	329	307	249	203
115	78.8	84.4	97.0	111	119	128	147	158	169	181	181	181	181	181	208	267	307	352	377	377	352	329	267	217
116	84.4	90.5	104	119	128	137	158	169	181	194	194	194	194	194	223	286	329	377	404	404	377	352	286	233
117	90.5	97.0	111	128	137	147	169	181	194	208	208	208	208	208	239	307	352	404	433	433	404	377	307	249
118	97.0	104	119	137	147	158	181	194	208	223	223	223	223	223	256	329	377	433	464	464	433	404	329	267
119	104	111	128	147	158	169	194	208	223	239	239	239	239	239	274	352	404	464	497	497	464	433	352	286
120	111	119	137	158	169	181	208	223	239	256	256	256	256	256	294	377	433	497	533	533	497	464	377	307
121	119	128	147	169	181	194	223	239	256	274	274	274	274	274	315	404	464	533	571	571	533	497	404	329
122	128	137	158	181	194	208	239	256	274	294	294	294	294	294	338	433	497	571	611	611	571	533	433	352
123	137	147	169	194	208	223	256	274	294	315	315	315	315	315	362	464	533	611	655	655	611	571	464	377
124	147	158	181	208	223	239	274	294	315	338	338	338	338	338	388	497	571	655	702	702	655	611	497	404
125	158	169	194	223	239	256	294	315	338	362	362	362	362	362	416	533	611	702	752	752	702	655	533	433

SPL	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
126	169	181	208	239	256	274	315	338	362	388	388	388	388	388	446	571	655	752	806	806	752	702	571	464
127	181	194	223	256	274	294	338	362	388	416	416	416	416	416	478	611	702	806	863	863	806	752	611	497
128	194	208	239	274	294	315	362	388	416	446	446	446	446	446	512	655	752	863	925	925	863	806	655	533
129	208	223	256	294	315	338	388	416	446	478	478	478	478	478	549	702	806	925	991	991	925	863	702	571
130	223	239	274	315	338	362	416	446	478	512	512	512	512	512	588	752	863	991	1062	1062	991	925	752	611
131	239	256	294	338	362	388	446	478	512	549	549	549	549	549	630	806	925	1062	1137	1137	1062	991	806	655
132	256	274	315	362	388	416	478	512	549	588	588	588	588	588	676	863	991	1137	1219	1219	1137	1062	863	702
133	274	294	338	388	416	446	512	549	588	630	630	630	630	630	724	925	1062	1219	1306	1306	1219	1137	925	752
134	294	315	362	416	446	478	549	588	630	676	676	676	676	676	776	991	1137	1306	1399	1399	1306	1219	991	806
135	315	338	388	446	478	512	588	630	676	724	724	724	724	724	832	1062	1219	1399	1499	1499	1399	1306	1062	863
136	338	362	416	478	512	549	630	676	724	776	776	776	776	776	891	1137	1306	1499	1606	1606	1499	1399	1137	925
137	362	388	446	512	549	588	676	724	776	832	832	832	832	832	955	1219	1399	1606	1721	1721	1606	1499	1219	991
138	388	416	478	549	588	630	724	776	832	891	891	891	891	891	1024	1306	1499	1721	1844	1844	1721	1606	1306	1062
139	416	446	512	588	630	676	776	832	891	955	955	955	955	955	1098	1399	1606	1844	1975	1975	1844	1721	1399	1137
140	446	478	549	630	676	724	832	891	955	1024	1024	1024	1024	1024	1176	1499	1721	1975			1975	1844	1499	1219
141	478	512	588	676	724	776	891	955	1024	1098	1098	1098	1098	1098	1261	1606	1844					1975	1606	1306
142	512	549	630	724	776	832	955	1024	1098	1176	1176	1176	1176	1176	1351	1721	1975						1721	1399
143	549	588	676	776	832	891	1024	1098	1176	1261	1261	1261	1261	1261	1448	1844							1844	1499
144	588	630	724	832	891	955	1098	1176	1261	1351	1351	1351	1351	1351	1552	1975							1975	1606
145	630	676	776	891	955	1024	1176	1261	1351	1448	1448	1448	1448	1448	1664									1721
146	676	724	832	955	1024	1098	1261	1351	1448	1552	1552	1552	1552	1552	1783									1844
147	724	776	891	1024	1098	1176	1351	1448	1552	1664	1664	1664	1664	1664	1911									1975
148	776	832	955	1098	1176	1261	1448	1552	1664	1783	1783	1783	1783	1783	2048									
149	832	891	1024	1176	1261	1351	1552	1664	1783	1911	1911	1911	1911	1911										
150	891	955	1098	1261	1351	1448	1664	1783	1911	2048	2048	2048	2048	2048										

Table 10. Example of tone correction calculation for a turbofan engine

①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪
Band (i)	f Hz	SPL dB	S dB Step 1	|ΔS| dB Step 2	SPL′ dB Step 4	S′ dB Step 5	$\bar{s}$ dB Step 6	SPL″ dB Step 7	F dB Step 8	C dB Step 9
1	50	—	—	—	—	—	—	—	—	—
2	63	—	—	—	—	—	—	—	—	—
3	80	70	—	—	70	−8	−2⅓	70	—	
4	100	62	−8	—	62	−8	+3⅓	67⅔	—	
5	125	⑦⓪ 70	+8	16	71	+9	+6⅔	71	—	
6	160	80	+10	2	80	+9	+2⅔	77⅔	2⅓	0.29
7	200	82	+2	8	82	+2	−1⅓	80⅓	1⅔	0.06
8	250	83	+1	1	79	−3	−1⅓	79	4	0.61
9	315	76	−7	8	76	−3	+⅓	77⅔	—	
10	400	80	+4	11	78	+2	+1	78	2	0.17
11	500	80	0	4	80	+2	0	79	—	
12	630	79	−1	1	79	−1	0	79	—	
13	800	78	−1	0	78	−1	−⅓	79	—	
14	1 000	80	+2	3	80	+2	−⅔	78⅔		
15	1 250	78	−2	4	78	−2	−⅓	78	—	
16	1 600	76	−2	0	76	−2	+⅓	77⅔	—	
17	2 000	79	+3	5	79	+3	+1	78		
18	2 500	85	+6	3	79	0	−⅓	79	6	2
19	3 150	79	−6	12	79	0	−2⅔	78⅔	—	
20	4 000	78	−1	5	78	−1	−6⅓	76	2	0.33
21	5 000	71	−7	6	71	−7	−8	69⅔	—	
22	6 300	60	−11	4	60	−11	−8⅔	61⅔	—	
23	8 000	54	−6	5	54	−6	−8	53		
24	10 000	45	−9	3	45	−9	—	45	—	
						−9				

Step 1	③(i) − ③(i − 1)	Step 6	[⑦(i) + ⑦(i + 1) + ⑦(i + 2)] ÷ 3
Step 2	|④(i) − ④(i − 1)|	Step 7	⑨(i − 1) + ⑧(i − 1)
Step 3	see instructions	Step 8	③(i) − ⑨(i)
Step 4	see instructions	Step 9	see Table A36-2
Step 5	⑥(i) − ⑥(i − 1)		

Note.— Steps 5 and 6 may be eliminated in the calculations if desired. In this case in the example shown, columns ⑦ and ⑧ should be removed and existing columns ⑨, ⑩ and ⑪ become ⑦, ⑧ and ⑨ covering new steps 5, 6 and 7 respectively. The existing steps 5, 6, 7, 8 and 9 in 4.3.1 of Appendix A are then replaced by:

STEP 5 [⑥(i − 1) + ⑥ i + ⑥ (i + 1)] ÷ 3

STEP 6 ③(i) − ⑦(i) if > 0

STEP 7 See Table A36-2.

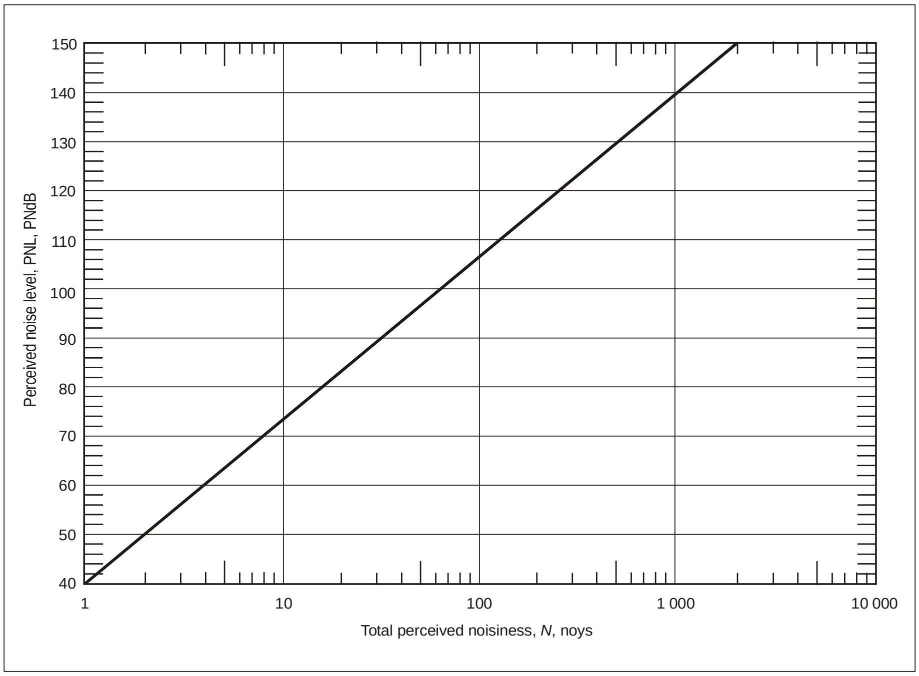

Figure 7. Perceived noise level as a function of total perceived noisiness

Chapter 4

GUIDELINES FOR TRANSPORT CATEGORY LARGE AIRPLANES, SUBSONIC JETAIRPLANES, AND HELICOPTERS EVALUATED UNDER APPENDIX A OR H OF 14 CFR PART 36

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401 EXPLANATORY INFORMATION [ETM 4.1]

401(a) Noise Measurements §A36.2 [ETM 4.1.1]

See 301 for technical procedures generally applicable for noise certification tests of all aircraft types including those evaluated under the provisions of Appendices A or H of part 36. Procedures specific to Appendix A or H are presented in the following section.

401(b) Noise Certification Test and Measurement Conditions §A36.2 [ETM 4.1.2]

401(b)(1) Ambient temperature GM §A36.2.2.2(b) [ETM GM A2 2.2.2.4.1 b)]

(1) Criteria for measuring atmospheric conditions

Experience has shown that proper measurement of non-reference meteorological conditions and the associated adjustment of noise data for these conditions are crucial to obtaining accurate, consistent and repeatable test results. For airplanes, meteorological observations of the temperature and relative humidity are required over the whole sound propagation path from the aircraft to the vicinity of the noise measurement points. For helicopters, temperature and relative humidity measurements are required at 33 ft (10 m) in the vicinity of the noise measurement points.

AMC §A36.2.2.2(b) [ETM AMC A2 2.2.2.4.1 b)]

(1) Atmospheric measurements

Several methods have been approved for the measurement of atmospheric conditions from 33 ft (10 m) above the ground to the altitude of the test airplane. Some applicants have used instrumented balloons. Another method consists of a meteorological airplane, manned or unmanned, flown in a spiral flight path in the vicinity of the noise measurement points to measure the dry bulb temperature and dew point along the sound propagation path.

401(b)(2) Calculation of sound attenuation coefficients for the effects of atmospheric absorption AMC §A36.2.2.2(d) [ETM AMC A2 2.2.2.2.1)]

(1) Basic data

Measurements of the ambient temperature and relative humidity should be made at 33 ft (10 m) above the ground. The ambient temperature and relative humidity should also be determined with vertical height increments not greater than 100 ft (30 m) over the sound propagation path. All measurements of ambient temperature and relative humidity must be obtained within 30 minutes of each airplane test run.

(2) Determination of the average sound attenuation coefficient

Table 11 is an example of calculation of sound attenuation coefficients in the 3150 Hz one-third octave band for an airplane approach noise certification when multiple layering is not required. Temperature and humidity values obtained from atmospheric soundings performed before and after a series of airplane test runs are interpolated to the time of PNLTM.

Table 11. Basic data (layering not required)

Height (m)	*Temperature (°C)*	*Relative humidity (%)*	*α (3150 Hz) (dB/100 m)*
10	14.1	50	2.45
30	13.4	53	2.38
60	12.9	56	2.30
90	12.2	57	2.33
120	11.5	58	2.37
150	11.3	61	2.27

The individual coefficients shown in Table 11are calculated at vertical height increments of 30 m from 10 m to a height of 150 m. The ambient conditions from the ground to 10 m are assumed to be those measured at 10 m.

The individual sound attenuation coefficients for the 3150 Hz one-third octave band shown in Table 11 vary by less than 0.5 dB/100 m relative to the value determined at 10 m (33 ft). In this case the coefficient to be used for adjustment of sound pressure levels from test to reference conditions is the average of the coefficients at 10 m (33 ft) and at the height of the airplane at the time of PNLTM.

For this example, the height of the test airplane at the time of PNLTM is 125 m. The associated attenuation coefficient is calculated by linear interpolation as follows:

$$y = y_a + \frac{(x - x_a) * (y_b - y_a)}{(x_b - x_a)}$$

$$\alpha(3150)_{125m} = 2.37 + \frac{(125 - 120) * (2.27 - 2.37)}{(150 - 120)}$$

$$\alpha(3150)_{125m} = 2.35 dB/100m.$$

Then the average attenuation coefficient for the 3150 Hz one-third octave band used for adjustment of the airplane sound pressure levels is calculated as follows:

$$\overline{\alpha(3150)} = \frac{\alpha(3150)_{10m} + \alpha(3150)_{125m}}{2}$$

$$\overline{\alpha(3150)} = \frac{2.45 + 2.35}{2}$$

$$\overline{\alpha(3150)} = 2.40 dB/100m.$$

The coefficients for the other one-third octave bands are determined in a similar manner. These average coefficients are then used in the adjustment of airplane SPLs to reference conditions. The same general procedure would be used if no layering was required for determining the average coefficients during flyover and lateral noise certification measurements.

(3) Determination of the cumulative sound attenuation coefficients

Table 12 is an example of calculation of sound attenuation coefficients in the 3150 Hz one-third octave band for an airplane flyover noise certification when multiple layering is required. Temperature and humidity values obtained from atmospheric soundings performed before and after a series of airplane test runs are interpolated to the time of PNLTM.

Table 12. Basic data (layering required)

Height (m)	*Temperature (°C)*	*Relative humidity (%)*	*α (3 150 Hz) (dB/100 m)*
10	7.2	80	2.09
30	7.2	75	2.23
60	8.9	73	2.11
90	10.0	67	2.19
120	10.6	63	2.27
150	10.6	62	2.31
180	10.6	61	2.34
210	10.6	59	2.43
240	11.1	55	2.57
270	11.7	53	2.59

Height (m)	*Temperature (°C)*	*Relative humidity (%)*	*α (3 150 Hz) (dB/100 m)*
300	11.7	51	2.70
330	11.1	51	2.79
360	11.1	50	2.84
390	11.1	47	3.04
420	11.1	46	3.10

The individual coefficients shown in Table 12 are calculated at vertical height increments of 30 m from 10 m to a height of 420 m. The ambient conditions from the ground to 10 m are assumed to be those measured at 10 m.

The individual sound attenuation coefficients for the 3150 Hz one-third octave band shown in Table 12 vary by more than 0.5 dB/100 m. In this case the coefficient to be used for adjustment of sound pressure levels from test to reference conditions is the cumulative sound attenuation from the ground to the height of the airplane at the time of PNLTM.

In the absence of extreme or anomalous conditions (e.g., large variations in, or inversions of, temperature and/or humidity), which will generally be the case, it is acceptable, subject to the approval by the FAA, to determine the cumulative sound attenuation coefficients for each one-third octave band from a simple average of the coefficients at the boundaries of each layer.

Where extreme or anomalous conditions are present (e.g., large variations in, or inversions of, temperature and/or humidity) the cumulative sound attenuation coefficients for each one-third octave band should be determined by apportioning the sound attenuation coefficients for each layer. Table 13 illustrates an example of such a method.

Table 13. Determination of the cumulative sound attenuation

Layer boundaries	*Effective layer depth (m)*	*Effective layer depth proportion (%)*	*Sound attenuation coefficients, α (3 150 Hz) (dB/100 m)*	*Average layer sound attenuation coefficients, α (3 150 Hz) (dB/100 m)*	*Apportioned sound attenuation coefficients, α (3 150 Hz) (dB/100 m)*
0–30	28.8	7.03	2.09–2.23	2.16	0.1518
30–60	30.0	7.32	2.23–2.11	2.17	0.1589
60–90	30.0	7.32	2.11–2.19	2.15	0.1574
90–120	30.0	7.32	2.19–2.27	2.23	0.1633
120–150	30.0	7.32	2.27–2.31	2.29	0.1676
150–180	30.0	7.32	2.31–2.34	2.32	0.1698
180–210	30.0	7.32	2.34–2.43	2.39	0.1750
210–240	30.0	7.32	2.43–2.57	2.50	0.1830
240–270	30.0	7.32	2.57–2.59	2.58	0.1889
270–300	30.0	7.32	2.59–2.70	2.65	0.1940
300–330	30.0	7.32	2.70–2.79	2.74	0.2006
330–360	30.0	7.32	2.79–2.84	2.82	0.2064

Layer boundaries	*Effective layer depth (m)*	*Effective layer depth proportion (%)*	*Sound attenuation coefficients, α (3 150 Hz) (dB/100 m)*	*Average layer sound attenuation coefficients, α (3 150 Hz) (dB/100 m)*	*Apportioned sound attenuation coefficients, α (3 150 Hz) (dB/100 m)*
360–390	30.0	7.32	2.84–3.04	2.94	0.2152
390–411	21.0	5.12	3.04–3.08	3.06	0.1568
				Cumulative sound attenuation coefficient, *α* (3150 Hz) (dB/100 m):	**2.49**

The atmosphere is first divided into layers from the ground to the airplane height. For this example the height of the airplane at the time of PNLTM is 411 m.

The sound attenuation coefficient at the height of the test airplane is calculated by linear interpolation of the sound attenuation coefficients at the upper and lower boundaries of the uppermost layer.

The effective layer depth is determined as follows: for all layers between the airplane and the microphone, except the lowest layer containing the microphone and the uppermost layer containing the airplane, the effective layer depth is the full 30 m; for the lowest layer containing the microphone, the effective layer depth is 30 m minus the 1.2 m height of the microphone; for the uppermost layer containing the airplane, the effective layer depth is the height of the airplane minus the height of the lower boundary of the layer.

The effective layer depth proportion for each layer is determined as the ratio of that layer's effective depth relative to the total vertical component of the sound propagation distance from the microphone to the height of the airplane at the time of PNLTM.

The average sound attenuation coefficient for each layer is obtained by averaging the coefficients at the upper and lower boundaries of the layer.

The apportioned sound attenuation coefficient for each layer is obtained by multiplying the average layer sound attenuation coefficient by the effective layer depth proportion.

The summation of all apportioned sound attenuation coefficients results in the cumulative sound attenuation coefficient. In this example the cumulative coefficient is calculated for the 3 150 Hz one-third octave band. The same general procedure would be used to obtain the cumulative sound attenuation coefficient for each one-third octave band. These coefficients are then used in the adjustment of airplane SPLs to reference conditions.

401(b)(3) Wind speed
AMC §A36.2.2.2(e) [ETM AMC A2 2.2.2.4.1 e) f) g) h)]

(1) *Real-time crosswind component measurements*

Applicants are advised to provide approved real-time crosswind component measurement systems such that the crosswind component speeds can be verified after each aircraft test run. When the applicant uses a wind measurement system that is remotely located and not readily accessible, such as chart recorders that simultaneously and independently measure and record wind speed and direction, it may not be practical to determine the real-time crosswind component for each test run. For airplanes, if the applicant does not provide an acceptable real-time crosswind component measurement system, the 10 kt (5.1 m/s) maximum crosswind component and the 7 kt (3.6 m/s) average crosswind component become the maximum wind limitations regardless of wind direction.

401(b)(4) Anomalous meteorological conditions
GM §A36.2.2.2(f) [ETM GM A2 2.2.2.4.1 i)]

(1) *Anomalous winds*

For airplanes, compliance of measured wind speeds with the requirements of A36.2.2.2 e) of part 36 may not be sufficient to ensure that the wind speeds at the airplane height or along the sound propagation path are not excessive. Such conditions may exist as a steady headwind, tailwind or crosswind, or as a wind from varying directions with increasing height. Anomalous winds may affect the handling characteristics of an aircraft during the noise duration. They also may affect the transmitted noise. Anomalous winds include not only gusts and turbulent winds, but also wind shear, strong vertical winds, and high crosswinds at the aircraft height and along the sound propagation path. An applicant may be required to measure winds aloft and provide FAA with the information. Acceptability of the wind conditions over the propagation path will be determined by the (see A36. 2.2.2(f) of part 36).

(2) *Winds aloft measurement*

Modern INS and DGPS can provide on-board aircraft data that can be used to quantify winds aloft. The measurement of winds aloft can further be processed to provide a permanent record of wind speed and direction.

(3) *Effects of wind on airplane control*

FAA has permitted a ±20 percent tolerance in overhead test height and a ±10° lateral tolerance relative to the extended runway centerline. If the flight crew cannot fly within the pre-test-approved flight path tolerance limits, or experiences major variations in airspeed, or the airplane crabs or yaws significantly during the flight, adverse or anomalous wind conditions aloft are often the cause.

(4) *Effects of wind on helicopter control*

If the test helicopter cannot be flown within the pre-test-approved flight path tolerance limits, or experiences major variations in airspeed, or the aircraft yaws or sideslips excessively during the flight, adverse or anomalous wind conditions aloft are often the cause. Normally such issues arise only with gusty wind conditions, high crosswinds or in the presence of strong thermals.

AMC §A36.2.2.2(f) [ETM AMC A2 2.2.2.4 i)]

(1) *Flight path*

The flight crew should observe and record any occurrence where conditions aloft cause difficulty in maintaining the flight path or airspeeds, or when rough air in general makes the flight unacceptable.

In the context of determining whether such conditions are present for airplanes, B36.8(g) of part 36 specifies that "for take-off, lateral, and approach conditions, the variation in instantaneous IAS of the airplane must be maintained within ±3 percent of the average airspeed between the 10 dB-down points. This shall be determined by reference to the pilot's airspeed indicator. However, when the instantaneous IAS varies from the average airspeed over the 10 dB-down points by more than ±3 kt (±5.5 km/h), and this is judged by the FAA representative on the flight deck to be due to atmospheric turbulence, then the flight so affected shall be rejected for noise certification purposes."

401(b)(5) Time of meteorological measurements
GM §A36.2.2.2(g) [ETM GM A2 2.2.2.2.1]

(1) *Upper atmospheric condition measurements*

Atmospheric conditions affect sound propagation. Therefore, measurements of temperature and relative humidity must be made before and after each aircraft test run, at least one of which must be made within 30 minutes of the test run. To avoid the possibility that the meteorological conditions might change significantly over time, both measurements must be representative of the prevailing conditions during the test run. The measurements must be made using an approved method at 33 ft (10 m) above the ground surface and, for airplanes only, from 33 ft (10 m) above the ground surface to the airplane test height at time of PNLTM. These measurements must be obtained and validated throughout the test period to ensure acceptable meteorological data for the noise data evaluation process.

AMC §A36.2.2.2(g) [ETM AMC A2 2.2.2.2.1]

(1) *Atmospheric measurements*

Applicants should consider the maximum height that will be attained within the next 60 minutes, or less, of airplane test runs to ensure that adequate upper atmospheric measurements are acquired. Interpolations of atmospheric data for all test runs are made to the airplane height at the time of PNLTM. To have sufficient meteorological data to perform the interpolation to the actual time of each test run, the first meteorological measurement flight of the day should be made not earlier than 30 minutes before the first test run, and the last meteorological measurement flight of the day should be made not later than 30 minutes after the last test run flight of the day.

(2) *Atmospheric data interpolation*

The temperature and relative humidity data at the actual time of the test run must be interpolated over time and height, as necessary, from the measured meteorological data. The interpolation time of the test run may be taken to be either the time the aircraft flew overhead or abeam the noise measurement point, or the time of PNLTM.

401(b)(6) Aircraft position measurement
GM §A36.2.3.1 [ETM GM A2 2.3.1]

(1) *Independent aircraft position determination*

The FAA will approve only those aircraft position and height indicating and recording systems that are independent from the direct aircraft flight path indicating systems. The data from such independent systems should be recorded to produce a time-coordinated permanent record of each test.

The independent system restriction does not prohibit use of real-time flight guidance systems (e.g., CDI or GDI) on-board the aircraft to assist the flight crew during noise certification tests. Systems such as microwave space position systems, INS, precision distance measuring unit (DMU), and DGPS can also provide guidance to the flight crew by providing the direct, real-time aircraft position relative to the extended runway centerline.

401(b)(7) Time space position information (TSPI) measurement system characteristics
GM §A36.2.3.2 [ETM GM A2 2.3.2]

(1) *Measurement system synchronization*

Approved aircraft position and height measurement systems must be time-synchronized with the noise and meteorological measurement systems. The time synchronization between noise measurements and aircraft position should be precise. A common time base should be used to synchronize noise, aircraft tracking and meteorological measurements (see §A36.2.3.2(b)(1)(3)(3)) of part 36 for details).

TSPI should be determined at intervals no greater than one-half second throughout the sound-measuring period (i.e., within 10 dB of PNLTM) by an approved method that is independent from systems installed aboard, and normally used to control, the aircraft. During processing, measured TSPI data must be interpolated over time to the time of sound emission of each one-half second noise data record within the 10 dB-down period. The time associated with each one-half second record is 0.75 seconds before the end of each 2-second exponential averaging period (see A36.3.7.6 of part 36).

Although the simplified procedure requires adjustment of only the (PNLT) maximum record to the reference track, sound emission coordinates should be determined for each one-half second record for use in background noise adjustment procedures and/or for determination of incidence-dependent free-field microphone and windscreen adjustments.

(2) *Measurement system component approval*

Some off-the-shelf TSPI equipment may require software enhancement to accommodate the specific installation. Each applicant should submit information to the FAA about the software used. The FAA will determine whether the software yields results that satisfy the part 36 Standards. All TSPI equipment and software should be demonstrated to, and approved by, the FAA to ensure the system's operational accuracy.

(3) *Methods of time synchronization*

Special care should be taken to properly synchronize noise data recordings with TSPI data (see 304 of this AC for details of specific methods).

401(b)(8) Aircraft performance
GM §A36.2.3.3 [ETM GM A2 2.3.3]

(1) *Aircraft and engine performance parameters*

Examples of parameters needed for measurement of aircraft and engine performance include aircraft height, climb angle, airspeed, gross weight, flap position, landing gear position, engine thrust (power) setting parameters (e.g., compressor rotor speed, engine pressure ratio, exhaust gas temperature), and aircraft accessory condition (e.g., air conditioning and auxiliary power unit (APU) "on" or "off"). Any other parameters that may affect measurement or adjustment of noise data and/or aircraft or engine performance should also be recorded throughout the 10 dB-down period (e.g., the status of surge bleed valves (SBV) and the center of gravity (CG) position).

AMC §A36.2.3.3 [ETM AMC A2 2.3.3]

(1) *Aircraft performance measurements*

Calibrated instrumentation is required to determine aircraft performance. Adequate aircraft and engine parameters are to be recorded during all certification testing to ensure that aircraft performance can be accurately determined. For example, for transport airplanes this may necessitate measurement and recording of flap position, landing gear position, speed brake position, APU operation, and normal engine thrust (power) setting and associated flight parameters. Determination and recording of adequate information enables validation of the test configuration and adjustment of performance and engine performance from test conditions to reference conditions specified in B36.7(a)(5) of part 36.

(2) *Recorder sampling rate*

The measurements of aircraft position, airspeed, performance and engine performance parameters are to be recorded at an approved sampling rate sufficient to permit adjustments from test to reference conditions throughout the 10 dB-down period. An acceptable recording sampling rate for transport category airplanes is two to five samples per second.

401(c) Measurement of Aircraft Noise Received on the Ground
§A36.3 [ETM 4.1.3]

401(c)(1) Environmental specifications
GM §A36.3.2.1 [ETM GM A2 3.2]

(1) *Measurement system performance*

The environmental conditions for specifying the performance of a measurement system are specified in A36.3.2.1 of part 36.

401(c)(2) Measurement system specification
GM §A36.3.3.1 [ETM GM A2 3.3.1]

(1) *Measurement system criteria*

The specifications for a measurement system allow flexibility in the procurement of measurement system components by the applicant. While on-site EPNL analysis may be useful for estimation of recording levels or for other diagnostic purposes, a true acoustical analysis requires that data be recorded in the field. This will allow for later re-analysis or auditing of acoustical data. A recording also facilitates later offline processing of acoustic data, including application of adjustments for items such as system frequency response, microphone pressure response and analyzer bandwidth error. Recording simplifies synchronization with other pertinent data, such as tracking and meteorological measurements. Such synchronization is necessary for proper application of many of the required adjustments to noise data, such as adjustments for microphone free-field response, windscreen incidence-dependent insertion loss, the influence of ambient noise, high altitude jet noise effects, non-reference flight performance, and non-reference meteorological conditions.

(2) *Approval of measurement system*

The approval by the FAA should be obtained for systems used for measurement, recording and analysis of aircraft noise. Most of the currently available system components that are appropriate for aircraft noise certification have already been approved, but implementation of new technology and variants or upgrades of existing components may require approval by the FAA. Of special concern is the potential for a digital component's functionality to change as a result of firmware or operating system upgrades or modifications. Applicants should be aware that approval of a particular component might be version-dependent.

401(c)(3) Microphone orientation
AMC §A36.3.5.2 [ETM AMC A2 3.5.2]

(1) *Microphone orientation*

Figure 8 shows the orientations relative to a microphone sensing unit for grazing and normal incidence. For microphones located directly under the flight path, an orientation angle of 90° from vertical is appropriate regardless of target height. For noise measurements to the side of the flight path, applicants may wish to reorient the microphones for grazing incidence for each target height in order to maintain substantially grazing incidence throughout the 10 dB-down periods. In many cases, this reorientation can eliminate the need to apply data adjustments for varying incidence, since the incidence angles will be more likely to be contained within ±30º of grazing incidence. Figure 8 provides illustrations of microphones positioned for grazing incidence under the flight path and to the side of the flight path of an airplane.

401(c)(4) Microphone specification
GM §A36.3.5.4(b) [ETM GM A2 3.5.4]

(1) *Microphone specifications*

Table A36-1 specifies the maximum permitted differences between the free-field sensitivity of a microphone at normal incidence and the free-field sensitivity at specified sound incidence angles for sinusoidal sound waves at each one-third octave band nominal midband frequency over the range of 50 Hz to 10 kHz. These differences are larger at higher frequencies, allowing for the effect of the microphone body in a free-field environment.

(2) *Microphone characteristics*

The specifications of Table A36-1 are based on the performance characteristics of typical one-half inch condenser microphones designed for nearly uniform frequency response at grazing incidence (see Figure 8). Other microphones may be used, provided they meet the specified performance requirements. For example, pre-polarized (i.e., electret condenser) free-field microphones greatly minimize the possibility of arcing in humid environments and do not require an external polarization voltage. Although many of these microphones are intended primarily for use in normal-incidence free-field applications, they can be used in aircraft noise certification testing if their performance at grazing incidence meets the requirements of A36.3.5 of part 36.

401(c)(5) Recorder specifications
GM §A36.3.6.1 [ETM GM A2 3.6.1]

(1) *Recorder types*

An applicant has a choice of recorder types that will satisfy the requirement for recording “the complete acoustic signal” during certification testing. In addition to a magnetic tape recorder, other means of attaining a “true” acoustic recording include digital audiotape (DAT), recordable compact disc (CD-R) and direct-to-hard-disk recording. The applicant should be aware that systems that use data compression techniques that result in substantial data loss, such as mini-disc (MD) or digital compact cassette (DCC), are not acceptable.

AMC §A36.3.6.1 [ETM AMC A2 3.6.1]

(1) *Frequency range for recordings*

The time-varying waveform produced by the microphone response to noise signals during certification tests should be recorded. If there are questions about the data observed during the tests, the recording can be replayed, multiple times if necessary, to verify the results. Recorded data, whether digital or analog in nature, should allow reproduction and reprocessing of an analog signal over the frequency range of 40 Hz to 12.6 kHz. A dynamic range of at least 60 dB is recommended.

Many typical instrumentation DAT recorders feature a nominal 10 kHz bandwidth operating mode in which the attenuating response of the anti-aliasing filter intrudes within the 10 kHz one-third octave passband. In such cases, the recorder should be operated in a nominal 20 kHz bandwidth mode, which may reduce the number of available channels or the duration of available time per tape.

Note.— Although the one-third octave bands of interest are those with nominal center frequencies of 50 Hz through 10 kHz, to ensure that the entire actual bandwidth of the uppermost and lowermost bands is included, the center frequencies of the one-third octave bands immediately outside this range are specified.

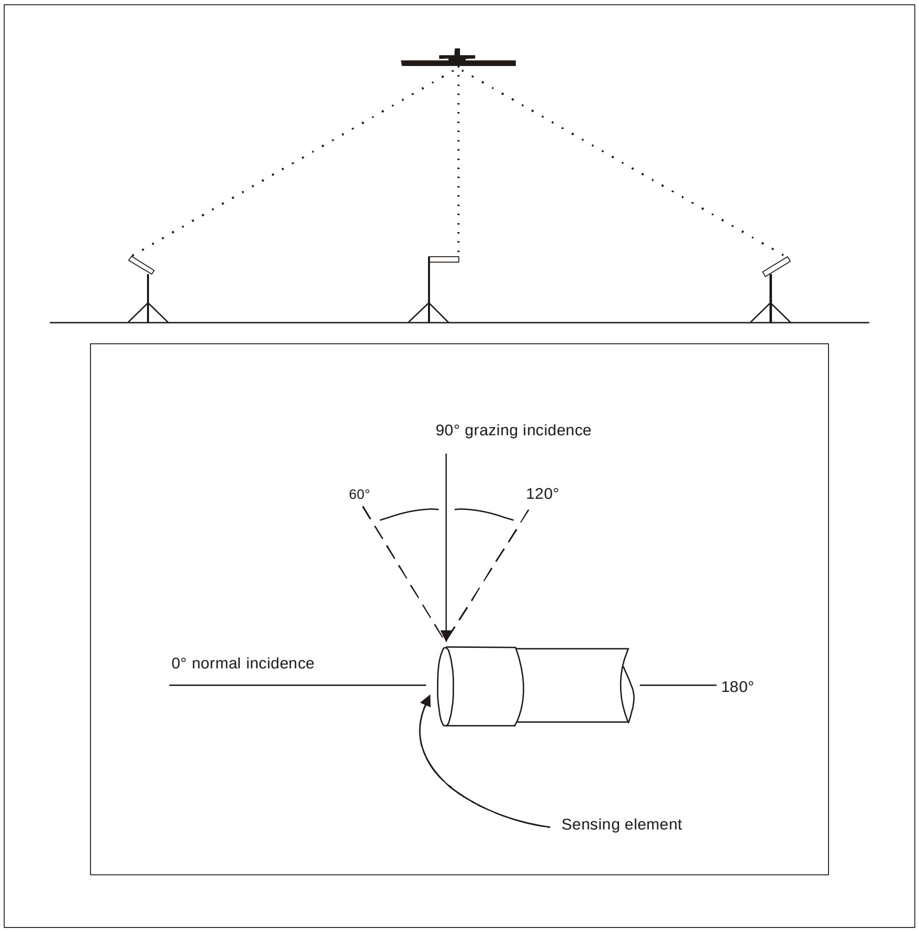


Figure 8. Illustration of sound incidence angles on a microphone

(2) *Digital recording levels*

The overload characteristic of a digital system is determined primarily by the limits of the analog-to-digital conversion. Since such an overload condition is characterized by an abrupt, catastrophic type of distortion, the level range should be set so that the anticipated maximum signal level is at least 10 dB, and preferably 20 dB, below the upper boundary of the linear operating range.

(3) *Dynamic range limits for digital recorders*

The lower limit of a digital recording system's usable dynamic range is more often determined by amplitude non-linearity due to "quantization error", rather than by the presence of a noise floor. Digital devices such as recorders or analyzers that are to be used for aircraft noise certification purposes should be tested to determine the extent of such non-linearity.

(4) *16-bit quantization systems*

The theoretical dynamic range of such a system is usually assumed to be near 96 dB (i.e., 20 log (2^{16})). At the lower limit of this range, there is a potential for a 6 dB error in the digitized signal versus the analog input signal that it represents. Reference T1 imposes a ±0.4 dB limit on acceptable linearity error in the reference level range and ±0.5 dB for a linear operating range of at least 50 dB. As amplitude levels are increased above the lower quantization limit, the linearity error is reduced. If the guidance for setting the level range is followed, the usable dynamic range is further decreased. Significant improvement of amplitude linearity can be obtained via the implementation of techniques such as oversampling and dithering. Therefore, testing must be performed to determine the actual limits for each digital recording system. Note that assumptions based on experience with analog systems do not always apply.

401(c)(6) Pre-emphasis
AMC §A36.3.6.2(a) [ETM AMC A2 3.6.2]

(1) *Pre-emphasis systems*

Use of pre-emphasis systems will be allowed only if the system also employs complementary de-emphasis. Attempts to compensate for the effects of a pre-emphasis filter by applying one-third octave band de-emphasis adjustments, either numerically to analyzed data via a pink noise adjustment, or on a band-by-band basis using separate gain stages for each one-third octave band filter, are not allowed. In addition, use of a pre-emphasis/de-emphasis system will require testing and documentation of all filters and gain stages involved to ensure that any errors are quantified and minimized and that the system performs predictably and reliably.

401(c)(7) Attenuator specifications
AMC §A36.3.6.9 [ETM AMC A2 3.6.9]

(1) *Attenuator specifications*

Attenuator specifications allow for the use of switchable voltage input range settings, now commonplace on DAT recorders, as controllable attenuation steps for gain-setting purposes. In all cases, attenuators should have fixed repeatable steps. Any devices in the measurement system that use vernier or continuously-adjustable gain controls should also have some demonstrable means of being fixed, or locked at a specific setting, to eliminate non-traceable gain errors.

401(c)(8) Linear integrating analyzer specifications
GM §A36.3.7.2(c) [ETM GM A2 3.7.2]

(1) *Externally controlled linear-integrating analysers*

In cases where a computer or other external device is used to control and/or communicate with an analyser performing linear integration, extra care should be taken to ensure that the integration period requirements are met. Some analysers from major manufacturers have required a factory modification in order to provide an integration time within 5 ms of the specified 500-ms integration period.

401(c)(9) Analyzer performance specifications
GM §A36.3.7.4 [ETM GM A2 3.7.3]

(1) *Analyzer specifications*

Reference T2 specifies the electrical performance requirements of one-third octave band filters, including tolerances for the attenuation in the transition bands (i.e., “skirts”) adjacent to the one-third octave passbands. Most digital one-third octave band analysis systems offer only hardwired filtering algorithms that emulate the response of a traditional third-order analysis filter having a maximally flat passband. However, some analysis systems allow the selection of other filtering algorithms which might not provide equivalent performance. Applicants should demonstrate the effects that alternate filter design response characteristics might have on noise certification EPNL values.

(2) *Determination of bandwidth error adjustments*

The manufacturer can establish the geometric center frequencies of one-third octave band filters using either

Base 2 or Base 10 systems. While the use of either method results in frequencies close to the nominal center frequencies referred to in Table A36-3, it is important to note which system is used so that the bandwidth error adjustment can be properly determined. Use of test frequencies calculated by a different base-number system than that for which the analyzer was designed can result in erroneous values for these adjustments.

401(c)(10) Microphone incidence adjustments
AMC §A36.3.9.3 [ETM AMC A2 3.9.3]

(1) *Applications of adjustments for incidence*

When using microphones whose frequency response is nearly flat at grazing incidence, and when the angles of incidence of sound emitted from the aircraft are within ±30° of grazing incidence, a single set of data adjustments for free-field response and windscreen insertion loss, based on grazing incidence, is considered sufficient to account for incidence effects. When it is impractical to orient the microphone properly to maintain grazing incidence, provided that a continuous record of TSPI is available, free-field and windscreen insertion-loss incidence data adjustments can be applied to the noise data on a spectral-record by spectral-record basis. These adjustments are obtained by calculating the angle of incidence for each record, using the point of time which characterizes the 2-second averaging period (see A36.3.7.6 of part 36) and determining the aircraft's sound emission coordinates and angle of incidence for the sound measured at that time.

401(c)(11) Pink noise specification
GM §A36.3.9.4 [ETM GM A2 3.9.4]

(1) *Pink noise*

Pink noise contains equal energy in each octave band or fractional octave band (e.g., the octave from 100 Hz to 200 Hz contains the same amount of energy as the octave from 1 kHz to 2 kHz, although for the lower-frequency octave, it is distributed over a frequency range 10 times narrower).

(2) *Pink noise usage*

Because of the dynamic nature of the pink noise signal, longer samples produce statistically better measurements. A minimum duration of 30 seconds of pink noise should be recorded.

401(c)(12) Measurement system field calibration
AMC §A36.3.9.5 [ETM AMC A2 3.9.5]

(1) *Measurement system field calibration (all components of the measurement system, except microphones)*

All components of the measurement system, except microphones, should be tested while deployed in the field, using pink noise at a level within 5 dB of the calibration level (see A36.3.9.5 of part 36). The signal should be recorded for a duration of at least 30 seconds so that one-third octave band system frequency response adjustments can be determined and applied during analysis. The pink noise generator should be calibrated within 6 months of the measurement and is acceptable for certification use only if its output in each one-third octave band does not change by more than 0.2 dB between calibrations.

401(c)(13) Field acoustical calibrations
AMC §A36.3.9.8 [ETM AMC A2 3.9.8]

(1) *Field acoustical calibrations*

All components of the system, excluding the windscreen, should be in place at this time, including cables, attenuators, gain and signal-conditioning amplifiers, filters (including pre-emphasis) and power supplies. During calibration, attenuators and gain stages should be set to prevent overload and to maintain the calibration signal level on the reference level range within the limits specified in A36.3.6.6 of part 36. If any switchable filters that could affect the calibration signal are utilized during measurements, then calibrations should be performed both with and without these filters enabled. Components of the electrical system should not be added, removed or replaced without re-calibrating the entire system immediately before and after each change.

401(c)(14) Windscreen loss adjustment
AMC §A36.3.9.10 [ETM AMC A2 3.9.10]

(1) *Determination of windscreen data adjustments*

The physical condition of a windscreen can significantly affect its performance, and manufacturer-provided windscreen data adjustments for insertion loss are valid only for new, or clean, dry windscreens. For these adjustments, a single set of values based upon windscreen insertion loss tests at grazing incidence may be used when the angles of incidence of sound emitted from an aircraft are within +30° of grazing incidence. For other cases, the windscreen insertion loss adjustments should be determined and applied on the basis of intervals between angles tested not exceeding 30°.

When the windscreen data adjustments provided by the manufacturer are presented in the form of curves, care should be taken to include the insertion loss throughout each one-third octave band, rather than just at the nominal midband frequency. Windscreen insertion loss can vary substantially within the frequency range of a single band and must be averaged or faired to more accurately correct one-third octave band data for the presence of the windscreen. Windscreen data adjustments may also be obtained by free-field calibration in an anechoic chamber.

401(c)(15) Measurement system background noise
AMC §A36.3.10.1 [ETM AMC A2 3.10.1]

(1) *Measurement system noise*

Since measurement system noise can add energy to measured aircraft noise levels, the background noise measurement described in A36.3.10.1 of part 36 should be made with all gain stages and attenuators set as they would be used during the aircraft noise certification measurements. If it is expected that multiple settings will be required during the measurements, background noise data should be collected at each of these settings. Care should be taken to ensure that the background noise is truly representative of that present during the aircraft noise certification tests.

(2) *Mean background noise assessments*

At least 30 seconds of background noise data must be time-averaged to determine the mean level for each one-third octave band. The PNL value for this averaged spectrum should then be calculated using the procedures defined in A36.4.1.3 a) of part 36. The aircraft noise level data should also be analyzed and PNL values calculated for each spectral record. The maximum aircraft PNL value should be at least 20 dB above the PNL of the averaged background noise spectrum for the data to be considered acceptable.

401(d) Calculation of EPNL from Measured Data
§A36.4 [ETM 4.1.4]

401(d)(1) Instantaneous sound pressure levels
GM §A36.4.1.2 [ETM GM A2 4.2]

(1) *Instantaneous sound pressure levels*

For the purposes of this procedure, "instantaneous" sound pressure levels are considered to be one-third octave band sound pressure levels for each one-half second record obtained using a continuous exponential averaging process, as described in A36.3.7.5 of part 36 or its equivalent.

401(d)(2) Tone correction calculation
AMC §A36.4.3.1 [ETM AMC A2 4.3.1]

(1) *Data precision for tone correction computation*

Prior to Step 1, it is recommended that all one-third octave band sound pressure levels be temporarily rounded to 0.1 dB resolution. The tone correction procedure presented here includes several steps that utilize decibel level criteria to characterize the significance of tonal content. These criteria can become artificially sensitive to small variations in level if a resolution finer than 0.1 dB is used in the computations.

401(d)(3) Adjustments relating to background noise
AMC §A36.4.3.1(d) & (e) [ETM AMC A2 4.3.1 (Steps 4, 5)]

(1) *Data adjustments for background noise*

When the technical procedure presented in 306(c)(2) of this AC is used for adjustment for the effects of background noise, Steps 4 and 5 of this tone correction procedure should be modified as follows:

— *Step 4.* The LGB should be used in place of the highest frequency band ($i = 24$); and

— *Step 5.* A new slope, $s'(25,k)$, should be calculated for the band beyond LGB as described for an imaginary 25th band. This slope should be used in place of the slope derived from the actual level of the band beyond LGB.

401(d)(4) Data resolution after tone correction calculation
AMC §A36.4.3.1(j) [ETM AMC A2 4.3.1 (Step 10)]

(1) *Data precision (after calculation of tone correction factor)*

At this point, the original sound pressure level resolution of 0.01 dB should be restored. Although the required precision of reported EPNL is 0.1 dB, all other intermediate calculations external to the tone correction process should maintain a precision of at least 0.01 dB.

(2) *Identification of pseudo-tones*

Section 403(b)(2) presents guidance material on methods for identifying pseudo-tones. Note that the use of ground plane or 33 ft (10 m) microphones is supplemental to the required 4 ft (1.2 m) microphones and is allowed only for identification of frequency bands within which pseudo-tones might occur and not for the determination of aircraft certification noise levels.

(3) *Tone correction factor adjustment*

When tone correction factors result from false or fictitious tones, recalculation is allowed using revised sound pressure level values, based on narrow-band analysis, of the smoothed spectral levels obtained in Step 7. Once the levels have been revised, the tone correction factor should be recomputed for the revised one-third octave band spectrum. This recomputed maximum tone correction factor should be applied, even if it occurs at or near the band associated with an artificial tone, and approval by the FAA should be obtained for the methodology used.

401(d)(5) Band sharing adjustment
GM §A36.4.4.2 [ETM GM A2 4.4.2]

(1) *Band-sharing adjustment concept*

The one-third octave band filtering process specified for analysis of aircraft noise certification data in A36.4.3.2 of part 36 may allow the tone correction procedure to under-predict a tone correction factor when the frequency of a tone is located at or near the edge of one or more one-third octave bands. To account for this phenomenon, a band-sharing adjustment is computed that takes advantage of the fact that, as a result of the Doppler effect, a tone that is suppressed at PNLTM will probably appear normally in the spectra that occur before or after PNLTM. By averaging the tone correction factors calculated for the spectra within a 2-second period around PNLTM, the tone correction factor that would have occurred at PNLTM if it were not suppressed can be reasonably estimated.

401(d)(6) Calculation of band sharing adjustment
AMC §A36.4.4.2 [ETM AMC A2 4.4.2]

(1) *Computation of band-sharing adjustment*

Although part 36 refers to identification of the frequency bands in which maximum tone corrections occur for the records near PNLTM, the presence or absence of band-sharing cannot be established merely by observing these frequencies. Even though the maximum tone that occurs in a one-third octave band spectrum may not be related to the band of maximum tone correction in the PNLTM spectrum, a related tone may still be present. Therefore, the average of the tone corrections of all spectra within one second (i.e., five, one-half-second data records) of PNLTM should be used regardless of the bands in which maximum tones are found. If the band-sharing adjustment is believed to result from effects other than band-sharing, the applicant should demonstrate its absence for each event.

(2) *Adjustment of PNLTM for band-sharing*

The band-sharing adjustment should be computed before the determination of the 10 dB-down period and should be included in the reported PNLTM and EPNL values for the test condition data.

(3) *Application of band-sharing adjustment for simplified procedure*

When the simplified procedure is used to adjust data to reference conditions, the band-sharing adjustment should be applied to the PNLTr at time of PNLTM before “Δ1” and EPNLr are calculated.

(4) *Application of band-sharing adjustment for integrated procedure*

When the integrated procedure is used to adjust data to reference conditions, a new band-sharing adjustment should be calculated as in A36.4.4.2 of part 36. This new band-sharing adjustment uses the average of the tone correction factors of the PNLTMr spectrum and the two preceding and two succeeding spectra, after adjusting them to reference conditions, and should be applied to the PNLTMr value prior to identification of the reference condition 10 dB-down points and calculation of EPNLr.

401(d)(7) Noise Duration
AMC §A36.4.5 [ETM AMC A2 4.5]

(1) *Noise duration (10 dB-down period)*

This period is the portion of the aircraft flyover in which the measured noise level is within 10 dB of PNLTM (i.e., the period to be used for the calculation of EPNL). To ensure an adequate duration of recorded noise, recording systems should be activated, and the aircraft maintaining a stable condition, when the noise level at the first microphone location is estimated to be approximately 20 dB(A) below what is expected to be L_{Amax}. Care should be taken during use of the flight path intercept method (see 402(a)(1)(i)) to ensure that noise levels have fallen 20 dB(A) below L_{Amax} before flight path go-around procedures are initiated.

Note.— If recorded data do not encompass the entire 10 dB-down period, an EPNL *cannot be calculated from those data, and the event should not be used for aircraft noise certification purposes.*

(2) Identification of the first and last records within the noise duration

When identifying the records that define the limits of the noise duration, those records having PNLT values closest to the actual value of PNLTM – 10 dB should be used. As a result, the PNLT values for the PNLTM – 10 dB points may not always be greater than or equal to PNLTM – 10 dB.

In order to illustrate the correct identification of the 10 dB-down points, Figure 9 provides examples of PNLT time-histories made up of records calculated from measured one-half-second values of SPL in accordance with the procedures specified in A36.4.2 of part 36. The shaded record k_M represents the record associated with PNLTM. Shaded records k_F and k_L represent respectively the first and last 10 dB-down points.

In the first example the PNLT value associated with k_F is greater than PNLTM – 10. The PNLT value associated with k_L is less than PNLTM – 10.

In the second example there are two records after k_M with a value equal to PNLTM – 10. In this case k_L is the last of the two records. The first 10 dB-down point, k_F, is the record closest in value to PNLTM – 10, ignoring any records that precede it with greater values but which are less in value than PNLTM – 10.

Note.— In all cases in the calculation of EPNL*, the contribution of all the records from* k_F *to* k_L *inclusive should be included.*

401(d)(8) Equations for computing duration correction GM §A36.4.5.4 [ETM GM A2 4.6.2]

(1) *Duration correction factor*

The equation for the duration correction factor, *D*, in A36.4.5.4 of part 36 is valid only for records of one-half second in length. The constant value 13 is used to normalize the one-half second values to the 10 seconds standard duration (i.e., 10 seconds duration comprising twenty 0.5-second data records and 10 log (20) = 13.01).

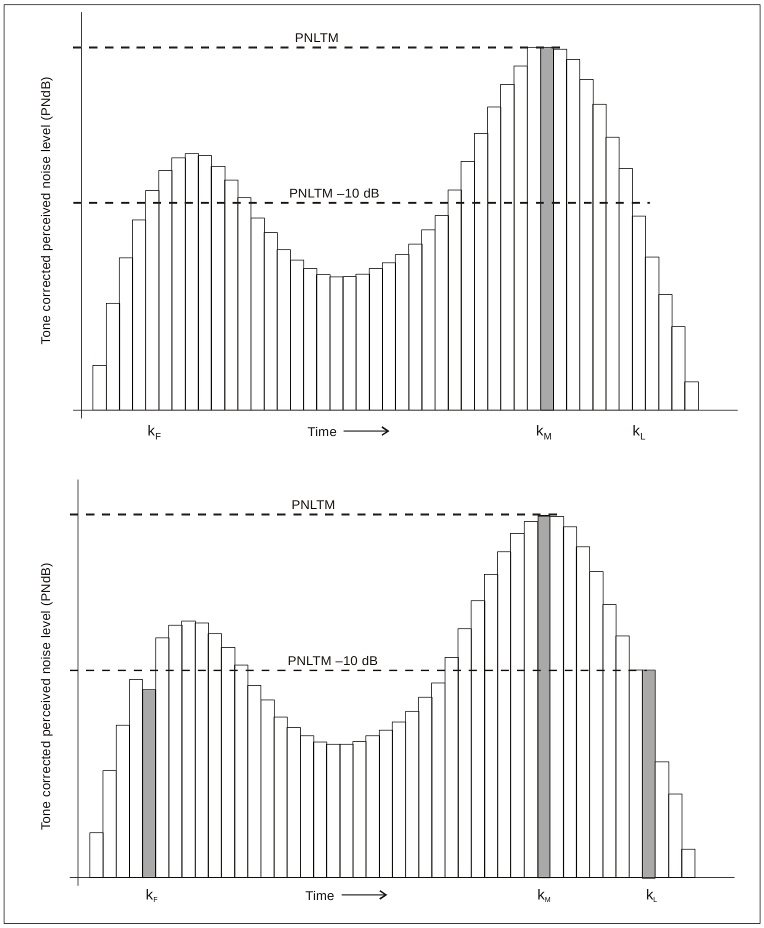


Figure 9. Illustrated example of identification of first and last 10 dB-down records

401(e) Reporting of Data to the FAA §A36.5 [ETM 4.1.5]

401(e)(1) Compliance records GM §A36.5.2 [ETM GM A2 5.1]

(1) *Compliance records*

For compliance with A36.5 of part 36, all data measured during noise certification testing, including time-histories of physical measurements, noise recordings, instrument calibrations, etc., are to be recorded in permanent form and made available to the FAA for review, inspection and approval. A common procedure is for the applicant to submit representative samples of test data for each noise measurement point and adjustments to measured data to permit the FAA to determine compliance with part 36. The applicant may either submit the complete test records along with the required data adjustments, or when approved by the FAA, the applicant may instead submit samples of test data along with the required data adjustments.

401(e)(2) EPNL average values GM §A36.5.4.2 [ETM GM A2 5.4]

(1) *Average* $EPNL_r$ *levels when using the NPD equivalent procedure*

For airplanes the average value of $EPNL_r$ from an NPD database (see 402(a)(1)(ii)(A)) is the noise level determined along the regression line through the adjusted data set at the appropriate thrust (power) and distance values, including any other additional adjustments necessary (e.g., adjustment to the aircraft reference speed).

(2) *Single test values*

When more than one noise measurement system is used at any one noise measurement point, the resulting noise level is to be the average of the measured noise levels for each noise measurement point. This requirement does not apply to noise levels measured by microphones not required for acquisition of noise certification data.

(3) *Valid conditions*

All valid noise measurements are to be included in the confidence interval calculations even when they produce results that are outside the 90 percent confidence limit of ±1.5 dB. The cause of erratic or possibly invalid noise data may include testing under different temperature and humidity extremes, anomalous winds aloft, changes in noise measurement system components, changes in aircraft hardware, background noise, shift in instrument calibrations, or not testing in accordance with the approved test plan, etc. The FAA is to make a determination, during the course of noise certification testing, as to the validity of all noise measurements. A noise measurement may not be excluded from the confidence interval calculations at a later date without approval by the FAA. Noise measurements determined in the field to be invalid for any reason may need to be repeated in order to achieve the required minimum number of valid test runs.

401(e)(3) Calculation of 90 percent confidence intervals
AMC §A36.5.4.2 [ETM AMC A2 5.4]

(1) *Methods for calculating 90 percent confidence intervals*

Section 305, provides confidence interval calculation methods for clustered measurements, regression mean line, static-test-derived NPD curves and analytically derived NPD curves, along with worked examples. Calculation methods for determining 90 percent confidence interval values for clustered and pooled data sets are presented in 305(f)(2) and 305(f)(5) of this AC.

(2) *Retest requirements*

The FAA may require an applicant to retest or provide additional test data for any of the three noise measurement points when the reported results indicate:

a) a required measurement is reported to be invalid;

b) an insufficient number of measurements were conducted by the applicant to determine a suitable data sample;

c) data scatter indicates that the data are not from a normal population or trend (e.g., a discontinuity due to low power SBV operation);

d) the 90 percent confidence interval for a noise measuring condition exceeds the allowable ±1.5 dB; or

e) the test was not conducted in accordance with an approved noise certification compliance demonstration plan.

401(f) Nomenclature: Symbols and Units
§A36.6 [ETM 4.1.6]

(Reserved)

401(g) Sound Attenuation in Air
§A36.7 [ETM 4.1.7]

(Reserved)

401(h) Adjustment of Helicopter Flight Test Results
§H36.205 [ETM 4.1.8]

The objective of a noise certification test is to acquire data for establishing an accurate and reliable definition of a helicopter's noise characteristics. Appendix H establishes a range of test conditions and procedures for adjusting measured data to reference conditions.

401(h)(1) Adjustments to reference conditions
GM §H36.205(a) [ETM GM No. 1 A2 8.3]

(1) *Adjustments to reference conditions*

Most noise certification tests are conducted during conditions other than the reference conditions. This includes differences in height, lateral position, airspeed, rotor speed, temperature and relative humidity. Therefore, measured noise data should be adjusted to reference conditions to determine whether compliance with the noise certification limits of Appendix H may be achieved. Both positive and negative adjustments must be applied for the differences between the test and reference conditions. Adjustment procedures and analysis methods should be reviewed and approved by the FAA. The FAA should ensure that data adjustment and analysis methods that are proposed by applicants satisfy the requirements of part 36 and approved procedures. Any changes, including software revisions, firmware upgrades or instrumentation changes, are subject to the review of the FAA before they can be used for noise certification evaluations. Program validation should be planned and the required information submitted to the FAA early in the certification cycle, since the time required for evaluation and approval may vary depending upon the issues encountered.

(2) *Non-positive SPLs*

Whenever non-positive one-third octave band aircraft noise levels are obtained, whether as part of the original one-third octave band analysis or as a result of adjustments for background noise, or other approved procedures, their values should be included in all relevant calculations. The practice of "band-dropping", where masked levels are methodically set equal to zero, is not considered to be an acceptable substitute for reconstruction of masked levels as per the background noise adjustment guidance provided in 306. For any aircraft noise spectrum subject to adjustment to reference conditions, all one-third octave bands, including those containing masked levels or reconstructed levels, including values less than or equal to zero dB, should be adjusted for differences between test and reference conditions.

(3) *Direction of flight considerations*

Since flyovers are made in two directions with headwind and tailwind components, the lateral (sideline) microphones will be either "left sideline" or "right sideline" depending on the direction of flight. Hence sideline flyover data need to be sorted by left microphone and right microphone for data adjustments and reporting. Note that sorting by left and right sideline microphone is also appropriate for takeoff and approach if more than one direction of flight is used.

It should also be noted that an equal number of flyover test runs with headwind and tailwind components are required. If after analysis the applicant finds that there is at least the required minimum of three measured values in each flight direction, but there are more in one direction than in the other, the applicant then will need approval by the FAA as to which are to be used in the determination of the final EPNL value for flyover.

401(h)(2) Reference data sources
GM §H36.111(c) [ETM GM No. 2 A2 8.2.1]

(1) *Manufacturer's data*

Adjustment of noise values from test to reference conditions should be based on approved manufacturer's data. Manufacturer's data should include:

a) reference flight profiles;

b) takeoff and flyover engine power settings at reference conditions; and

c) reference airspeeds.

401(h)(3) Adjustments to measured noise data
GM §H36.205 [ETM GM A2 8.3.1.2]

(1) *Reference flight path noise propagation angle*

In calculating the position of the PNLTM on the reference flight path, the acoustic emission (i.e., noise propagation) angle (θ) relative to the flight test path must be kept the same as for the test flight path. The elevation angle (ψ) relative to the ground plane is not constrained, and determination and reporting of this angle is required.

(2) Maximum adjustments

To prevent excessive adjustments to the measured data, the summation of all the adjustments for differences between the test flight path and the reference flight path for flyover and approach is limited to 2 EPNdB. For takeoff the summation of the adjustments is limited to 4 EPNdB of which the sum of Δ_1 and the –7.5 log term from Δ_2 must not exceed 2 EPNdB. The additional allowance for takeoff acknowledges that larger differences between the test flight path and reference flight path can occur for this condition as a result of the influence of wind speed on the test flight path. It is recommended, however, that the applicant note that methods discussed in H36.3(c)(a)(c)(2) can be used to minimize this difference for takeoff.

401(h)(4) Takeoff profile
GM §H36.205(b) [ETM GM A2 8.1.2.1]

(1) *Reference takeoff profile*

Figure 10 illustrates the reference takeoff profile and an idealized test or measured takeoff profile under zero wind conditions.

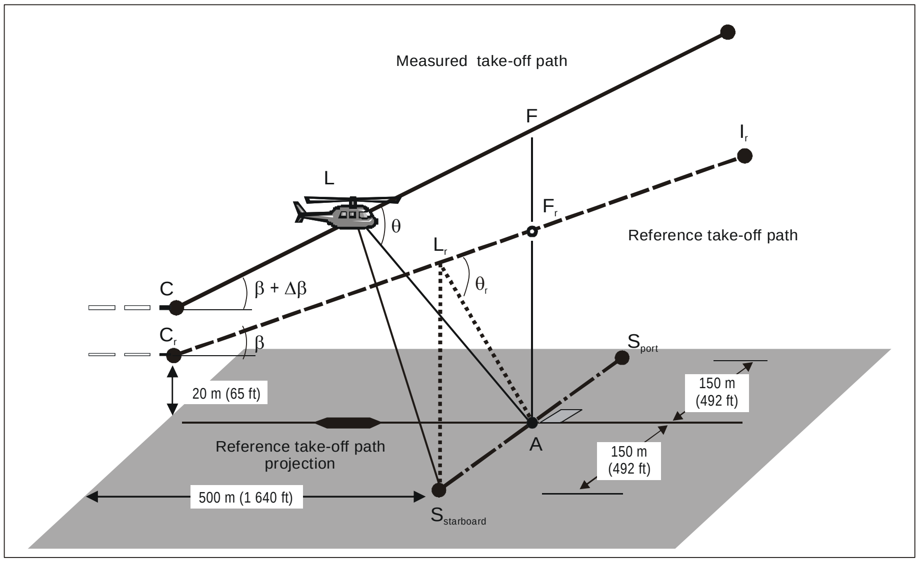


Figure 10. Comparison of measured and reference takeoff profiles

The reference takeoff profile is a straight line segment. It starts from a defined point C_r that is 1640 ft (500 m) from the center microphone location A and at a height of 65 ft (20 m) above the ground. The reference climb angle (β) of the straight line path will depend on the certificated best rate of climb and V_y at the reference conditions. The reference profile ends at a point I_r which will encompass the 10 dB-down period of the noise measurements.

Note.— For clarity the location of the test and reference PNLTM points, L *and* L_r*, are illustrated at the same position for both the centerline noise measurement point* A *and the starboard lateral (sideline) noise measurement point* S*. Normally however* L*, and hence* L_r*, will be a different position on the test and reference flight paths for each noise measurement point.*

(2) *Reference climb angle*

The reference climb angle, β, is based on the best rate of climb and V_y airspeed determined from approved manufacturer's data for the takeoff performance of the helicopter at the reference conditions. Since airspeed is defined as being in the direction of the flight path, the climb angle β is the arcsine of the ratio of best rate of climb to V_y. On a helicopter that is engine-power-limited at the reference conditions, the best rate of climb has to be calculated from the minimum specification engine(s) performance. On many helicopters the takeoff characteristics will be dependent on gearbox torque limit, and this will be typically less than the torque associated with minimum specification engine(s) at the reference conditions. Since all procedures have to be consistent with the airworthiness regulations, the gearbox takeoff torque limit should be used to calculate the applicable best rate of climb at the maximum noise certification weight for those helicopters which are performance-limited by the gearbox characteristics at the reference conditions.

401(h)(5) Takeoff test conditions
AMC §H36.101(d) [ETM AMC No. 1 A2 8.1.2.1]

(1) *Takeoff requirements*

The takeoff profile is commenced from a level flight at a height of 65 ft (20 m). After reaching position C, takeoff power has to be applied to initiate the climb. The takeoff power will either be dependent on the gearbox torque limit for takeoff or minimum installed engine(s) takeoff power torque at the reference conditions at sea level and 77ºF (25°C).

(2) *Test airspeed*

The best rate of climb airspeed V_y to be used is that determined from the takeoff performance at sea level and 77°F (25°C) during airworthiness certification. This is to be maintained during the complete takeoff procedure. To account for test-to-test variation and slight variations during each test run, a tolerance of ±5 kt (±9 km/h) is allowed.

(3) *Rotor speed*

The mean value of the rotor speed during the 10 dB-down period is to be within ±1 percent of the maximum normal operating rotor speed value at the reference takeoff condition.

(4) *Flight path deviations*

To minimize lateral flight path deviations, and hence the difference in noise levels due to off-track position at the PNLTM emission point, the helicopter must fly over the reference flight track during the 10 dB-down period within ±10° or ±65 ft (±20 m) from the vertical, whichever is the greater. This is illustrated in Figure 11. There is no direct height limitation, but the adjustments that take into account differences between the reference and test sound propagation distances at PNLTM are limited to 2 EPNdB as discussed in H36.205(f) and H36.111(c) & (d) of part 36.

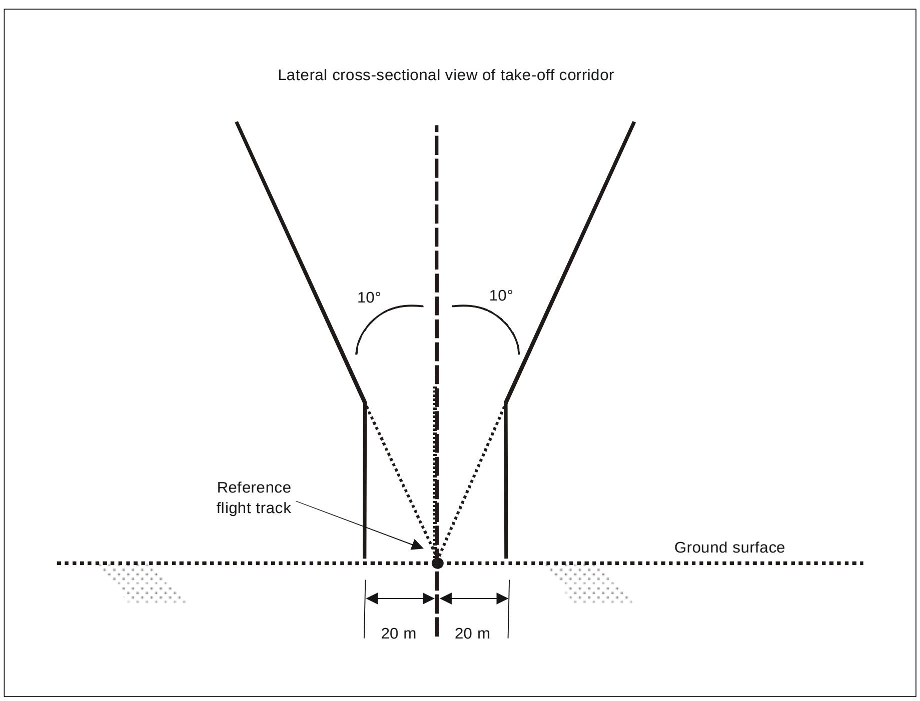


Figure 11. Lateral deviation tolerances for takeoff

(5) *Helicopter test weight*

The weight of the helicopter during the noise certification demonstration (see H36.101(b) of part 36) must lie within the range of 90 percent to 105 percent of the maximum takeoff weight for the takeoff demonstration. No adjustment of the noise data to maximum takeoff weight is required. At least one takeoff test run must be completed at or above this maximum certificated takeoff weight. If the value of the maximum takeoff weight selected for noise certification is less than that used for airworthiness certification, then the lower weight may become the operating limitation defined in the appropriate section of the RFM

401(h)(6) Takeoff flight test procedures
AMC §H36.103 [ETM AMC No. 2 A2 8.1.2.1]

(1) *Test takeoff profile*

The test takeoff profile requires stabilized flight conditions only over the 10 dB-down period in the climb portion of the procedure.

(2) *Number of test runs*

At least six test runs are required with simultaneous noise measurements at each of the noise measurement points. It should also be remembered that synchronized noise and flight path data are required. Since it cannot be determined until the analysis is partly completed if each test run meets all the requirements of Appendix H, the applicant will find considerable merit in conducting additional takeoff test runs. Experience suggests that 8 to 10 test runs would normally provide an adequate safeguard against some test runs being determined invalid during subsequent analysis. If additional test runs are conducted and more than six valid noise measurements are simultaneously obtained at all three measurement points, then the results of such test runs are also required to be included in the averaging process for calculating EPNL. The results of test runs without simultaneous noise measurements at all three measurement points are not included in the calculation process.

(3) *Flight airspeed tolerance*

A ±5 kt (±9 km/h) tolerance about the reference airspeed is specified in H36.103(b) of part 36. This is not intended to allow tests at different speeds but rather to account for variations during the 10 dB-down period which occur during an individual test run as a result of the pilot attempting to maintain the other takeoff requirements and test-to-test variations.

The value of V_y is published in the takeoff performance section of the RFM and is typically defined as an IAS. The applicant should note the reference airspeed is the true airspeed (TAS). Since most airspeed instruments do not indicate the TAS value, airspeed calibration curves and meteorological conditions should be used to convert between TAS and IAS.

(4) *Horizontal adjustment of climb initiation*

Position C in Figure 10 may be varied, subject to approval by the FAA, to minimize the difference between the test and reference heights vertically above the flight track noise measurement point. This difference can result from the effect of wind on the climb angle during testing. Figure 12 illustrates the case of a headwind. Note that even for zero or very low wind, the transition from the horizontal flight to the climb can take a significant time. This will be the case normally on larger and heavier helicopters. The resulting flight path could be well below the reference profile. In this case there would be merit in moving position C further away from the noise measurement point. This is illustrated in Figure 13.

(5) *Vertical adjustment of climb initiation*

Subject to approval by the FAA, the height of the initial level flight may also be varied in order that the height (distance) adjustment associated with the climb phase can be minimized. This is an equivalent procedure, which can be used in the place of adjusting the horizontal location of position C from the flight track noise measuring point to achieve the same result.

The applicant should note that under many test conditions no such adjustments are required to comply with the data adjustment procedures defined in H36.205(f).

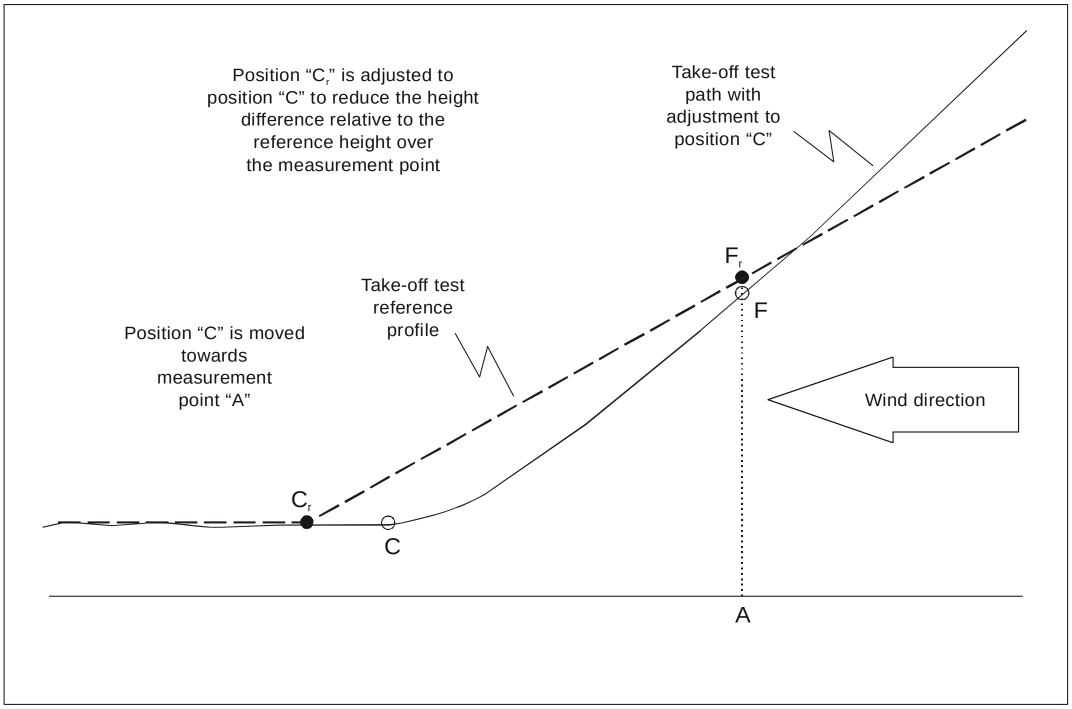


Figure 12. Adjustment of takeoff profile position "C" for headwind

Note.— The above procedures for horizontal or vertical adjustment of climb initiation are based on consideration of the height above the flight track or center noise measuring point, even though the adjustments to the noise measurements are applied for the PNLTM point. However, since the PNLTM point, which is normally within close proximity of the overhead point, cannot be determined until after the noise analysis is conducted, use of height over the noise measuring point to determine the location of position C *(or the initial horizontal height) is acceptable.*

(6) *Practice flight*

Irrespective of which method is used to control the height over the flight track noise measurement point, an applicant may find it helpful, if not essential, to conduct a number of practice or pre-noise certification test runs to adjust the height/location of position C. With prior approval of the FAA, these practice runs can be excluded from the noise compliance evaluation. These runs should also be documented in the noise certification report as practice flights.

(7) *Power setting*

Takeoff power at sea level and 77°F (25°C) has to be applied at position C to initialize the climb. On many helicopters the airworthiness power limit will be set by the takeoff gearbox torque limit. When this is not the case, the takeoff torque will be that torque determined during the airworthiness certification and will be based on the minimum specification engine(s) power.

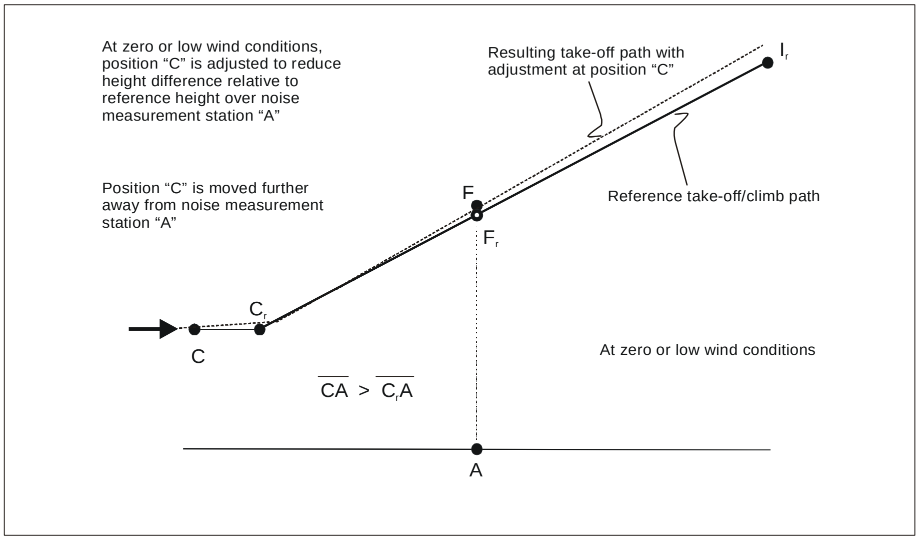


Figure 13. Adjustment of takeoff profile position "C" for zero or low wind

In some cases the applicant may find that the takeoff gearbox torque limit to which the helicopter is to be airworthiness certificated has not been approved and hence cannot be used during the noise certification test. When testing only at a lower torque is possible, the FAA may approve, as an equivalent procedure, the extrapolation of noise data from lower torque settings. Tests conducted at the maximum available, and a minimum of two, lower gearbox torque settings would be required for extrapolation, subject to approval by the FAA, to a higher torque value. Experience suggests that extrapolation of no more than 10 percent is likely to be acceptable. The applicant will also need to document in detail the extrapolation procedure to be used.

(8) *Rotor speed*

Rotor speed may be manually or automatically varied on some helicopters. On many designs variation in rotor speed can occur due to the limits of the engine/rotor governing system. In order that the noise levels are representative of normal takeoff operation, the rotor speed is to be the maximum normal value associated with the reference takeoff airspeed. Since on most helicopters small rotor speed changes occur during a stabilized flight, a ±1 percent rpm variation in the rotor speed is allowed.

Note.— Noise measurements should be made at the maximum rotor speed during normal operations. Testing at the maximum tolerance rpm is not required.

On some helicopter designs more than one rotor speed may be available (see 402(e)(1)(vi)). If multiple rotor speeds can be used for normal operations, then noise certification has to be conducted at the highest value allowed at the reference conditions. If the highest speed is limited to special operations, or if the helicopter is configured such that the highest rotor speed cannot be used at the reference conditions or test height, then, subject to approval by the FAA, testing at a lower rotor speed may be allowed.

On some helicopter designs, rotor speed may be automatically varied within the 10 dB-down period. In such cases, a reference rotor rpm schedule as a function of position along the reference flight path should be defined and tests should be conducted so as to maintain the test rotor rpm within ±1% of the reference rpm schedule. If the variation in rotor speed results in changes to the best rate of climb, a non-linear reference flight profile should be defined and used in the calculation of reference distances for adjustments of the noise data to reference conditions.

For example, for a helicopter that automatically varies rotor speed (N_r) during takeoff, a reference rotor speed schedule may be defined as a function of height above ground level along the reference flight path during the 10 dB-down period as illustrated in Figure 14. In the typical case where the helicopter is main gearbox torque limited at the noise certification reference conditions, the rotor speed schedule may also result in a non-constant (curved) reference flight path segment during the N_r transition as illustrated in Figure 14. The ±1% test requirement for rotor speed would be applied to the reference rotor speed schedule as shown in Figure 14.

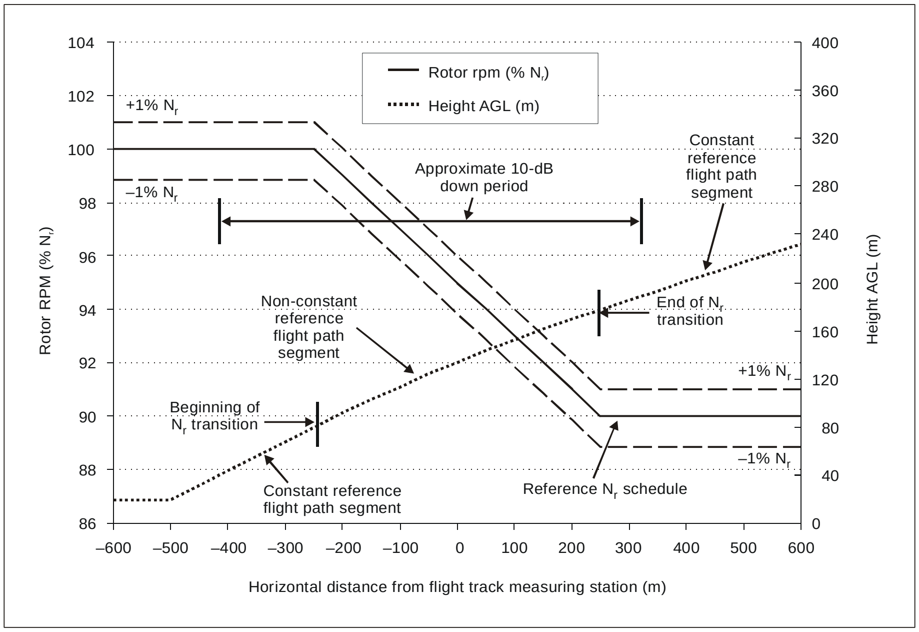


Figure 14. Example of a reference takeoff flight path and rotor speed schedule (with ±1% N_r limits) for a variable rotor speed helicopter

(9) *Flight path guidance*

To meet the requirement of being within ±10° of the vertical, the applicant may need to use flight track markings that are clearly visible and/or on-board flight track guidance instrumentation and a real-time position measuring system or some other approved method of checking that this requirement is satisfied. Pilot visibility of the ground when climbing may be somewhat limited and thus markers well ahead of the noise measuring point may be required. Some of the flight path measurement systems outlined in 302, provide flight track data in real time, or in a short period after the test run. In this case the applicant will readily be able to determine if a test run is within the allowable deviation limits. If a simpler system is utilized, such as photographic scaling based on the use of still cameras, the applicant may find it useful, if not essential, to develop a method to enable timely confirmation that the test run is acceptable. The actual height and off-track deviations do not need to be established at the time of the test run. However the applicant needs to ensure that otherwise acceptable test runs are not rejected during analysis for failing to meet the ±10° limit for lateral deviation.

401(h)(7) Flyover configuration
GM §H36.105 [ETM GM No. 1 A2 8.1.2.2]

(1) *Reference flyover profile*

Appendix H specifies the reference procedure as a level flyover at 492 ft (150 m) above the ground at the flight track measurement point as illustrated in Figure 15, in which the reference flight profile is indicated as D_r to J_r and the test profile as D to J.

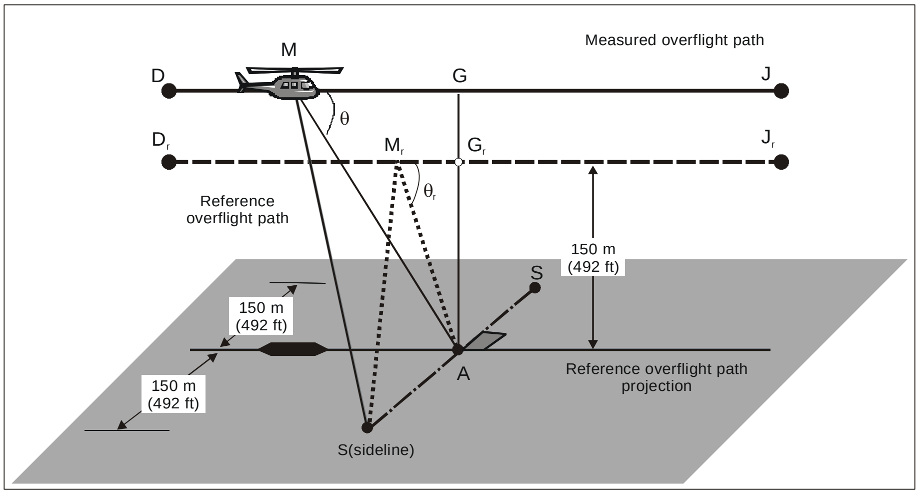


Figure 15. Comparison of measured and reference flyover profiles

The reference airspeed is 0.9 V_H, 0.9 V_{NE}, 0.45 V_H + 65 kt (0.45 V_H + 120 km/h) or 0.45 V_{NE} + 65 kt (0.45 V_{NE} + 120 km/h), whichever is less, throughout the 10 dB-down period. The rotor speed (rpm) is fixed at the maximum normal operating value. Note that if V_H is greater than V_{NE} then the reference airspeed will be related to V_{NE}.

Note.— For clarity the location of the test and reference PNLTM *points,* M *and* M_r*, are illustrated at the same position for both the centerline noise measurement point* A *and the lateral noise measurement point location* S. *Normally, however,* M*, and hence* M_r*, will be a different position on the test and reference flight path for each noise measurement point.*

GM §H36.105 [ETM GM No. 2 A2 8.1.2.2]

(1) *Flight path deviations*

To enable the flyover noise characteristics to be obtained, the flyover test has to be a level flight at a fixed height above the flight track noise measurement point. The test runs also have to be within ±10° or ±65 ft (±20 m), whichever is the greater, from the vertical throughout the 10 dB-down period. The ±65 ft (±20 m) is not relevant in the case of flyover since the off-track deviation allowed, at the test height, is controlled by the ±10° requirement.

(2) *Test airspeed tolerance*

The flight airspeed is defined in H36.3(d) of part 36 and a ±5 kt (±9 km/h) tolerance from the reference airspeed during each flyover is allowed within the 10 dB-down period. The power is to be stabilized, and the mean value of the rotor speed during the 10 dB-down period is to be within ±1 percent of the normal operating rpm value for each flyover.

(3) *Source noise adjustment testing*

The applicant should consider the requirement for source noise adjustments since it is unlikely that the tests can be conducted precisely at the reference temperature of 77°F (25°C), reference rotor speed and reference airspeed. This dictates that, if the test advancing blade tip Mach number is different from the reference Mach value, the development of a PNLTM versus advancing blade tip Mach number sensitivity curve is necessary. This requires testing at different flight speeds around the reference flight speed. The number of additional test runs will to some extent depend on the character of the variation of PNLTM with flight speed, but since this cannot be determined until after the analysis is complete, conservative estimates for the number of additional test runs and the actual airspeeds to be used need to be considered.

Note.— The equivalent Mach number procedure, discussed in section 10 of 401(h)(8), is an acceptable method of compliance that eliminates the need for a source noise adjustment.

(4) *Helicopter test weight*

The weight of the helicopter during the noise certification demonstration (see H36.101(b)(6)(ii) of part 36) must lie within the range of 90 percent to 105 percent of the maximum takeoff weight for the flyover demonstration. At least one flyover test must be completed at or above this maximum certificated weight. If the value of the maximum takeoff weight selected for noise certification is less than that used for airworthiness certification, then the lower weight may become the operating limitation defined in the appropriate section of the RFM.

401(h)(8) Flyover test procedure
AMC §H36.105 [ETM AMC A2 8.1.2.2]

(1) V_H

V_H is defined as the airspeed in level flight at the reference conditions and maximum certificated takeoff weight and is obtained using the minimum specification engine(s) torque at maximum continuous power. V_H will need to be determined specifically for the noise certification flyover tests, since its determination is not required for the airworthiness certification. V_H, by itself, is never limited by airworthiness considerations. However the maximum continuous power on which it is based may be limited due to airworthiness issues and that, in effect, could limit the value of V_H.

(2) V_{NE}

V_{NE} is determined as a part of the airworthiness approval and will therefore be readily available.

(3) *Reference airspeed*

On some helicopters V_H may be in excess of the level flight V_{NE} imposed and approved by the FAA. The intent of noise certification is not to relate test airspeeds to reference airspeeds that may be beyond the airworthiness V_{NE} limit of the helicopter. Under H36.3(d) of part 36, V_{NE} would therefore apply in place of V_H. Also on some helicopters with high airspeed capabilities, the typical cruise airspeed will be less than 0.9 V_H (or 0.9 V_{NE}) and thus if 0.9 V_H (or 0.9 V_{NE}) were used as the reference, it would no longer be representative of a cruise flight. In this case a lower airspeed of 0.45 V_H + 65 kt (0.45 V_H + 120 km/h) or 0.45 V_{NE} + 65 kt (0.45 V_{NE} + 120 km/h) is used. This applies when 0.9 V_H (or 0.9 V_{NE}) is 130 kt (240.8 km/h) or higher (i.e., when V_H (or V_{NE}) is 144.4 kt (267.5 km/h) or higher). Thus the reference airspeed will be the least of the following four airspeeds:

a) 0.9 V_H;

b) 0.45 V_H + 65 kt (0.45 V_H + 120 km/h);

c) 0.9 V_{NE}; or

d) 0.45 V_{NE} + 65 kt (0.45 V_{NE} + 120 km/h).

(4) *Flight path/height determination*

The flight path is required to be "straight and level". Since there is no requirement for the terrain over which the helicopter is flying to be perfectly level, the height of the helicopter above the ground may vary slightly over the distance corresponding to the 10 dB-down period. If a ground-based system such as a differential GPS base station or a three-camera system is used, then the flight path/height determination will need to account for the actual ground elevations at which the system components are placed.

(5) *Flight track deviations*

The allowable off-track deviation from the vertical above the reference track is limited by ±10° or ±65 ft (±20 m), whichever is the greater. The height above the flight track noise measurement point must be within ±30 ft (±9 m) of the reference height of 492 ft (150 m). The allowed off-track deviation is ±81.5 ft (±24.9 m) at the lower height limit of 462 ft (141 m) and is ±92 ft (±28 m) at the higher height limit of 522 ft (159 m). Thus the helicopter must pass through a "test window" located above the reference flight track, as illustrated in Figure 16, throughout the 10 dB-down period.

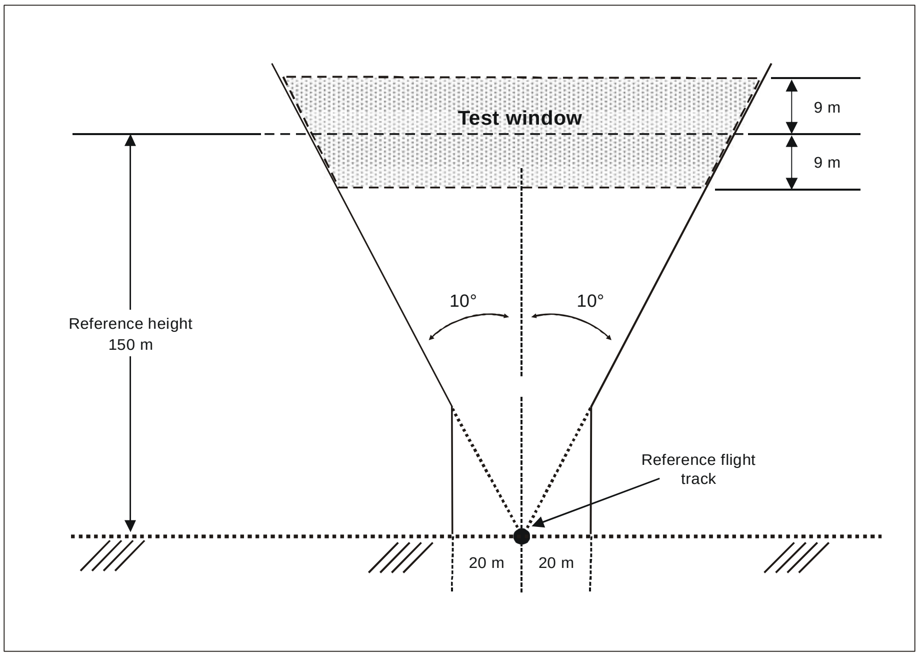


Figure 16. Flight boundaries for flyover test condition

(6) *Number of test runs*

At least six flyover test runs are required, with equal numbers with headwind and tailwind. Since the data will be adjusted, there are no requirements for these to be flown in pairs immediately one after the other. Conducting the test runs in pairs, however, would alleviate the need to take the wind direction into account. The applicant will therefore typically find it expedient to conduct tests in such a manner and include additional pairs of test runs in case any of the test runs are proved invalid on subsequent analysis. In addition to the simultaneous noise measurement at the three measurement points, the applicant should note that synchronized noise and flight path measurements are required throughout the 10 dB-down period. If additional test runs are conducted and more than six valid noise measurements are simultaneously obtained at all three measurement points, then the results of such test runs are also required to be included in the averaging process for calculating EPNL. The results of test runs without simultaneous noise measurements at all three measurement points are not included in the calculation process.

Note.— If the absolute wind speed component in the direction of flight, as measured at a height of 10 m (33 ft) above ground, is less than 5 kt (2.6 m/s), then the effect of wind direction can be considered to be negligible. In this case the measured flyover can be considered to be either a headwind or tailwind test run.

(7) *Test height*

Since most test sites will not be completely flat, the height (distance) between the helicopter and ground track will vary during the flyover The flight path and the relative position between the helicopter and the reference profile can be determined using a number of different systems (see 302 of this AC).

(8) *Test airspeed*

The flyover test airspeed will be either the reference airspeed if a source noise adjustment is applied, or the adjusted reference airspeed if the equivalent Mach number method is used. The applicant should also note that the airspeed defined in part 36 is the true airspeed (TAS). Since most airspeed instruments do not indicate the TAS value, airspeed calibration curves and test-day meteorological conditions should be used to determine the IAS for use by the pilot.

(9) *Source noise adjustment*

Source noise adjustments have to be developed for noise data measured at the center, left sideline and right sideline microphones. Test runs are conducted in two directions. “Left sideline” and “right sideline” are defined relative to the direction of flight for each test run. It follows that if a microphone is “left sideline” for a test run in one direction then it is “right sideline” for a test run in the other direction. The applicant should take care to ensure the measured noise is correctly designated.

Two methods have been adopted by various applicants to establish the source noise adjustment. The first involves testing, relative to the reference flight speed, at a number of fixed airspeeds such as V_r – 10 kt (9 km/h), V_r – 20 kt (37 km/h) and V_r + 10 kt (19 km/h). To retain the same accuracy as associated with the reference condition, six test runs (three in each direction) at each of the additional flight airspeeds are typically needed. A sensitivity curve is then developed from this data as indicated in Figure 17. Other applicants have tested over a range of airspeeds from, for example, V_r – 20 kt (19 km/h) to V_r + 10 kt (9 km/h) and developed a sensitivity curve in this manner. In this case at least six valid test runs are of course still required at the reference airspeed. A statistically acceptable curve using this method is illustrated in Figure 18. The number of test runs required for either method for developing source noise sensitivity curves is subject to approval by the FAA.

(10) *Equivalent Mach number test procedure*

To avoid testing at a large number of airspeeds over a wide airspeed range to develop a PNLTM versus a Mach number sensitivity curve, the applicant may, subject to approval by the FAA, use the equivalent procedure presented in 402(c)(2)(B). With this procedure a single series of test runs is conducted at an adjusted reference airspeed. The minimum number of acceptable test runs is six (three in each direction), and the previous comments on the need for the applicant to consider making additional test runs to cover the case where some test runs may subsequently be found to be invalid is equally applicable. When this procedure is used the airspeed tolerance is reduced from ±5 kt (±9 km/h) to ±3 kt (±5.5 km/h) In addition all the other limits applicable to testing at the reference airspeed also apply.

This equivalent procedure requires measurement of the on-board outside air temperature just prior to each test run. Under stable ambient temperature conditions this is relatively straightforward and calculations can be made on the ground prior to each test run. When changes in temperature are occurring during the test period, it may be necessary to take the on-board temperature in flight just prior to reaching the initial 10 dB-down point. These can be used to make the necessary calculations to adjust the flight airspeed appropriately and ensure that the applicable adjusted airspeed and reference advancing blade tip Mach number are used for the test run.

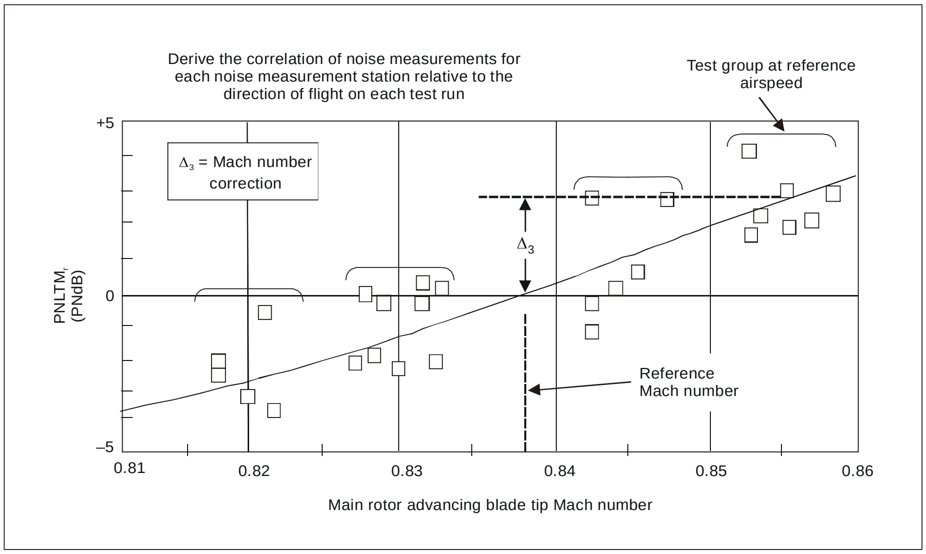


Figure 17. Example of source noise correlation using pooled (clustered) test data

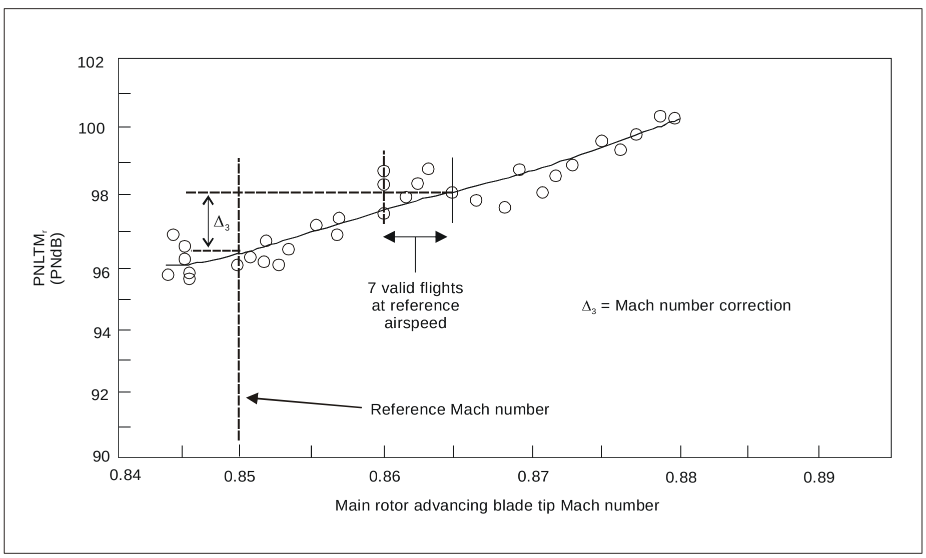


Figure 18. Example of source noise correlation using distributed test data

When this equivalent procedure is used the test runs are conducted at the reference blade tip Mach number, and hence no additional source noise adjustments are required. The applicant should also note the airspeed defined in part 36 is the true airspeed (TAS), and since most airspeed instruments do not indicate the TAS value, airspeed calibration curves and test-day meteorological conditions should be used to determine the IAS for use by the pilot.

(11) *Equivalent Mach number test speed*

Each flyover noise test must be conducted such that the adjusted reference true airspeed (V_{ar}) is the reference airspeed (V_r) specified in H36.105(c) of part 36, adjusted as necessary to produce the same main rotor advancing blade tip Mach number as associated with reference conditions.

Note.— The reference advancing blade tip Mach number (M_r) *is defined as the ratio of the arithmetic sum of the main rotor blade tip rotational speed* (V_T) *and the helicopter reference speed* (V_r) *divided by the speed of sound* (c_r) *at 77°F (25℃) 1135.6 ft/s (346.1 m/s) such that:*

$$M_r = \frac{V_T + V_r}{c_r}$$

and the adjusted reference airspeed (V_{ar}) *is calculated from:*

$$V_{ar} = c(\frac{V_T + V_r}{c_r}) - V_T$$

where c *is the speed of sound calculated from the on-board measurement of outside air temperature.*

(12) *Rotor speed/flight path guidance*

The comments on rotor speed and flight path guidance discussed in H36.3(c) and H36.103(b) of part 36 are equally applicable for flyover noise testing.

401(h)(9) Approach configuration
GM §H36.3(f) [ETM GM No. 1 A2 8.1.2.3]

(1) *Reference approach profile*

The reference approach profile is illustrated in Figure 19 together with an idealized measured test profile. part 36 requires flight tests to be conducted under stable flight conditions within a 6° ± 0.5° approach angle with the noise data adjusted to a 6° reference profile. The reference airspeed is V_y, as used for the takeoff test, or the lowest airworthiness-approved speed for approach, whichever is the greater.

Note.— For clarity the location of the test and reference PNLTM *points,* N *and* N_r*, are illustrated at the same position for both the centerline noise measurement point* A *and the starboard lateral noise measurement point* S*. Normally however* N*, and hence* N_r*, will be a different position on the test and reference flight paths for each noise measurement point.*

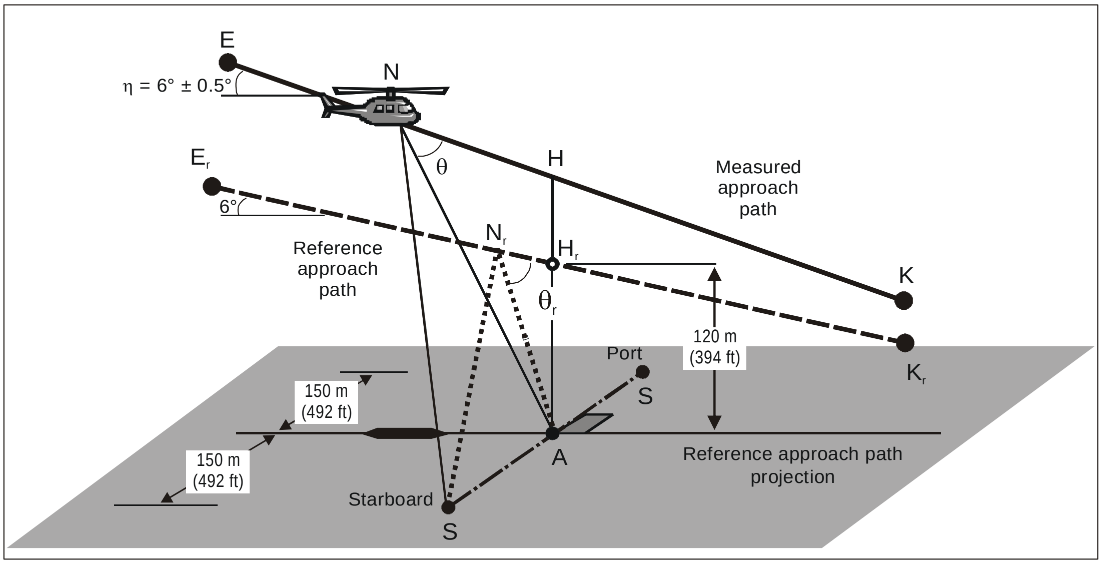


Figure 19. Comparison of measured and reference approach profiles

(2) *Reference approach path*

The touchdown position is located 3740 ft (1140 m) from the intersection of the 6° reference approach path with the ground plane through position A. The flight path reference point, H_r, is located 394 ft (120 m) above position A on the ground.

(3) *Helicopter test weight*

The weight of the helicopter during the noise certification demonstration (see H36.101(b) of part 36) must lie within the range of 90 percent to 105 percent of the maximum landing weight for the approach demonstration. At least one approach test must be completed at or above this maximum certificated weight. For most helicopters the maximum landing weight will be the same as the maximum takeoff weight and, as a result, the same maximum weight will apply to all three test conditions. If the value of the maximum landing weight selected for noise certification is less than that used for airworthiness certification, then the lower weight may become the operating limitation defined in the appropriate section of the RFM.

401(h)(10) Approach test condition
GM §H36.107 [ETM GM No. 2 A2 8.1.2.3]

(1) Test airspeed

Since there is no single common or well-defined approach airspeed applicable to helicopters, the tests are conducted at the certificated best rate of climb airspeed, V_y, which approximates to a typical approach speed, or the lowest airworthiness approved speed for approach, whichever is the greater.

(2) *Flight path deviations*

Test runs are to be conducted with a 6° ± 0.5° approach angle using stabilized flight airspeed within ±5 kt (±9 km/h) of the reference V_y airspeed, rotor speed within ±1 percent of the normal maximum operating rotor speed, and power. To limit the magnitude of the off-track distance, the flight path is to be maintained to within ±10° or ±65 ft (±20 m) of the vertical, whichever is the greater, throughout the 10 dB-down period (see Figure 20).

(3) *Maximum noise level measurement*

The intent of the Standard is to obtain noise measurements of the maximum noise levels which are likely to occur in practice during an approach flight condition. Since it is known that the maximum main rotor noise, known as blade vortex interaction (BVI) or blade slap, occurs at around 6º descent angle at a constant speed of V_y, this has been chosen as the reference condition. Only in the case where the lowest airworthiness-approved speed for approaches is greater than V_y can any approach angle exception be allowed. This would require approval by the FAA and, irrespective of approved angle, the height above the ground at the flight-track measurement point would have to be 394 ± 33 ft (120 ± 10 m).

Experience suggests however that normally there is little difficulty in conducting the approach test with a descent angle of 6° at an airspeed of V_y within the allowable limits of ±0.5° and ±5 kt (±9 km/h) respectively.

(4) *Blade vortex interaction*

Since a 6° descent angle at a speed of V_y is the approach condition likely to give the highest level of main rotor BVI, the applicant should note that although on some helicopters this will result in a steady noise signature, on other helicopters the BVI noise character can vary even under nominally steady flight conditions. This may be subjectively noticeable but is not a technical problem since the average of six test runs will normally give results well within the maximum acceptable 90 percent confidence interval of ±1.5 EPNdB.

(5) *Practice flights*

Flying a constant 6º approach angle at a constant airspeed may be a somewhat demanding requirement for some helicopters, particularly since, in practice, a decelerating approach at a varying descent angle is the common method utilized in helicopter operations. The applicant/pilot may find merit, therefore, in the test procedure being practiced prior to any noise certification testing.

401(h)(11) Approach test procedure
AMC §H36.3(f), §H36.107 [ETM AMC A2 8.1.2.3]

(1) *Reference approach procedure*

The 6° reference procedure is defined as being under stable flight conditions in terms of torque, rotor speed, airspeed and rate of descent throughout the 10 dB-down period. The reference airspeed is the best rate of climb true airspeed (TAS), V_y, approved by the FAA.

(2) *Number of test runs*

At least six test runs are required with simultaneous noise measurements at each of the noise measurement points. The applicant should, as in the case of takeoff and flyover, consider additional test runs to ensure that a sufficient number of valid data points are available. Synchronized noise and flight path measurements are required throughout the 10 dB-down period. If additional test runs are conducted and more than six valid noise measurements are simultaneously obtained at all three measurement points, then the results of such test runs are also required to be included in the averaging process for calculating EPNL. The results of test runs without simultaneous noise measurements at all three measurement points are not included in the calculation process.

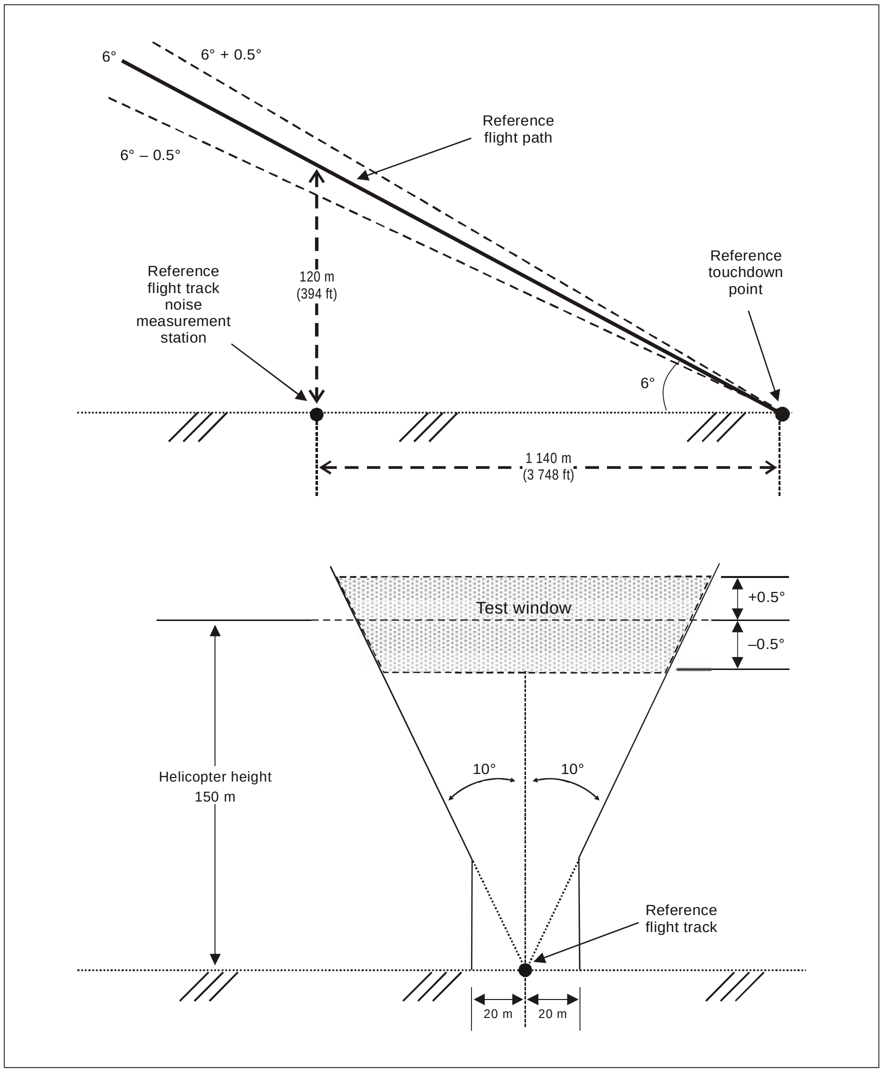


Figure 20. Flight boundaries for approach test condition

(3) *Flight path guidance*

The helicopter has to fly within the 6° ± 0.5° approach angle range and within ±10° or ±65 ft (±20 m), whichever is greater, of the vertical above the reference flight track throughout the 10 dB-down period. Thus the helicopter has to fly within a "rectangular funnel" as illustrated in Figure 20. To ensure flight within these limits, positive guidance to the pilot will most likely be required. This guidance can take many different forms, varying from on-board instrumentation providing, for example, a box in which the pilot flies the aircraft, cross hairs where the pilot flies the helicopters at the center, or an external light guidance system such as a visual approach slope indicator (VASI) or pulsating light approach slope indicator (PLASI) located at or near the imaginary touchdown point where the 6° angle reaches the ground. The system chosen by the applicant should be approved by the FAA prior to testing.

(4) *Flight path intercept*

H36.3(f) of part 36 specifies that each approach test run be continued to a normal touchdown. The noise data are taken during stabilized flight conditions within the 10 dB-down period and thus may not be impacted by the flare or the final touchdown. Also, for flight safety reasons, it may not be desirable to continue the test run on a 6° profile to the ground. As a result an equivalent procedure may be used, subject to approval by the FAA, where the helicopter can break off from the descent after the second 10 dB-down point is reached. This can be completed without the need to actually land the helicopter, offering considerable savings in flight time, providing the other requirements are met.

(5) *Wind direction*

Although part 36 does not specifically require that the test runs be conducted into the wind, this is advisable since it will provide a safer and more stable flight environment.

(6) *Rotor speed guidance*

The comments on rotor speed guidance discussed in H36.3(c) and H36.101(b) of part 36 are equally applicable for approach noise testing.

(7) *Other test requirements*

The comments on the height, flight airspeed variation and rotor speed measurements discussed in H36.3(d) & (e), H36.105(b), and H36.105(c) & (d) of part 36 are equally applicable for approach.

401(h)(12) Adjustments of PNL and PNLT
GM §H36.205(f) [ETM GM A2 8.3.2]

(1) *Units*

For calculations in SI units, the distances are measured in meters and $\alpha(i)$ and $\alpha(i)_0$, used in determining Δ_1, are expressed in dB/100 m. In this case a constant factor of 0.01 is used for the first and second terms of the Δ_1 adjustment. If the U.S. Customary (English) system of units is used the distances are measured in feet and $\alpha(i)$ and $\alpha(i)_0$ are expressed in dB/1000 ft. In this case a constant factor of 0.001 is used for the first and second adjustment terms.

(2) *Zero adjustment test window*

If the test conditions fall within the “zero attenuation adjustment window” shown in Figure 37of 402(c)(1), the sound attenuation adjustment for the effects of atmospheric absorption of the test data may be taken as zero subject to prior approval by the FAA (see 402(c)(1) for details).

401(h)(13) Duration adjustment to EPNL
AMC §H36.205(g) [ETM AMC A2 8.3.4]

(1) *Adjustment for flight path*

The distances associated with the PNLTM position used to calculate the adjustments under H36.205 of part 36 are used in the calculation of the first term of the Δ2 duration adjustment to EPNL.

Note.— If the test conditions fall within the window shown in Figure 37of 402(c)(1), the ratios of the reference and test slant distances for the propagation path adjustments in the first term of the adjustments to the duration correction may be replaced by the ratios of the reference and test distances to the helicopter when it is overhead the flight track noise measurement point (see 402(c)(1) for details).

(2) *Adjustment for ground speed differences*

The ground speed must not be confused with the actual airspeed used during the tests and will be a function of both the flight test airspeed and wind speed. The reference ground speed, V_{Gr} (based on the assumption of a zero wind condition) is, for takeoff and approach, the horizontal component of the reference airspeed, V_y (in true airspeed) defined in H36.103(b) and H36.107(b) of part 36 and, for flyover, the reference airspeed defined in H36.105(c) of part 36. For takeoff the reference ground speed V_{Gr} is the reference airspeed V_y times the cosine of the reference climb angle β.

(3) *Microphone height*

To make the necessary adjustments, the microphone height above the ground, 4 ft (1.2 m), is to be taken into account when calculating the sound propagation path from the position at which the PNLTM occurs, to the microphone.

Note.— For each noise measurement point during each test run, the PNLTM will normally occur at a different position on both the test and reference flight paths.

401(i) Adjustment of Airplane Flight Test Results
§A36.9 [ETM 4.1.9]

401(i)(1) Adjustments to reference conditions
GM §A36.9.1 [ETM GM A2 8.2]

(1) *Adjustments to reference conditions*

Most noise certification tests are conducted during conditions other than reference conditions. During these tests the airplane may be at a different height over the microphone, or deviate laterally from the intended flight path. The engine thrust (power), atmospheric conditions, airplane height and/or gross weight might also differ from reference conditions. Therefore, measured noise data should be adjusted to reference conditions to determine whether compliance with the noise certification limits of Stage 3 or 4 or 5 of part 36 may be achieved. Adjustment procedures and analysis methods should be reviewed and approved by the FAA. The FAA should ensure that data adjustment and analysis methods that are proposed by applicants satisfy the requirements of part 36 and approved procedures. Any changes, including software revisions, firmware upgrades or instrumentation changes, are subject to review by the FAA before they can be used for noise certification evaluations. Program validation should be planned and the required information submitted to the FAA early in the certification cycle, since the time required for evaluation and approval may vary depending on the issues encountered.

(2) *Non-positive SPLs*

Whenever non-positive one-third octave band aircraft noise levels are obtained, whether as part of the original one-third octave band analysis or as a result of adjustments for background noise, or other approved procedures, their values should be included in all relevant calculations. The practice of “band-dropping”, where masked levels are methodically set equal to zero, is not considered to be an acceptable substitute for reconstruction of masked levels as per the background noise adjustment guidance provided in 306(c). For any aircraft noise spectrum subject to adjustment to reference conditions, all one-third octave bands, including those containing masked levels or reconstructed levels, including values less than or equal to zero dB, should be adjusted for differences between test and reference conditions.

(3) *High altitude test sites*

For test sites at or above 1200 ft (366 m), data must be adjusted to account for jet noise suppression due to the difference in the engine jet velocity and jet velocity shear effects resulting from the change in air density. This adjustment is described in 403(b)(3).

401(i)(1)(A) Origin of reference data
GM §A36.9.1.1 [GM A2 8.2.1]

(1) *Manufacturer's data*

Adjustment of noise values from test to reference conditions should be based on approved manufacturer's data. Manufacturer's data should include:

a) reference flight profiles during takeoff with maximum gross weight;

b) flyover, lateral and approach engine thrust (power) or thrust settings at reference conditions;

c) engine cutback thrust (power) reduction requirements at reference flyover conditions;

d) data defining negative runway gradients (not applicable when an applicant uses flight path intercept techniques); and

e) reference airspeeds during flyover, lateral and approach tests at maximum gross weight.

401(i)(2) Takeoff configuration/profile
GM §B36.7(b)/A36.9.2.1 [ETM GM A2 8.1.1.2]

(1) Takeoff tests

The reference takeoff configuration selected by the applicant should be within the approved airworthiness certification envelope. Special flight crew procedures or aircraft operating procedures are not permitted.

(2) *Takeoffs with thrust (power) reduction*

Figure **21** and Figure 22 illustrate an example of the effect of thrust (power) reduction on the PNLT time history and the associated flight path. After thrust (power) reduction a slight decrease in the climb gradient may occur due to the thrust (power) lapse that results from increased height during the 10 dB-down period.

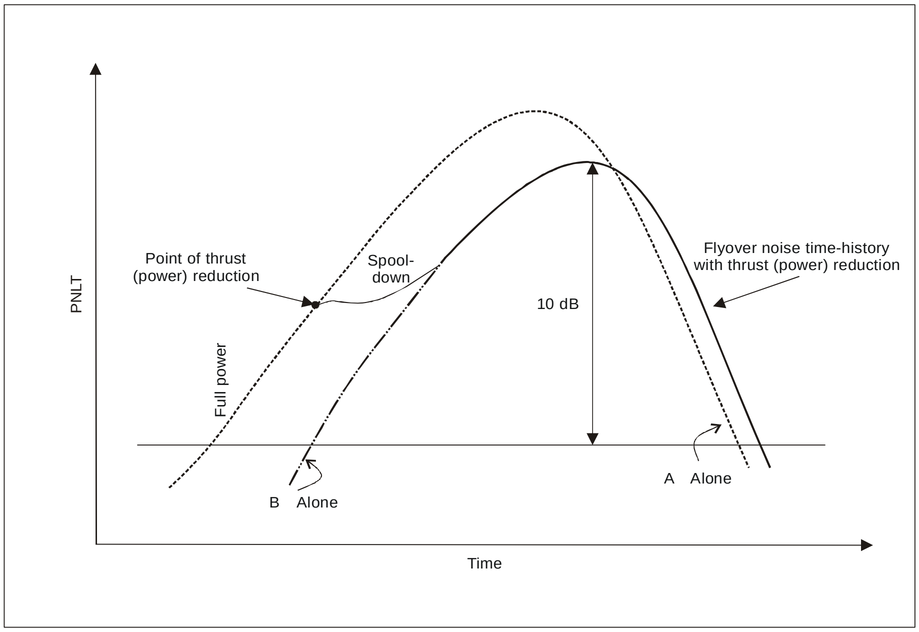


Figure 21. Takeoff noise time history

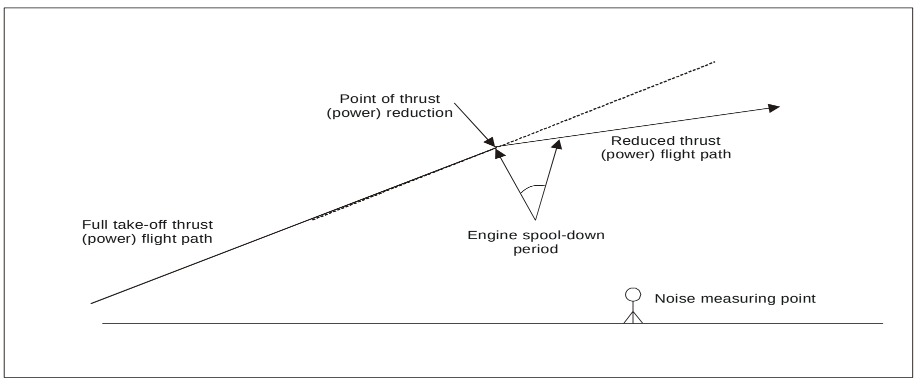


Figure 22. Takeoff flight path over flyover measuring point with thrust (power) reduction

(3) Full thrust (power) takeoffs

Full thrust (power) takeoffs are also permitted as the reference flyover noise certification procedure and are a requirement for the lateral noise certification procedure. Maximum approved takeoff thrust (power) is to be used from the start-of-roll (see point A in Figure 23). Lift-off from the runway is at point B, after which the landing gear is retracted and flap positions adjusted. At point C, the stabilized climb angle and airspeed are achieved while maintaining full takeoff thrust (power). The airplane continues to climb until sufficiently past point F to ensure that the 10 dB-down time noise value is measured at point K. Between points C and F, the thrust (power), flight path and aircraft configurations are to be kept constant.

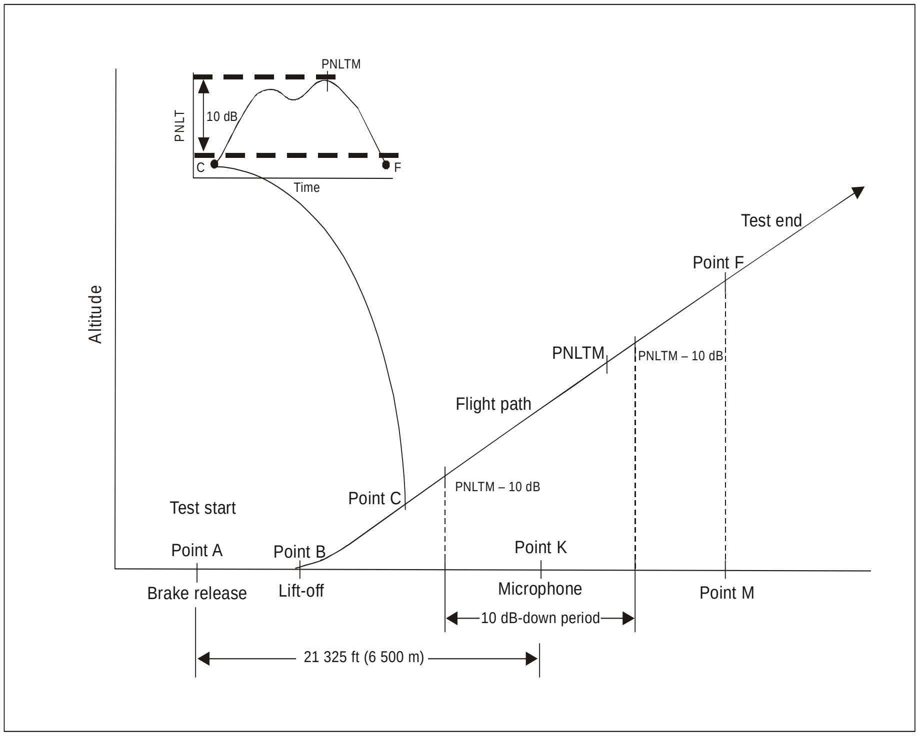


Figure 23. Normal full thrust (power) takeoff

(4) *Flight path*

Figure 24 illustrates the envelope for flight path tolerance within which the flight crew should fly between points C and F. FAA have permitted a ±20 percent tolerance in overhead test height and a ±10° lateral tolerance relative to the extended runway centerline. These tolerances permit the applicant to conduct testing during most wind conditions with minimal risk of retesting being required due to off-target flight paths. In conjunction with the climb gradient and approach angle, these flight path deviation limitations define the takeoff "flight path" through which the aircraft is to fly during and throughout the noise measurements (i.e., throughout the 10 dB-down period).

During flyover and lateral noise measurements, the extended centerline is not visible and it may be more difficult to conduct flight within the approved flight path, especially during conditions with anomalous winds aloft. Several methods have been devised to assist and provide direction to the flight crew in order to stay within the required flight path envelope. Indicators located in the airplane cockpit can provide flight path direction and indicate deviations from the extended runway centerline. Transmissions from the airplane position-indicating system (e.g., microwave position system, precision DMU or DGPS) can also provide useful inputs.

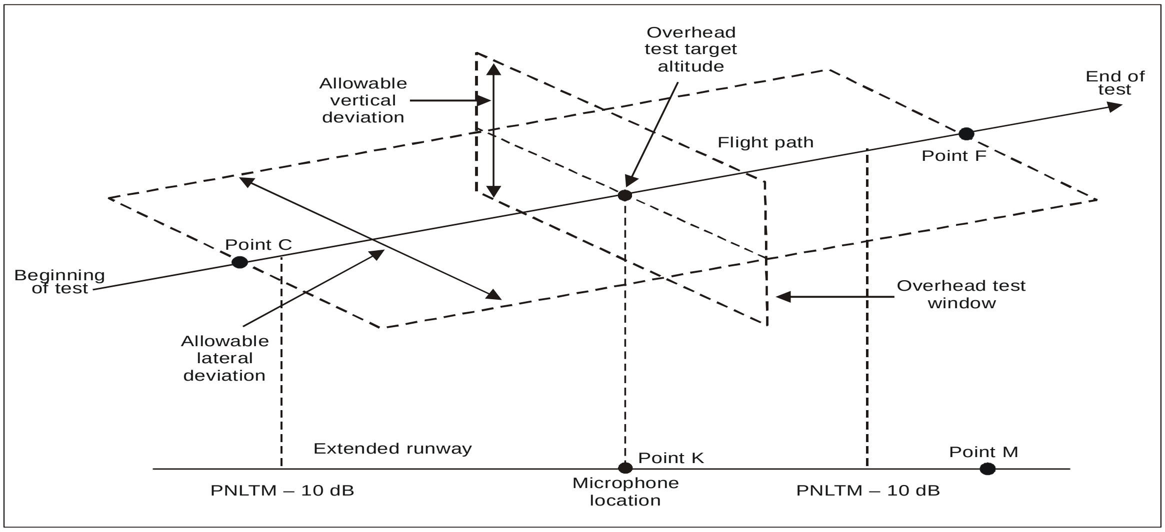


Figure 24. Takeoff flight path tolerances

401(i)(3) Takeoff test procedure
AMC §A36.9.2.1(c) [ETM AMC A2 8.1.1.2]

(1) Target test conditions

Target test conditions are established for each noise measurement. These target conditions specify the flight procedure, aerodynamic configuration to be selected, airplane weight, engine thrust (power), airspeed and, at the closest point of approach to the noise measurement point, airplane height. Regarding choice of target airspeeds and variation in test weights, the possible combinations of these test elements may affect the airplane angle-of-attack or airplane height and, therefore, possibly the airplane noise generation or propagation geometry (see 402(a)(1)(ii)(A) for guidance on the choice of target airspeeds and variation in test weights).

(2) *Flight test procedures*

Before the start of noise testing the FAA should approve flight path tolerances (see A36.9.2.1 of part 36). Except when takeoffs with thrust (power) reduction are being demonstrated, the engine thrust (power), airplane flight path and aerodynamic configuration should be kept constant between points C and F (see Figure 24) during each approved certification flight test.

(3) Invalid test data

Noise measurements obtained when the airplane flies outside the approved flight path envelope between points C and F (see Figure 24) during a noise certification test are considered invalid, and the noise measurement is to be repeated.

401(i)(4) Approach test configuration
GM §A36.9.2.2/B36.7(c) [ETM GM A2 8.1.1.3]

(1) Approach tests

Figure 25 depicts the reference approach flight test configuration for noise certification testing of airplanes. The approach angle (steady glide angle) for this condition is 3° ± 0.5°, and the target airplane height vertically above the noise measurement point is 394 ft (120 m). Maximum PNLT may occur before or after the approach noise measurement point.

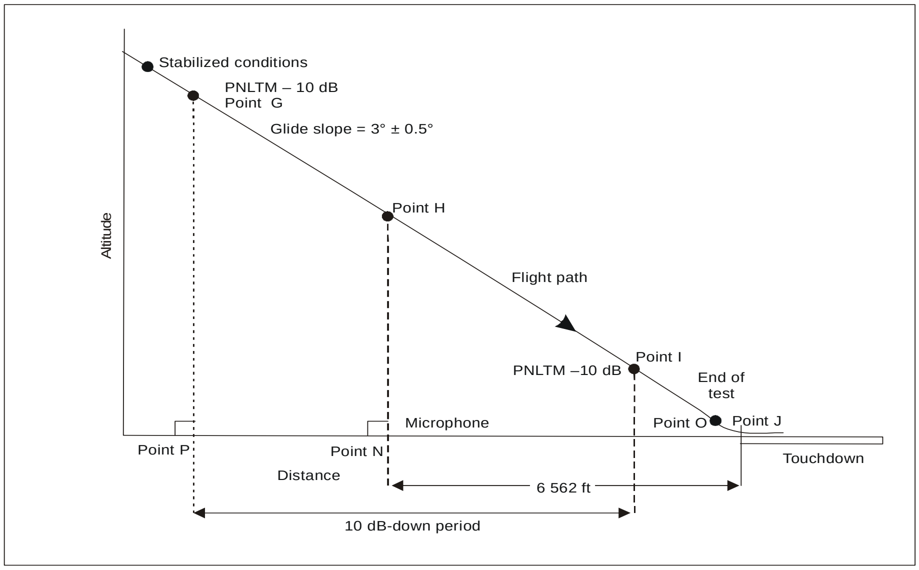


Figure 25. Approach with full landing

(2) Flight path deviations

Approved height and centerline deviations along the extended runway approach flight path (see Figure **26**) define an approved flight path envelope within which the flight crew should fly between points G and I. In cases where the flight crew has a clear view of the airport runway during the approach, it is common for the crew to consistently fly within the approved flight path envelope. Therefore, the approved centerline and height deviations for approach conditions may be smaller than during takeoff conditions.

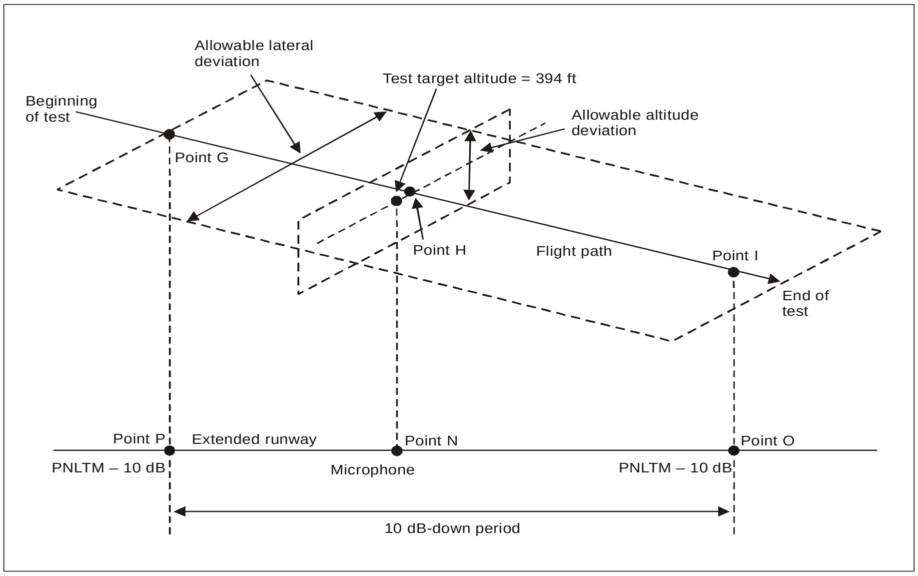


Figure 26. Approach flight path tolerances

401(i)(5) Approach test procedure
AMC §B36.7(c) [ETM AMC A2 8.1.1.3]

(1) Target test conditions

Target test conditions should be established for each noise measurement. These specify the selected aerodynamic configuration, system operation, airplane weight, flight procedure (such as complete landings or flight path intercepts) height, thrust (power) and airspeed during each noise measurement. The applicant is required to select the approved airworthiness configuration for the approach noise certification that produces the highest noise level (i.e., the most critical from the standpoint of noise). The airspeed requirement for subsonic jet airplanes is V_{REF} + 10 kt (V_{REF} +19 km/h)). This airspeed is kept constant, within ±3.0 percent, throughout the 10 dB-down period (i.e., between points G and I in
Figure **26**). The airplane configuration (e.g., flap setting, air conditioning and/or APU system operation) is to remain constant during the noise measurement period. Airspeed variations are measured in terms of IAS as determined by the pilot's airspeed indicator.

(2) Engine idle trim

For engines where the idle trim may affect the inter-compressor bleed valve schedule during the approach condition, the engine in-flight idle trim should be adjusted to the highest engine speed setting permitted by the engine manufacturer and consistent with airworthiness requirements. The engine may also provide ground idle trim adjustment, but the trim that needs adjustment is that which is operable during flight. In-flight idle trim may be adjusted to improve engine acceleration characteristics to satisfy airworthiness compliance. The higher idle trim will cause the highest engine speed, and hence idle thrust (power), which results in a greater airplane angle-of-attack and will result in the loudest approach noise required for certification. The applicant is to make those adjustments necessary to satisfy the airworthiness regulations. This idle trim adjustment may affect the performance or evaluation of approach NPD testing.

(3) Internal compressor bleed adjustment

The internal compressor bleed operation, sometimes referred to as the surge bleed valve (SBV) operation, should be adjusted within the engine manufacturer's specification to represent reference conditions as closely as possible. Most turbojet engines are equipped with internal compressor bleed systems. The internal compressor bleed operates to reduce the possibility of internal engine surges during rapid throttle movements. Some jet engines have overboard bleed systems that generate high noise levels. These systems normally operate above in-flight idle and do not present a problem unless the applicant chooses to prepare an NPD database and the thrust (power) settings higher than in-flight idle. The applicant is responsible for substantiating that either the internal compressor bleed operation does not affect the reference EPNL values during noise certification reference conditions, or the data contains the effects of the internal compressor bleed operation.

(4) Invalid test data

Noise measurements obtained when the aircraft flies outside the approved flight path envelope between points G and I are invalid, and the noise measurement must be repeated.

401(i)(6) Lateral noise measurement
GM §B36.4(b) [ETM GM A2 8.1.1.1]

(1) *Measured lateral noise levels*

Measured lateral noise levels may not be the same at symmetrical noise measurement points even when the data are adjusted for airplane position for flight directly over the extended runway centerline. This non-symmetrical nature of measured sideline noise is primarily attributable to the direction of engine or propeller rotation. Because of inlet shielding, jet-powered airplanes may exhibit 1 to 2 dB differences in lateral noise levels. Turbo-propeller-powered airplanes can exhibit differences in lateral noise levels in excess of 6 dB. Due to their inherent lateral noise asymmetry, B36.4(b) of part 36 specifies that, for propeller-driven airplanes, simultaneous measurements be made at each and every test noise measurement point at its symmetrical position on the opposite side of the flight track.

401(i)(7) Integrated procedure adjustment
GM §A36.9.4 [GM A2 8.4]

(1) *Integrated procedure adjustments*

Section A36.9.4 of part 36 provides details of an approved integrated adjustment method when the airplane is operated at stabilized flight path and thrust (power) conditions during the noise measurement period. Measured and reference flight paths are illustrated in Figures A36-11 (a) and A36-11 (b) of part 36.

401(i)(8) Acoustic emission angles
GM §A36.9.4.2 [GM A2 8.3.1.2]

(1) Acoustic e*mission angles*

For the integrated method, each one-half-second noise data record will define a separate acoustic emission angle. This angle will then define the location of each data record along the reference flight path. The distance between consecutive data records along the reference flight path, divided by the reference path speed, provides the time interval between reference data records. The reference duration of each of these data records can be determined by obtaining the average of the two intervals between the adjacent data records. This may be different than 0.5 seconds. Section 403(a)(1)(iv) provides methods for time interval computations using the integrated method.

402 EQUIVALENT PROCEDURES INFORMATION
[ETM 4.2]

402(a) Subsonic Jet Airplanes
[ETM 4.2.1]

402(a)(1) Flight test procedures [ETM 4.2.1.1]

The following methods have been used to provide equivalent results to the procedures for jet airplanes described in part 36.

402(a)(1)(A) Flight path intercepts [ETM 4.2.1.1.1]

Flight path intercept procedures, in lieu of full takeoff and/or landing profiles described in A36.9.2.1 and A36.9.2.2 of part 36, have been used to meet the demonstration requirements for noise certification. The intercept procedures have also been used in the implementation of the generalized flight test procedures described in 402(a)(1)(B). The use of intercepts eliminates the need for actual takeoffs and landings, with significant cost and operational advantages at high gross weight, and substantially reduces the test time required. Site selection problems are reduced, and the shorter test period provides a higher probability of stable meteorological conditions during testing. Airplane wear and fuel consumption are reduced, while greater consistency and quality of noise data are obtained.

402(a)(1)(A)(i) For takeoff [ETM 4.2.1.1.1.1]

Part a) of Figure 27 illustrates a typical takeoff profile. The airplane is initially stabilized in level flight at point A and continues to point B where takeoff power is selected and a steady climb is initiated. The steady climb condition is achieved at point C, intercepting the reference takeoff flight path and continuing to the end of the noise certification takeoff flight path. Point D is the theoretical takeoff rotation point used in establishing the reference flight path. If thrust (power) reduction is employed, point E is the point of application of thrust (power) reduction, and point F is the end of the noise certification takeoff flight path. The distance TN is the distance over which the position of the airplane is measured and synchronized with the noise measurement at point K.

402(a)(1)(A)(ii) For approach [ETM 4.2.1.1.1.2]

The airplane usually follows the planned flight trajectory while maintaining a constant configuration and power until there is no influence on the noise levels within 10 dB of the PNLTM. The airplane then carries out a go-around rather than continuing the landing (see part b of Figure 27).

For the development of the NPD data for the approach case, the speed and approach angle constraints imposed by B36.3(c) and B36.7(c) of part 36 cannot be satisfied over the typical ranges of thrust (power) needed. For the approach case, a steady speed of V_{REF} + 10 kt (V_{REF} + 19 km/h) should be maintained to within ±5 kt (±9 km/h), and the height over the microphone should be 394 ± 100 ft (120 ± 30 m). Within these constraints the test approach angle at the test thrust (power) should be that resulting from the test aircraft conditions (i.e., weight, configuration, speed and thrust (power)).

The flight profiles should be consistent with the test requirements of part 36 over a distance that corresponds at least to noise levels that are 10 dB below the PNLTM (i.e., throughout the 10 dB-down period) obtained at the measurement points during the demonstration.

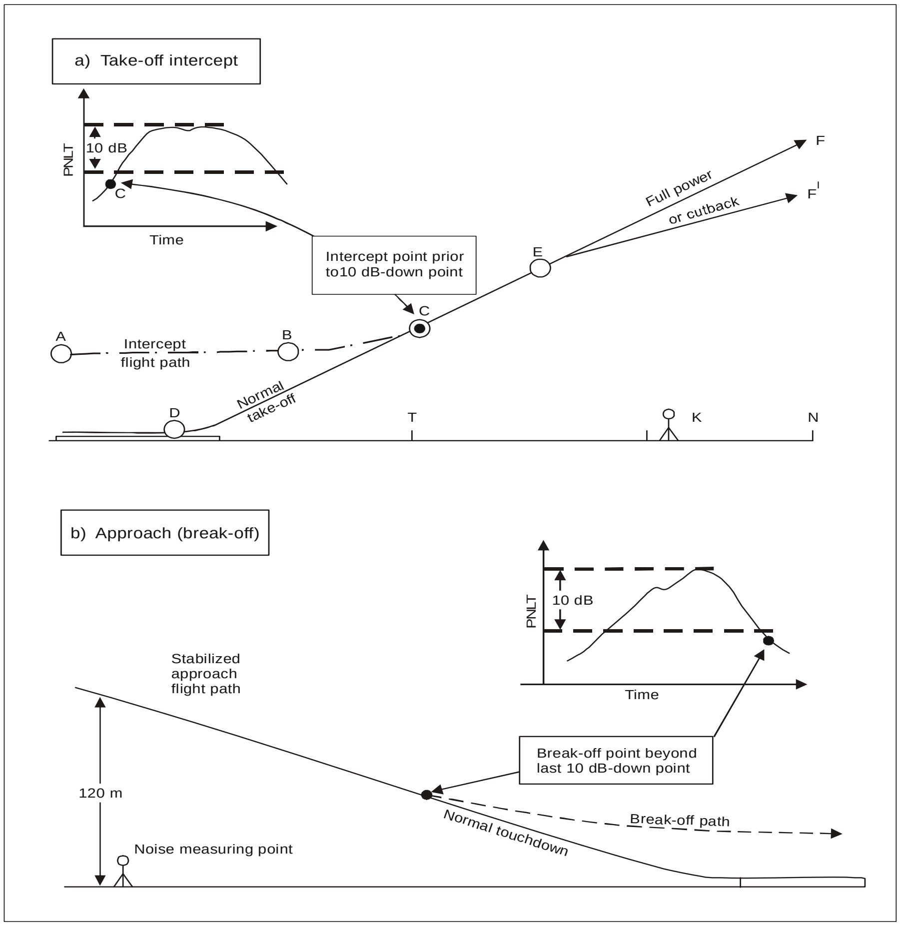


Figure 27. Flight path intercept procedures

402(a)(1)(B) Generalized flight test procedures [ETM 4.2.1.1.2]

The following equivalent flight test procedures have been used for noise certification compliance demonstrations.

402(a)(1)(B)(i) For derivation of noise-power-distance (NPD) data [ETM 4.2.1.1.2.1]

For a range of thrust (power) covering full takeoff and reduced thrust (power), the airplane is flown past lateral and under-flight-path microphones according to either the takeoff procedures defined in B36.7(b) of part 36 or, more typically, the equivalent flight path intercept procedures described above in 402(a)(1)(i). Target test conditions are established for each sound measurement. These target test conditions define the flight procedure, the aerodynamic configuration to be selected, airplane weight, power, airspeed and the height at the closest point of approach to the measurement location. Regarding choice of target airspeeds and variation in test weights, the possible combinations of these test elements may affect the airplane angle-of-attack or airplane attitude and, therefore, possibly the airplane sound generation or propagation geometry.

The airplane angle-of-attack will remain approximately constant for all test weights if the tests are conducted at takeoff reference airspeed appropriate for each test weight. For example, if the appropriate takeoff reference airspeed for the airplane is V_2 + 15 kt, then by setting the target airspeed at the V_2 + 15 kt appropriate for each test weight, while the actual airspeed will vary according to each test weight, the airplane test angle-of-attack will remain approximately constant. Alternatively, for many airplanes the airplane attitude remains approximately at the attitude associated with the takeoff reference airspeed corresponding to the maximum takeoff weight. Review of these potential airplane sensitivities may dictate the choice of target airspeeds and/or test weights in the test plan in order to limit excessive changes in angle-of-attack or airplane attitude that could significantly change measured noise data. In the execution of each condition, the pilot should "set up" the airplane in the appropriate condition in order to pass by the noise measurement location within the target height window, while maintaining target power and airspeed, within agreed tolerances, throughout the 10 dB-down period.

A sufficient number of noise measurements are made in order to establish noise-power curves at a given distance for both lateral and flyover cases These curves are extended, either by calculation or by the use of additional flight test data to cover a range of distances, to form the generalized noise database for use in the noise certification of the "flight datum" and derived versions of the airplane type and are often referred to as NPD plots (see Figure 28). If over any portion of the range for the NPD plot, the criteria for calculating the EPNL given in A36.9.1.2 of part 36 requires the use of the integrated procedure, then this procedure must be used for the whole NPD plot. The 90 percent confidence intervals about the mean lines are constructed through the data (see 305 of this AC).

Note.— The same techniques may be used to develop NPD plots that are appropriate for deriving approach noise levels by flying over an under-flight-path microphone for a range of approach powers, using the speed and airplane configuration given in B36.7(c) of part 36 or, more typically, the flight test procedures described in 402(a)(1)(i)(B).

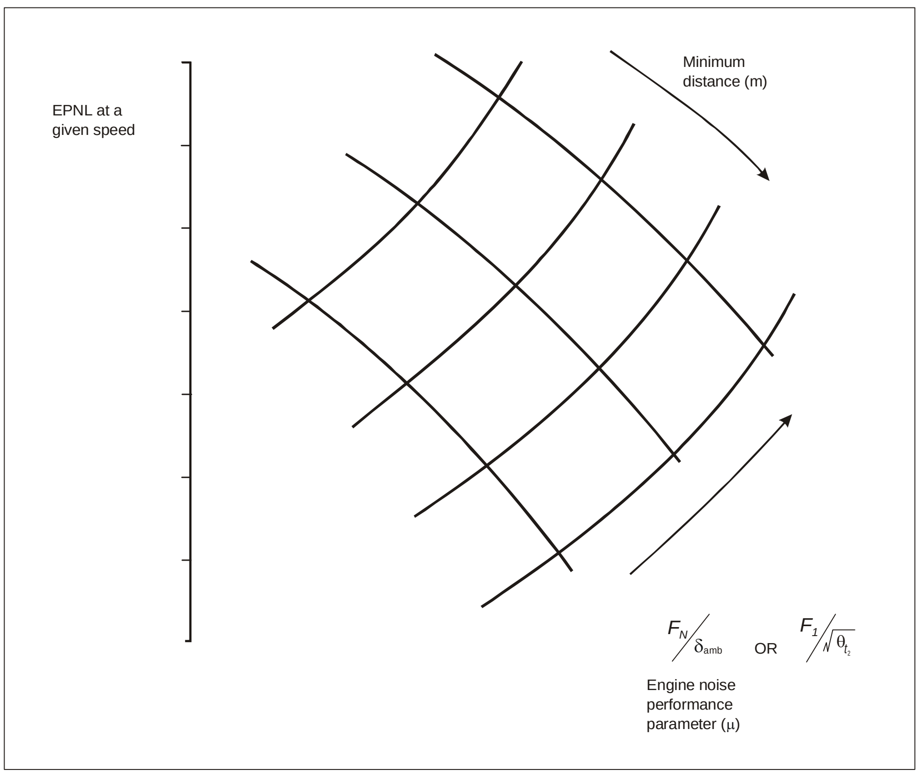


Figure 28. Form of noise-power-distance (NPD) plot for jet-powered airplanes

The availability of flight test data for use in data adjustment (e.g., speed and height) should be considered in test planning, as such availability may limit the extent to which a derived version may be certificated without further flight testing, especially where the effects of airspeed on source noise levels become significant. The effects of high altitude test-site location on jet source noise levels should also be considered in test planning. High altitude test-site locations have been approved under conditions specified in 403(b)(3), provided that jet source noise adjustments are applied to the noise data. The correction method described in 403(b)(3) has been approved for this purpose.

Flyover, lateral and approach noise measurements should be corrected to the reference speed and atmospheric conditions over a range of distances in accordance with the procedures described in Appendix A of part 36. NPD plots can then be constructed from the adjusted EPNL, power and distances. These plots present the EPNL values for a range of distance and engine noise performance parameters.

The parameters are usually the corrected low pressure rotor speed $(\frac{N_1}{\sqrt{\theta_{t2}}})$ or the corrected net thrust $(\frac{F_N}{\delta_{amb}})$ (see Figure 28), where:

— N_1 is the actual low pressure rotor speed;

— θ_{t2} is the ratio of the absolute static temperature of the air at the height of the airplane to the absolute temperature of the air for an ISA at mean sea level (i.e., 288.15 K);

— F_N is the actual engine net thrust (power) per engine; and

— δ_{amb} is the ratio of the absolute static pressure of the ambient air at the height of the airplane to ISA air pressure at mean sea level (i.e., 101.325 kPa).

Generalized NPD data may be used in the certification of the flight-tested airplane and derivative versions of the airplane type. For derived versions, these data may be used in conjunction with analytical procedures, static testing of the engine and nacelle, or additional limited flight tests to demonstrate compliance.

402(a)(1)(B)(ii) For flight test procedures for determination of changes in airplane certification noise levels [ETM 4.2.1.1.2.2]

Noise level changes determined by comparison of flight test data for different configurations of an airplane type have been used to establish certification noise levels of newly derived versions by reference to the noise levels of the “flight datum” airplane. These noise level changes are added to or subtracted from the noise levels obtained from individual flights of the “flight datum” airplane. Confidence intervals of new data are statistically combined with the “flight datum” data to develop overall confidence intervals (see 305 of this AC).

402(a)(1)(C) Determination of the lateral certification noise levels [ETM 4.2.1.1.3]

The lateral full-power reference noise measurement point for jet-powered airplanes is defined as the point on a line parallel to and 1476 ft (450 m) from the runway centerline, where the noise level is a maximum during takeoff. Alternative procedures using two microphone stations located symmetrically on either side of the takeoff reference track have proven to be effective in terms of time and cost savings. Such an arrangement avoids many of the difficulties encountered when using multiple microphone arrays along the lateral lines. The procedure consists of flying the test airplane at full takeoff thrust (power) at several different specified heights above a track at right angles to and midway along the line joining the two microphone stations. When this procedure is used, matching data from both lateral microphones for each fly-past should be used for the lateral noise determination. Fly-pasts where data from only one microphone are available must be omitted from the determination. The following paragraphs describe this equivalent procedure for determining the lateral noise level for jet airplanes.

a) For airplanes being certificated under Appendix B, two microphone locations are typically used, symmetrically placed on either side of, and 1476 ft (450 m) from, the airplane reference flight track.

b) Fly-pasts are performed at constant full takeoff power, configuration and airspeed as described in B36.7(b)(3) and B36.7(b)(4) of part 36.

c) The airplane should be flown along a track that intersects, at right angles, the line joining the two microphones. A number of flights should be performed such that the height of the airplane as it crosses this line typically covers a range between 200 ft and 2000 ft (approximately between 60 m and 600 m).

d) Adjustment of measured noise levels should be made to the acoustical reference day conditions and to reference airplane operating conditions as specified in A36.9 of part 36.

e) If the adjusted noise levels show a reasonable degree of symmetry between the left and right sides, as will generally be the case for jet airplanes, the arithmetic average of the $EPNL_r$ values for the lateral microphone pair should be plotted against either the height of the airplane opposite the microphones or the average of the sound emission heights for PNLTM. A regression curve, which is typically second order, is plotted through the data points. The reported lateral EPNL at the reference condition needed for the purpose of demonstrating compliance with the applicable noise limit is the maximum value of the curve.

f) For airplanes for which the adjusted noise levels exhibit a marked degree of asymmetry, the $EPNL_r$ values for the left and right side should be plotted against either the height of the airplane opposite the microphone location or the height at the time of emission of PNLTM. Separate regression curves, which are typically second order, are plotted through the data points for the left and right sides. The reported lateral EPNL at the reference condition ($EPNL_r$) needed for the purpose of demonstrating compliance with the applicable noise limit is the maximum value of the curve midway between the left and right curves.

g) It should also be established that the confidence interval associated with the reported lateral EPNL (i.e., the maximum “regression” value of $EPNL_r$) is within the ±1.5 dB 90 percent confidence interval specified in A36.5.4 of part 36 (see 305(b)(2) of this AC).

Note.— Exceptionally, and in order to obtain a curve from which a maximum value can be clearly determined, either a third order regression curve or the removal from the analysis of some outlying data points might be permitted. Applicants will be required to provide technical justification for the use of such exceptional procedures, which will be subject to the approval by FAA

Certification lateral noise levels have also been determined by using multiple pairs of laterally opposed microphones rather than only one pair. In this case the microphones must be sufficiently spaced along the lateral line to ensure that the noise levels measured at each microphone are statistically independent. A sufficient number of data points, resulting from a minimum of six runs, must be obtained in order to adequately define the maximum lateral $EPNL_r$ value and provide an acceptable 90 percent confidence interval.

Lateral noise measurements for a range of conventionally configured airplanes with under-wing and/or rear-fuselage mounted engines having a bypass ratio of more than two have shown that the maximum lateral noise at full power normally occurs when the airplane is close to 984 ft (300 m) in height during the takeoff. Based on this finding, and subject to the approval by the FAA, the airplane may be flown on a minimum of six acceptable occasions such that it passes the microphone stations at a target height of 984 ft (300 m) while staying within +328 ft, –164 ft (+100 m, –50 m) of this target height.

402(a)(1)(D) Takeoff flyover noise levels with thrust (power) reduction [ETM 4.2.1.1.4]

Flyover noise levels with thrust (power) reduction may also be established without making measurements during takeoff with full thrust (power) followed by thrust (power) reduction (see 402(a)(2)(a) for details).

402(a)(1)(E) Measurements at non-reference points [ETM 4.2.1.1.5]

In some instances test measurement points may differ from the reference measurement points specified in B36.4 of part 36.Under these circumstances an applicant may request approval of data that have been adjusted from actual measurements in order to represent data that would have been measured at the reference noise measurement points at reference conditions. Reasons for requesting approval of such adjusted data may be:

a) to allow the use of a measurement location that is closer to the airplane flight path so as to improve data quality by obtaining a greater ratio of signal to background noise; whereas 306(e) of this AC describes a procedure for removing the effects of background noise, the use of data collected closer to the airplane avoids the interpolations and extrapolations inherent in the method;

b) to enable the use of an existing, approved noise certification database for an airplane type design in the certification of a derivative of that type, when the derivative is to be certificated under reference conditions that differ from the original type certification reference conditions; and

c) to avoid obstructions near the noise measurement points, which could influence sound measurements; when a flight path intercept technique is being used, flyover and approach noise measurement points may be relocated as necessary to avoid undesirable obstructions; lateral noise measurement points may be relocated by distances which are of the same order of magnitude as the airplane lateral deviations or offsets relative to the nominal flight paths that occur during flight testing.

Approval has been granted to applicants for the use of data from non-reference noise measurement points provided that measured data are adjusted to reference conditions in accordance with the requirements of A36.9 of part 36 and the magnitudes of the adjustments do not exceed the limitations cited in B36.8(d) of part 36.

402(a)(1)(F) Atmospheric test conditions [ETM 4.2.1.1.6]

The FAA has found it acceptable to exceed the sound attenuation coefficient limits of A36.2.2.2(c) of part 36 in cases when:

a) the dew point and dry bulb temperature are measured with a device which is accurate to ±0.5°C and are used to obtain relative humidity, and when “layered” sections of the atmosphere are used to compute sound attenuation coefficients in each one-third octave band in compliance with the provisions of A36.2.2.3 of part 36, or

b) the peak noy values at the time of PNLT, after adjustment to reference conditions, occur at frequencies of less than or equal to 400 Hz.

402(a)(1)(G) Layering equivalency [ETM 4.2.1.1.7]

A36.2.2.3 of part 36 defines the procedure for layering the atmosphere and determining the sound attenuation coefficients to be used in the adjustment of aircraft noise levels. The procedure requires that the atmosphere from the ground to at least the height of the airplane must be divided into layers of 100 ft (30 m) depth. Subject to the approval by FAA, the applicant may use layers of more or less, and not necessarily equal, depth. The applicant should demonstrate that the layering procedure being proposed is equivalent to the procedure defined in part 36.

402(a)(2) Analytical procedures [ETM 4.2.1.2]

Analytical equivalent procedures rely upon available noise and performance data obtained from flight tests for the airplane type. Generalized relationships between noise, power and distance (see 402(a)(1)(B)(i) for derivation of NPD plots) and adjustment procedures for speed changes in accordance with the methods of Appendix A of part 36 are combined with certificated airplane aerodynamic performance data to determine noise level changes resulting from type design changes. These noise level increments are then applied to noise levels in accordance with 402(a)(1)(ii).

402(a)(2)(A) Flyover noise levels with thrust (power) reduction [ETM 4.2.1.2.1]

Flyover noise levels with thrust (power) reduction may be established from the merging of PNLT versus time measurements obtained during constant power operations. As illustrated in Figure 29, the 10 dB-down PNLT noise time history recorded at the flyover point may contain portions of both full thrust (power) and reduced thrust (power) noise time-histories. As long as these noise time-histories, the average engine spool-down thrust (power) characteristics, and the airplane flight path during this period (see Figure 30), which includes the transition from full to reduced thrust (power), are known, the flyover noise level may be computed.

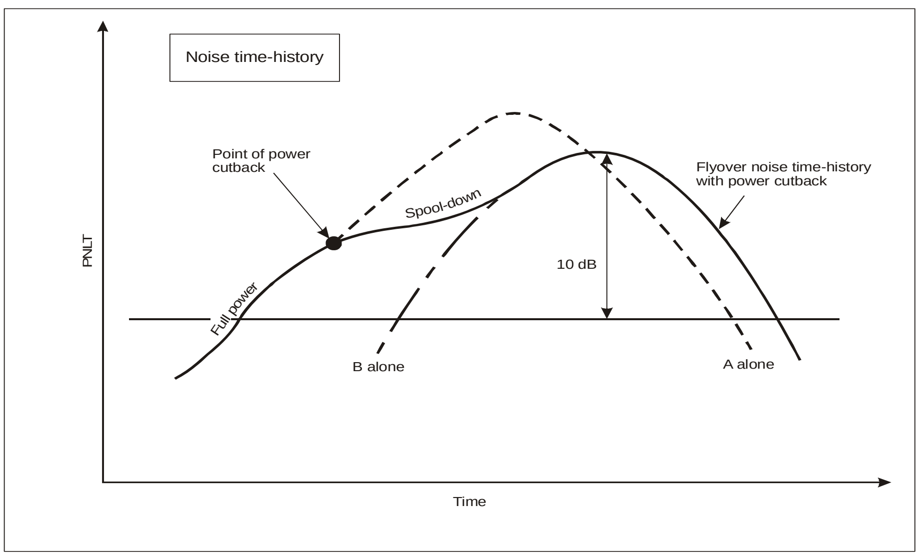


Figure 29. Computation of cutback takeoff noise level from constant power tests

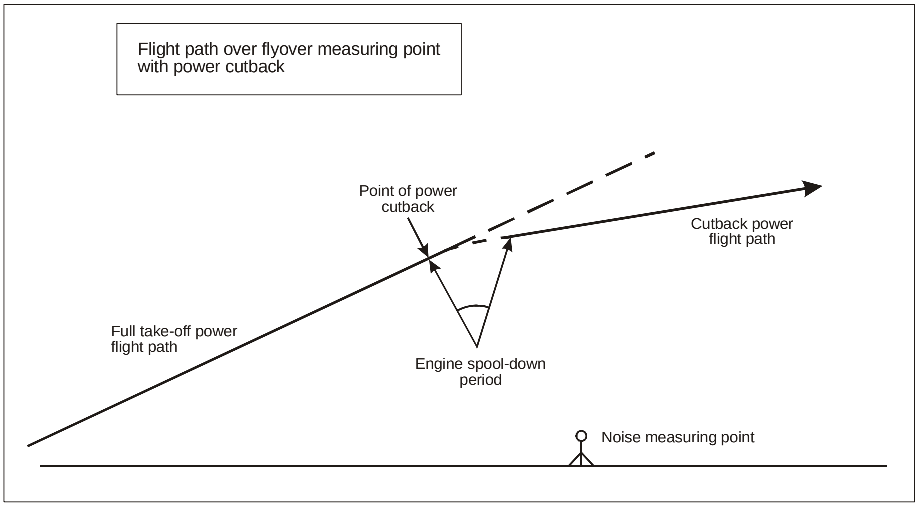


Figure 30. Computation of reduced thrust takeoff noise level from constant thrust tests

Where the full thrust (power) portion of the noise time history does not intrude upon the 10 dB-down time history of the reduced thrust (power), the flyover noise levels may be computed from a knowledge of the NPD characteristics and the effect of the average spool-down thrust (power) characteristics on the airplane flight path.

Note 1.— The selection of the height of an airplane within the reference flight path for initiation of thrust (power) reduction should take into account both the "average engine" spool-down time and a 1.0-second delay for flight crew recognition and response prior to movement of the throttles to the reduced thrust (power) position.

Note 2.— To ensure that the full thrust (power) portion of the noise-time history does not intrude upon the 10 dB-down noise levels, $\underset{aftercutback}{PNLTM} - \underset{before\ cuteback}{PNLT} \geq 10.5dB$.

402(a)(2)(B) Equivalent procedures based upon analytical methods [ETM 4.2.1.2.2]

Noise certification approval has been given for applications based on type design changes that result in predictable noise level differences, including the following:

a) changes to the originally certificated takeoff or landing weight, which in turn lead to changes in the distance between the airplane and the microphone and/or reduced thrust (power) for the takeoff case, and changes to the approach power; in this case the NPD data may be used to determine the certification noise level of the derived version;

b) noise changes due to engine power changes; however, care should be taken to ensure that when NPD plots are extrapolated, the relative contribution of the component noise sources to the EPNL remains essentially unchanged and a simple extrapolation of the NPD curves can be made; among the items which should be considered in extending the NPD are:

   1) the 90 percent confidence interval at the extended thrust (power);

   2) airplane /engine source noise characteristics and behavior;

   3) engine cycle changes; and

4) quality of data to be extrapolated;

c) airplane engine and nacelle configuration and acoustical treatment changes, usually leading to changes in the values of EPNLr of less than 1 dB;

Note 1.— It should however be ensured that new noise sources are not introduced by modifications made to the airplane, engine or nacelles. A validated analytical noise model approved by the FAA may be used to derive predictions of noise increments. The analysis may consist of modelling each airplane component noise source and projecting the sources to flight conditions in a manner similar to the static test procedure described in 402(a)(3)(D). A model of detailed spectral and directivity characteristics for each airplane noise component may be developed by theoretical and/or empirical analysis. Each component should be correlated to the parameters which relate to the physical behavior of source mechanisms. The source mechanisms, and subsequently the correlating parameters, should be identified through use of other supplemental tests such as engine or component tests. As described in 402(a)(3)(D), an $EPNL_r$ *value representative of flight conditions should be computed by adjusting airplane component noise sources for forward speed effects and for the number of engines and shielding, reconstructing the total noise spectra, and projecting the total noise spectra to flight conditions by accounting for propagation effects. The effect of changes in acoustic treatment, such as nacelle lining, may be modeled and applied to the appropriate component noise sources. The computation of the total noise increments, the development of the changed version NPD, and the evaluation of the changed version* $EPNL_r$ *values should be made by using the procedures described in 402(a)(3)(D). Guidance material on confidence interval computations is provided in 305.*

Note 2.— Some engine or aircraft design changes may change the nature of the noise signature of the engine or aircraft and prevent an ordered extension of noise data. In this case, static engine noise tests may not provide adequate proof that an extension of the noise database is valid. Changes that may cause transition of the fan tip velocity to supersonic, interaction of the mid-span fan shrouds or stator vanes, choking of the fan exit guide vanes or primary compressor entrance, operation of the surge bleed valve, an increase in the inlet bypass airflow or a change in aircraft configuration interaction are examples of such changes.

d) airframe design changes (e.g., changes in fuselage length, flap configuration and engine installation) that could indirectly affect noise levels because of an effect on airplane performance (e.g., increased drag).

Note 1.— Changes in airplane performance characteristics derived from aerodynamic analysis or testing have been used to demonstrate how these changes affect the airplane flight path and hence the demonstrated noise levels of the airplane.

Note 2.— In these cases care should be exercised to ensure that the airframe design changes do not introduce significant new noise sources or modify existing source generation or radiation characteristics. In such instances the magnitude of such effects may have to be established by test.

402(a)(2)(C) Equivalent procedure for calculating the certification noise levels of weight variants of a given airplane type [ETM 4.2.1.2.3]

Section 901 of Chapter 9 of this AC specifies that "In the case of an airplane being recertificated to the standard of part 36, Amendment 24, noise certification should be granted on the basis that the evidence used to determine compliance is as satisfactory as the evidence expected of a new type design." The lateral, flyover and approach noise levels and their 90 percent confidence intervals for the weight variants of a given airplane /engine model and acoustic configuration are typically derived from generalized NPD curves, based on the information in noise certification reports and supporting documentation, and in conjunction with certificated aerodynamic performance data for the airplane, as approved by FAA.

Some airplane manufacturers have used the noise level information initially certificated for several weight variants to demonstrate that when the basic airplane performance parameters (e.g., V_2 and V_{REF}) vary in a linear manner over a range of certificated takeoff or approach weight, the resulting noise (EPNL) versus weight relationship can be shown to be linear in that range as well. When this situation is demonstrated by the applicant and, subject to the approval by FAA, the applicant may derive the certification noise levels of additional weight variants using linear interpolation between previously certificated points. The confidence interval for the interpolated weight is then to be established in a process that utilizes the polynomial regression models that had been used by the applicant to develop the NPD. For a given airplane type, equivalency of the interpolated noise level values is demonstrated when the noise levels and the associated confidence intervals are calculated and reported in a manner acceptable to the FAA.

402(a)(3) Static engine noise tests and projections to flight noise levels [ETM 4.2.1.3]

402(a)(3)(A) General [ETM 4.2.1.3.1]

Static engine noise test data provide valuable definitive information for deriving the noise levels that result from changes to an airplane powerplant or from the installation of a broadly similar powerplant into the airframe following initial noise certification of the "flight datum" airplane. This involves the testing of both the "flight datum" and derivative powerplants using an open-air test facility where the effect on the noise spectra of the engine modifications on airplane noise characteristics may be assessed. It can also extend to the use of component test data to demonstrate that when minor development changes have been made the noise levels remain unchanged (see section 101(d) of this AC).

Approval of equivalent procedures for the use of static engine noise test data depends critically upon the availability of an adequate approved database (NPD plot) acquired from the flight testing of the "flight datum" airplane.

Static engine noise tests can provide sufficient additional data or source noise characteristics to allow for predictions about the effect of changes on the airplane certification noise levels.

Types of static tests accepted for the purposes of demonstrating certification compliance in airplane development include engine noise tests. Such tests are useful for assessing the effects on the individual noise sources of mechanical and thermodynamic cycle changes to the engine. Such configuration and/or design changes often occur as engines are developed, subsequent to the initial noise certification of an aircraft, to ease production difficulties, reduce cost, improve durability, and for operational reasons.

Static engine noise testing is discussed in detail in subsequent sections. For component tests, the criteria for acceptability are less definable. There are many instances, particularly when only small changes in $EPNL_r$ are expected, where component testing will provide an adequate demonstration of noise impact. Examples of such changes include:

a) changes in the specification of sound-absorbing linings within an engine nacelle;

b) changes in the mechanical or aerodynamic design of the fan, compressor or turbine;

c) changes to combustor designs, including material changes;

d) changes to bleed valves; and

e) changes to the exhaust system.

Each proposal by an applicant to use component test data should be considered by the FAA with respect to the significance of the relevant affected source on the values of $EPNL_r$ for the airplane that is being certificated.

402(a)(3)(B) Limitation on the projection of static-to-flight data [ETM 4.2.1.3.2]

Guidance on the acceptability, use and applicability of static engine test data are contained in subsequent sections.

The amount by which the measured noise levels of a derivative engine will differ from those of the reference engine is a function of several factors, including:

a) thermodynamic changes to the engine cycle, including increases in thrust (power);

b) design changes to major components (e.g., the fan, compressor, turbine, exhaust system); and

c) changes to the nacelle.

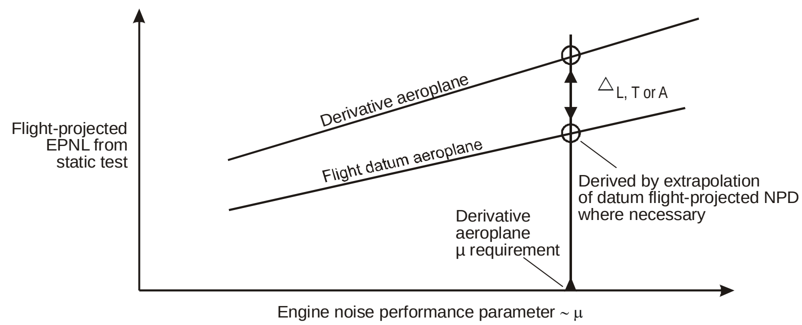
Additionally, day-to-day and test-site to test-site variables can influence measured noise levels, and therefore the test, measurement and analysis procedures described in this AC are designed to account for these effects. A limit is needed that can be used uniformly by FAA in order that the degree of change resulting from aspects such as a), b) and c), when extrapolated to flight conditions, is restricted to acceptable amounts before a new flight test is required.

The recommended guideline for this limit is that the summation of the magnitudes, neglecting signs, of the noise changes for the three reference certification conditions between the "flight datum" airplane and the derived version at the same thrust (power) and distance for the derived version is no greater than 5 EPNdB, with a maximum of 3 EPNdB at any one of the reference conditions (see Figure 31). For differences greater than this, additional flight testing at conditions where noise levels are expected to change is recommended in order to establish a new flight NPD database.

Provided that the detailed prediction procedures used are verified by flight tests for all the types of noise sources (i.e., tones, non-jet broadband and jet noise relevant to the airplane under consideration) and that there are no significant changes in installation effects between the airplane used for the verification of the prediction procedures and the airplane under consideration, the procedure may be employed without the limitations described above.

In addition to the limitations described above, a measure of acceptability regarding methodologies for static-to-flight projection is also needed for uniform application by FAA. This measure can be derived as the residual NPD differences between the flight test data and the projected static-to-flight data for the original airplane version. The guideline for a measure of acceptability is to limit these residual differences to 3 EPNdB at any one of the reference conditions.

In determining the noise levels of the modified or derived version, the same analytical procedures used in the first static-to-flight calculations for the noise certification of the airplane type must be used.



Definitions

$\triangle_L$ = Difference between flight datum and derivative aeroplane EPNL at the power requirement of the derivative aeroplane at the lateral condition.

$\triangle_T$ = Difference between flight datum and derivative aeroplane EPNL at the power requirement and altitude of the derivative aeroplane at the take-off condition.

$\triangle_A$ = Difference between flight datum and derivative aeroplane EPNL at the power requirement of the derivative aeroplane at the approach condition.

Limitations

(i) $|\triangle_L| + |\triangle_T| + |\triangle_A|$ shall not exceed 5 EPNdB.

(ii) $\triangle_L$, $\triangle_T$ or $\triangle_A$ shall not exceed ± 3 EPNdB individually.

Figure 31. Limitation on use of static test when no validating flight data exist

402(a)(3)(C) Static engine noise test procedures [ETM 4.2.1.3.3]

402(a)(3)(C)(i) General [ETM 4.2.1.3.3.1]

Test restrictions defined for flight testing in conformity with part 36 are not necessarily appropriate for static testing. Reference T13 provides appropriate, detailed guidance for measurement of far-field sound pressure levels during static operation of gas turbine engines installed on an outdoor test stand. The following sections provide guidelines supplemental to sections on test site characteristics, data acquisition and reduction, microphone types, locations and installations provided in Reference T13. These supplemental guidelines are specifically related to static engine noise testing for purposes of airplane noise certification.

Noise data acquired from static tests of engines with similar designs to those that were flight tested may be projected to flight conditions when appropriate. Once approved, noise data acquired from static tests may be used to supplement an approved NPD plot for the purpose of demonstrating compliance with the part 36 provisions in support of a change in type design. The engine designs, as well as the test and analysis techniques to be used, should be presented in the test plan and submitted to the FAA for approval prior to testing.

402(a)(3)(C)(ii) Test site characteristics [ETM 4.2.1.3.3.2]

(1) Inflow control devices (ICD)

Static engine noise test data for the noise certification of an airplane with a change of engine to another one of a similar design should be acquired by using an approved ICD for high bypass engines (i.e., BPR > 2.0). The ICD should meet the requirements in Reference T13. The specific ICD hardware should be inspected by the FAA to ensure that the ICD is free from damage and contaminants that may affect its acoustic performance.

(2) ICD calibration

An acceptable ICD calibration method is provided in Reference T13. In some cases large fluctuations in the value of the calibrations across adjacent one-third octave bands and between closely spaced angular positions of microphones can occur. These fluctuations can be related to reflection effects caused by the calibration procedure, and care must be taken to ensure that they do not introduce or suppress engine tones. This may be done by comparing EPNL computed with:

a) the ICD calibrations as measured;

b) a mean value of the calibration curves; and

c) the calibration values set to zero.

402(a)(3)(C)(iii) Data acquisition and reduction systems [ETM 4.2.1.3.3.3]

(1) Data acquisition, analysis and normalization

Data acquisition and analysis systems used for static test and the modus operandi of the test program may well vary according to specific test objectives. In general they should conform to those outlined in Reference T13.

For each engine power setting designated in the test plan, the engine performance, meteorological and sound pressure level data should be acquired and analyzed using measurement systems and test procedures described in Reference T13 or as approved by the FAA.

A range of static engine operating conditions should be selected to correspond to the expected maximum range of in-flight engine operating conditions for the appropriate engine power setting parameter. A sufficient number of stabilized engine power settings over the desired range should be included in the test to ensure that the 90 percent confidence intervals for values of flight-projected EPNL can be established (see 305(c)).

Noise measurements should be normalized to consistent conditions and include 24 one-third octave band sound pressure levels between band center frequencies of 50 Hz to 10 kHz for each measurement microphone. Before projecting the static engine data to flight conditions, the sound pressure level data should be adjusted for:

a) the frequency response characteristics of the noise measurement system; and

b) contamination by background or electrical system noise (see 306(c) of this AC).

(2) Data system compatibility

If more than one data acquisition system and/or data analysis system is used for the acquisition or analysis of static data, compatibility of the airframe and engine manufacturers' systems is necessary. Compatibility of the data acquisition systems can be accomplished through appropriate calibration. Compatibility of the data analysis systems can be verified by analyzing the same flight test noise data samples on both systems. The systems can be considered to be compatible if the resulting differences are no greater than 0.5 EPNdB. Evaluation should be conducted at flight conditions representative of those for certification.

The use of measured static engine test noise data or pseudo-random noise signals with spectral shape and tonal content representative of turbofan engines is an acceptable alternative to the use of actual flight test noise data samples for determination of analysis system compatibility. The systems can be considered to be compatible if the resulting differences are no greater than 0.5 PNdB for an integration time of 32 seconds.

402(a)(3)(C)(iv) Microphone types, locations and installations [ETM 4.2.1.3.3.4]

(1) Microphone locations

Microphones should be located over an angular range sufficient to include the 10 dB-down times after projection of the static noise data to flight conditions. The general guidance in Reference T13 describing microphone locations is sufficient to ensure adequate definition of the engine noise source characteristics.

The choice of microphone location with respect to the test surface depends on the specific test objectives and the methods to be used for data normalization. Certification experience with static engine testing has been primarily limited to microphone installations near the ground or at engine centerline height. In general, because of the difficulties associated with obtaining free-field sound pressure levels that are often desirable for extrapolating to flight conditions, near-ground-plane microphone installations or a combination of ground-plane and elevated microphones have been used. Consistent microphone locations, heights, etc., are recommended for noise measurements of both the prior approved and changed version of an engine or nacelle.

(2) Microphone installations

Where ground-plane microphones are used, special precautions as outlined in Reference T13 are necessary to ensure that consistent measurements (e.g., free from “acoustic shadowing” refraction effects) will be obtained. When there is a wind in the opposite direction to the sound wave propagating from the engine, or when there is a substantial thermal gradient in the test arena, refraction can influence near-ground-plane microphone measurements to a larger degree than measurements at greater heights.

402(a)(3)(D) Projection of static engine data to airplane flight conditions [ETM 4.2.1.3.4]

402(a)(3)(D)(i) General [ETM 4.2.1.3.4.1]

The static engine sound pressure level data acquired at each angular location should be analyzed and normalized to account for the effects identified in the paragraphs below. They should then be projected to the same airplane flight conditions used in the development of the approved NPD plot.

As appropriate, the projection procedure includes the:

a) effects of source motion including Doppler effects;

b) number of engines and shielding effects;

c) installation effects;

d) flight geometry;

e) atmospheric propagation, including spherical wave divergence and sound attenuation; and

f) flight propagation effects, including ground reflection and lateral attenuation.

To account for these effects, the measured total static noise data should be analyzed to determine contributions from individual noise sources. After projection of the one-third octave band spectral data to flight conditions, EPNLs should be calculated for the revised NPD plot. Guidelines on the elements of an acceptable projection procedure are provided in this section. The process is also illustrated in Figures 4-24 and 4-25.

It is not intended that the procedure illustrated in Figures 4-24 and 4-25 should be exclusive. There are several options, depending upon the nature of the powerplant noise sources and the relevance of individual noise sources to the EPNL of the airplane. The method presented does however specify the main features that should be considered in the computational procedure.

It is also not necessary that the computations illustrated in Figures 4-24 and 4-25 should always be carried out in the order specified. There are interrelations between the various steps in the procedure which depend on the particular form of the computation being followed. Hence the most efficient manner of structuring the computation cannot always be predetermined.

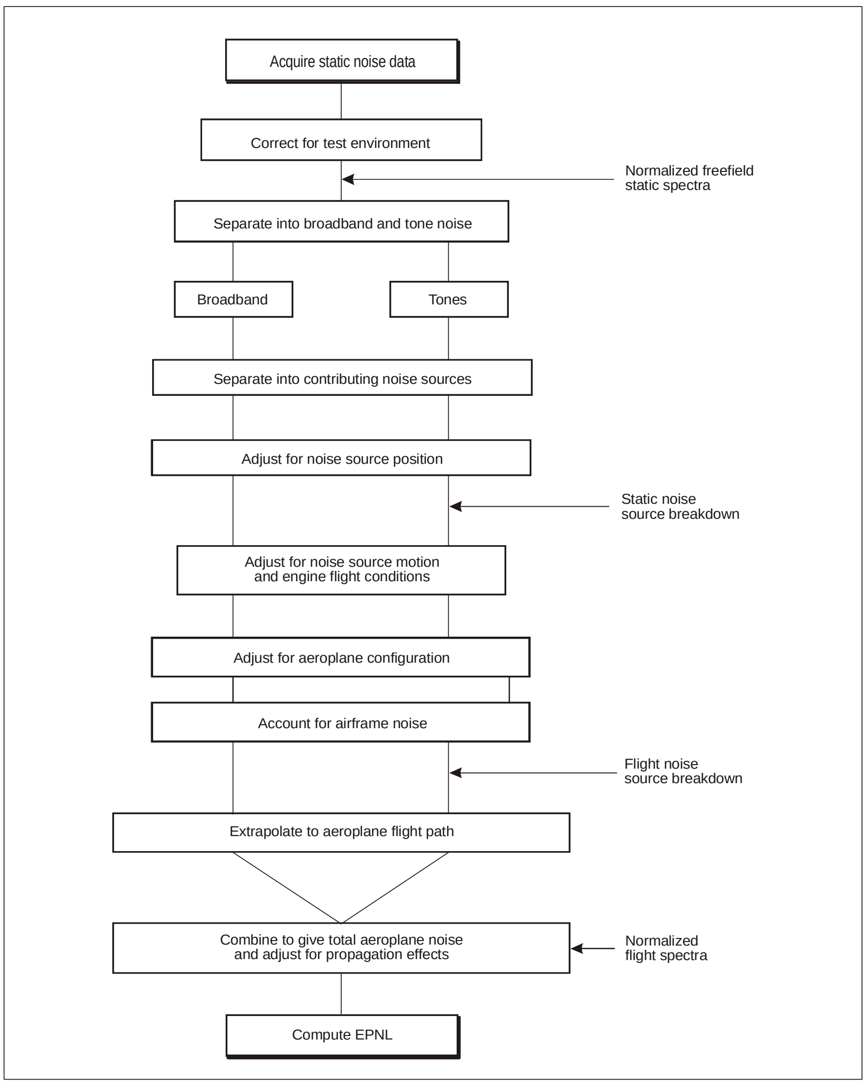


Figure 32. Generalized projection of static engine data to airplane flight conditions

(Refer to 402(a)(3))

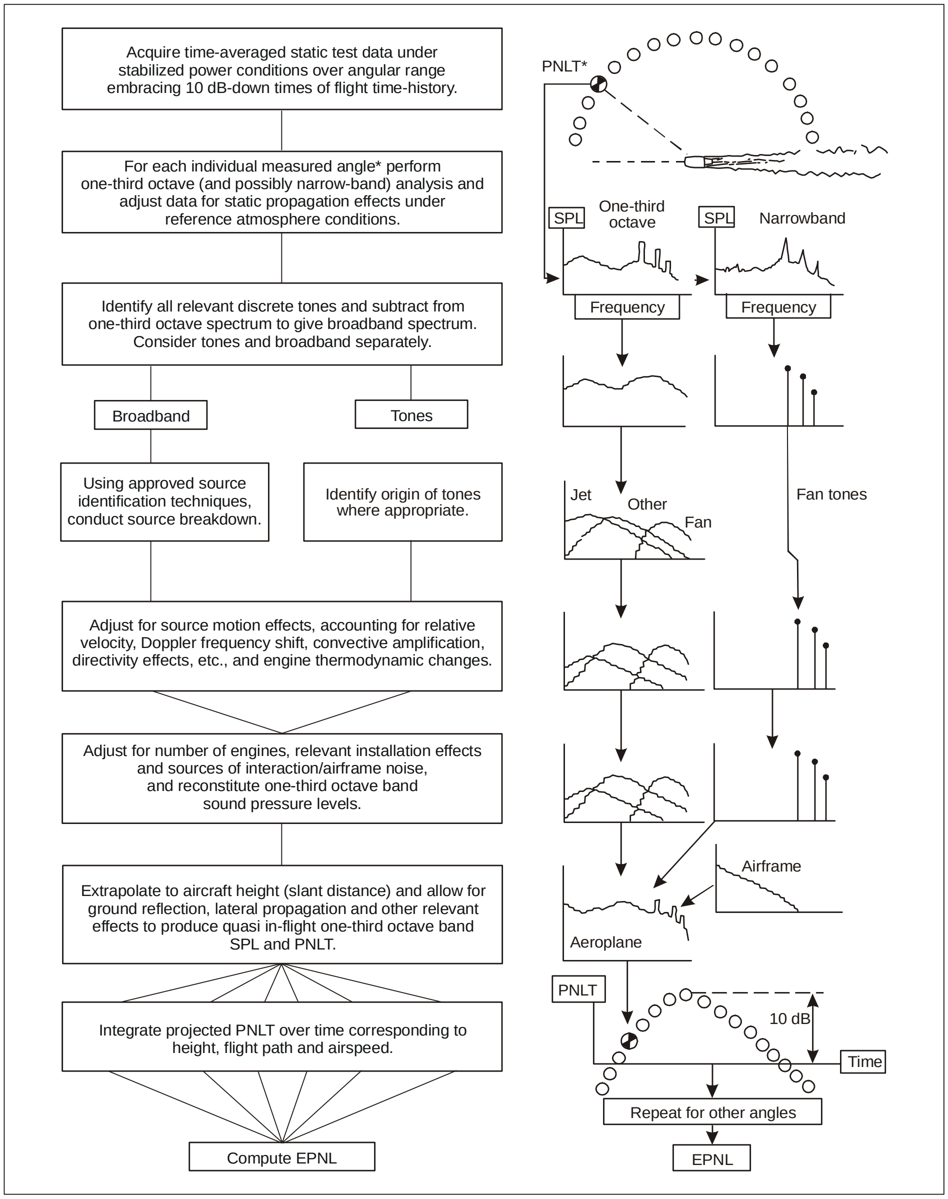


Figure 33. Example procedure for projection of static engine data to airplane flight conditions

There are several engine installation effects which can modify the generated noise levels but which cannot be derived from static tests. Additional noise sources such as jet/flap or jet/wind interaction effects may be introduced on a derived version of the airplane which are not present on the "flight datum" airplane Far-field noise directivity patterns (i.e., field shapes) may be modified by wing/nacelle or jet-by-jet shielding, tail plane and fuselage scattering or airframe reflection effects. However general methods to adjust for these effects are not yet available. It is therefore important that before the following procedures are approved for the derived version of the airplane, the geometry of the airframe and engines in the vicinity of the engines be shown to be essentially identical to that of the "flight datum" airplanes so that the radiated noise is essentially unaffected.

402(a)(3)(D)(ii) Normalization to reference conditions [ETM 4.2.1.3.4.2]

The analyzed one-third octave band sound pressure level static test data should be normalized to free-field reference atmospheric conditions specified in B36.7(a)(k)(5) of part 36.This adjustment can be applied only with knowledge of the total spectra being the summation of all the noise source spectra computed as described in the following paragraphs. The required adjustments include:

a) *Sound attenuation due to atmospheric absorption*. Adjustments to account for the acoustical reference-day sound attenuation are defined in Reference T16. In the event that minor differences in coefficient values are found in Reference T16 between equations, tables or graphs, the equations should be used. The sound attenuation coefficients should be computed over the actual distance from the effective center of each noise source to each microphone, as described in 402(a)(3)(D)(v) of this AC.

b) *Ground reflection.* Examples of methods for obtaining free-field sound pressure levels are described in References T5 and T15. Spatial distribution of noise sources do not have a first order influence on ground reflection effects and hence may be disregarded. It is also noted that measurements of far-field sound pressure levels with ground-plane microphones may be used to avoid the large spectral irregularities caused by interference effects at frequencies less than 1 kHz.

402(a)(3)(D)(iii) Separation into broadband and tone noise [ETM 4.2.1.3.4.3]

The purpose of procedures described in this section is to identify all significant tones in the spectra: first, to ensure that tones are not included in the subsequent estimation of broadband noise and, second, to enable the Doppler-shifted tones in-flight to be allocated to the correct one-third octave band at appropriate times during a simulated airplane flyover.

Broadband noise should be derived by extracting all significant tones from the measured spectra. One concept for the identification of discrete tones is the one used in Appendix A of part 36 for tone correction purposes (i.e., considering the slopes between adjacent one-third octave band levels). Care must be taken to avoid regarding tones as “non-protrusive” when the surrounding broadband sound pressure level is likely to be lower when adjusted from static-to-flight conditions, or when classifying a closely grouped pair or series of tones as broadband noise. One technique for resolving such problems is the use of narrow-band analysis with a bandwidth of less than 50 Hz.

Narrow-band analysis can also be used to check the validity of other tone identification procedures in establishing the spectral character at critical locations in the sound field (e.g., around the position of peak PNLT) or where predominant turbo-machinery tones exist.

402(a)(3)(D)(iv) Separation into contributing noise sources [ETM 4.2.1.3.4.4]

The number of noise sources which require identification will to some extent depend on the engine being tested and the nature of the change to the engine or nacelle. The separation of broadband noise into the combination of noise generated by external jet mixing and by internal noise sources is the minimum and sometimes adequate requirement. A more sophisticated analysis may be necessary depending upon the significance of the contribution from other individual sources, which could involve identifying broadband noise from fan, compressor, combustor and turbine. Furthermore, for fan and compressor noise, the split of both the broadband and the tone noise between that radiating from the engine intake and that from the engine exhaust nozzle(s) could be a further refinement.

To meet the minimum requirement, the separation of sources of broadband noise into those due to external jet mixing and those generated internally can be carried out by:

a) estimating the jet noise by one or more of the methods identified below; and

b) adjusting the level of the predicted spectrum at each angle to fit the measured low frequency part of the broadband spectrum at which jet noise can be expected to be dominant.

There are three methods which have been used to obtain predicted jet noise spectra shapes:

a) for single-stream engines with circular nozzles, the procedure detailed in Reference T12 may be used; the engine geometry however may possess features which can render this method inapplicable; sample procedures for coaxial flow engines are provided in Reference T11;

b) analytical procedures based on correlating full-scale engine data with model nozzle characteristics may be used; model data have been used to supplement full-scale engine data, particularly at low power settings, because of the uncertainty in defining the level of jet noise at the higher frequencies where noise from other engine sources may make a significant contribution to the broadband noise; and

c) special noise source location techniques are available which, when used during full-scale engine tests, can identify the positions and levels of separate engine noise sources.

402(a)(3)(D)(v) Noise source position effects [ETM 4.2.1.3.4.5]

Static engine noise measurements are often made at distances at which engine noise sources cannot be truly treated as radiating from a single acoustic center. This may not give rise to difficulties in the extrapolation to determine the noise increments from static data to flight conditions because noise increments in EPNL are not particularly sensitive to the assumption made regarding the spatial distribution of noise sources.

However, in some circumstances, for example where changes are made to exhaust structures and where the sources of external jet-mixing noise are of overriding significance, it may be appropriate to identify noise source positions more accurately. The jet noise can be considered as a noise source distributed downstream of the engine exhaust plane. Internal sources of broadband engine noise may be considered as radiating from the intake and the exhaust.

There are three principal effects to be accounted for as a consequence of the position of the noise source differing from the "nominal" position assumed for the "source" of engine noise:

a) *Spherical divergence.* The distance of the source from the microphone differs from the nominal distance, in which case an inverse square law adjustment needs to be applied.

b) *Directivity.* The angle subtended by the line from the source to the microphone and the source to the engine centerline differs from the nominal angle, in which case a linear interpolation should be made to obtain data for the proper angle.

c) *Sound attenuation due to atmospheric absorption.* The difference between the true and the nominal distance between the source and the microphone alters the allowance made for sound attenuation.

Source position can be identified either from noise source location measurements (made either at full or model scale) or from a generalized database.

Note.— No published standard on coaxial jet noise source distribution is currently available. An approximate distribution for a single jet is given by the following equation (see References T6 and T17):

$$x/D = (0.0575\ S + 0.0215\ S^{-2})^{-½}$$

where:

— S *is the Strouhal number* fD/V_i;

— x *is the distance downstream from the nozzle exit;*

— *D* *is the nozzle diameter based on total nozzle exit area;*

— V_j *is the average jet velocity for complete isentropic expansion to ambient pressure from average nozzle-exit pressure and temperature; and*

— *f* *is the one-third octave band center frequency.*

402(a)(3)(D)(vi) Engine flight conditions [ETM 4.2.1.3.4.6]

Some thermodynamic conditions within an engine tested statically differ from those that exist in flight and this difference should be taken into account. Noise source strengths may be changed accordingly. Therefore, the values for key correlating parameters for component noise source generation should be based on the flight condition, and the static database should be entered at the appropriate correlating parameter value. Turbo-machinery noise levels should be based on the in-flight corrected rotor speeds $\frac{N_1}{\sqrt{\theta_{t2}}}$ Jet noise levels should be based on the relative jet velocities that exist at the flight condition.

The variation of source noise levels with key correlating parameters can be determined from the static database which includes a number of different thermodynamic operating conditions.

402(a)(3)(d)(vii) Noise source motion effects [ETM 4.2.1.3.4.7]

The effects of motion on jet noise differ from speed effects on other noise sources and, hence, are considered separately during static-to-flight projection.

(a) *For external jet noise*

Account should be taken of the frequency-dependent jet-relative velocity effects and the convective amplification effects. Broadly speaking, two sources of information may be used to develop an approved method for defining the effect of flight on external jet noise:

1) for single-stream engines with circular exhaust geometries, Reference T12 provides guidance. Additional supporting evidence however may be needed to show when jet noise is the major contributor to the noise from an engine with a more complex nozzle assembly; and

2) full-scale flight data on a similar exhaust geometry can provide additional evidence. In general however, because of the difficulty of defining high frequency effects in the presence of internally-generated engine noise, it may be necessary to provide additional supporting information to determine the variation of EPNL with changes of jet noise spectra at high frequencies.

(b) For noise sources other than jet noise

In addition to the Doppler frequency effect on the non-jet noise observed on the ground from an airplane flyover, the noise generated by the engine's internal components and the airframe can be influenced by source amplitude modification and directivity changes:

1) *Doppler effect*. Frequency shifting that results from motion of the source (i.e., airplane) relative to a microphone is accounted for by the following equation:

$$f_{flight} = \frac{f_{static}}{(1 - Mcos\lambda}$$

where:

- f_{flight} is the flight frequency;
- f_{static} is the static frequency;
- M is the Mach number of the airplane; and
- λ is the the angle between the flight path in the direction of flight and a straight line connecting the airplane and the microphone at the time of sound emission.

It should be noted for those one-third octave band sound pressure levels dominated by a turbo-machinery tone, the Doppler shift may move the tone and its harmonics into an adjacent band.

2) *Source amplitude modification and directivity changes*. One-third octave band sound pressure level adjustments to airframe-generated noise that results from speed changes between the datum and derivative versions provided below.

For noise generated internally within the engine (e.g., fan noise), there is no consensus of opinion on the mechanisms involved or on a unique adjustment method that accounts for the detailed source modification and sound propagation effects. If an adjustment is used, the same technique must be applied to both the flight datum and derivative configuration when establishing noise changes. In such instances the adjustment for the one-third octave band sound pressure level changes that result from the motion of the source (i.e., airplane) relative to the microphone may be accounted for by using the following equation:

$$SPL_{flight} = SPL_{static} - Klog(1 - Mcos\lambda)$$

where:

- SPL_{flight} is the flight sound pressure level;
- SPL_{static} is the static sound pressure level; and
- M and λ are defined above and K is a constant.

Theoretically, K has a value of 40 for a point noise source, but a more appropriate value may be obtained by comparing static and flight data for the "flight datum" airplane.

402(a)(3)(D)(viii) Airplane configuration effects [ETM 4.2.1.3.4.8]

The contribution from more than one engine on an airplane is normally taken into account by adding 10 log *N*, where *N* is the number of engines, to each component noise source. It might be necessary however to compute the noise from engines widely spaced on large airplanes, particularly in the approach case, if they include both underwing and fuselage mountings. The noise from the intakes of engines mounted above the fuselage is known to be shielded.

If engine installation effects change between the "flight datum" airplane and a derived version, account should be taken of the change on one-third octave band sound pressure levels which should be estimated according to the best available evidence.

402(a)(3)(D)(ix) Airframe noise [ETM 4.2.1.3.4.9]

To account for the contribution of airframe noise, measured flight datum airframe noise on its own, or combined with an approved airframe noise analytical model, may be used to develop an airframe noise database. The airframe-generated noise, which can be treated as a point source for adjustment purposes, is normalized to the same conditions as those of the other (i.e., engine) sources, with due account given for the effects of spherical divergence, atmospheric absorption and airspeed as described in Appendix A of part 36.

Airframe noise for a specific configuration varies with airspeed (see Reference T5) as follows:

$$\Delta SPL_{airframe} = 50\log(V_{REF}/V_{TEST})$$

where:

— V_{REF} is the approved reference airspeed for the "flight datum" airplane; and

— V_{TEST} is model or measured airspeed.

The above equation is also valid for adjustments to EPNL where an empirically derived coefficient replaces the coefficient 50 since that number may be somewhat configuration-dependent. However, the approval of the FAA is required for values other than 50.

402(a)(3)(D)(x) Airplane flight path considerations [ETM 4.2.1.3.4.10]

When computing the one-third octave band sound pressure levels corresponding to the slant distance of the airplane in flight from the noise measuring point, the principal effects are spherical divergence (inverse square law) adjustments from the nominal static distance and sound attenuation due to atmospheric absorption (as described in Appendix A of part 36). Furthermore, account should be taken of the difference between the static engine axis and that axis in flight relative to the reference noise measuring points. The adjustments should be applied to the component noise source levels that have been separately identified.

402(a)(3)(D)(xi) Total noise spectra [ETM 4.2.1.3.4.11]

Both the engine tonal and broadband noise source components in flight, together with the airframe noise and any installation effects, are summed up on a mean-square pressure basis to construct the spectra of total airplane noise levels.

During the merging of broadband and tonal components, consideration should be given to appropriate band-sharing of discrete frequency tones.

The effects of ground reflections must be included in the estimate of free-field sound pressure levels in order to simulate the sound pressure levels that would be measured by a microphone at a height of 4 ft (1.2 m) above a natural terrain. Information in Reference T4 or T15 may be used to apply adjustments to the free-field spectra to allow for flight measurements being made at 4 ft (1.2 m). Alternatively, the ground reflection adjustment can be derived from other approved analytical or empirically derived models. Note that the Doppler adjustment for a static source at frequency (f_{static}) applies to a moving source (i.e., airplane) at a frequency (f_{flight}) where $f_{flight} = f_{static}/(1 - M\cos\lambda)$ using the same terminology as described above for the Doppler effect. This process is repeated for each measurement angle and for each engine power setting. With regard to lateral attenuation, the information in Reference T14, applicable to the computation of lateral noise may be applied.

402(a)(3)(D)(xii) EPNL computations [ETM 4.2.1.3.4.12]

For EPNL calculations, a time is associated with each extrapolated spectrum along the flight path. Note that the time is associated with each measurement location with respect to the engine/airplane reference point and the airplane's true airspeed along the reference flight path, assuming zero wind. For each engine power setting and minimum distance, an EPNL is computed from the projected time history using the methods described in Appendix A of part 36.

402(a)(3)(D)(xiii) Changes to noise levels [ETM 4.2.1.3.4.13]

An NPD plot can be constructed from the projected static data for both the original (i.e., flight datum) and the changed configurations of the engine or nacelle tested. Comparisons of the noise versus engine thrust (power) relationships for the two configurations at the same appropriate minimum distance will determine whether or not the changed configuration resulted in a change to the noise level from an engine noise source. If there is a change in the level of source noise, a new in-flight airplane NPD plot can be developed by adjusting the measured original NPD plot by the amount of change indicated by the comparison of the static-projected NPD plots for the original and changed versions within the limitations specified in 402(a)(3)(ii) for EPNL.

The certification noise levels for the derived version of an airplane may be determined from NPD plots at the relevant reference engine power and distance, with an additional adjustment of [10 log V_{nom}/V_r] for the velocity of the airplane at the certification reference condition relative to the nominal velocity (V_{nom}) used in developing the NPD plots.

402(b) Propeller-Driven Airplanes Over 19,000 lb [ETM 4.2.2]

The procedures described in this chapter have been used as equivalent in stringency for propeller-driven airplanes with maximum certificated takeoff weight exceeding 19,000 lb, as provided in Appendix B.

402(b)(1) Flight test procedures [ETM 4.2.2.1]

402(b)(1)(A) Flight path intercept procedures [ETM 4.2.2.1.1]

Flight path intercept procedures, as described in 402(a)(1)(i), have been used to meet the noise certification demonstration requirements in lieu of full takeoffs and/or landings.

402(b)(1)(B) Generalized flight test procedures [ETM 4.2.2.1.2]

Generalized flight test procedures, other than normal noise demonstration takeoffs and approaches, have been used to meet two equivalency objectives:

a) *NPD plots*

Noise data are acquired over a range of engine power settings at one or more heights. This information permits the development of generalized noise characteristics necessary for the certification of a "family" of similar airplanes. The procedures used are similar to those described in 402(a)(1)(ii), with the exception that the NPD plots employ engine noise performance parameters (μ) of propeller helical tip Mach number (M_H) and shaft horsepower (SHP/δ_{amb}) (see Figure 34), where δ_{amb} is defined in 402(a)(1)(ii)(A).

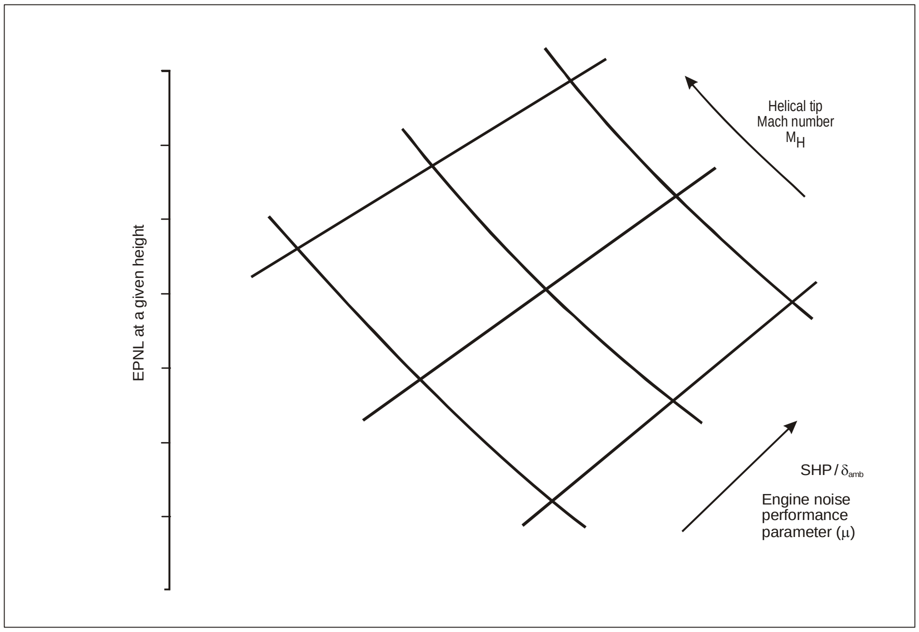


Figure 34. Form of noise-power-distance (NPD) plot for heavy propeller-driven airplanes

In order to ensure that propeller inflow angles are similar throughout the development of the noise-sensitivity data as the airplane weight changes, the airspeed of the airplane used in the flight tests for developing the lateral and flyover data must be V_2 + 10 kt (V_2 + 19 km/h) to within ±3 kt (±5.5 km/h), as appropriate for the weight of the airplane during the test.

For the development of the NPD data for the approach case, the speed and approach angle constraints imposed in B36.7(c) and B36.8 of part 36 cannot be satisfied over the typical range of power needed. For the approach case, a steady speed of V_{REF} + 10 kt (V_{REF} + 19 km/h) should be maintained to within ±3 kt (±5.5 km/h) and the flyover height over the microphone should be 400 ± 100 ft (122 ± 30 m). Within these constraints, the test approach angle at the test power should be that which results from the test airplane conditions (i.e., weight, configuration, speed and power).

b) Noise level changes

Comparisons are made of flyover noise test data for different developments of an airplane type (e.g., a change in propeller type). Such changes are used to establish certification noise levels of a newly derived version as described in 402(a)(1)(ii).

402(b)(1)(C) Determination of the lateral certification noise level [ETM 4.2.2.1.3]

For propeller-driven airplanes, B36.3(b) of part 36 specifies a full-power measurement point under the flight path as a replacement for the lateral measurement point. This section describes appropriate equivalent procedures for those airplanes for which the two-microphone lateral measurement method was applicable.

Determination of the lateral certification noise level employing an alternative procedure using two microphone stations located symmetrically on either side of the takeoff flight path similar to that described in 402(a)(1)(iii) has been approved. However, when this procedure is used, matching data from both lateral microphones for each fly-by must be used for the lateral noise determination. Cases where data from only one microphone is available for a given fly-by must be omitted from the determination. The following paragraphs describe the procedures for propeller-driven heavy airplanes:

a) the lateral EPNL from propeller-driven airplanes, when plotted against height opposite the measuring sites, can exhibit distinct asymmetry; the maximum EPNL on one side of the airplane is often at a different height and noise level from that measured on the other side;

b) in order to determine the average maximum lateral EPNL (i.e., the certification sideline noise level) it is therefore necessary to undertake a number of flights over a range of heights to define the noise versus height characteristics for each side of the airplane; a typical height range would cover between 100 ft (30 m) and 1800 ft (550 m) above a track at right angles to, and midway along, the line joining the two microphone stations; the intersection of the track with this line is defined as the reference point;

c) since experience has shown the maximum lateral noise level may often be near the lower end of this range, a minimum of six good sets of data, measured simultaneously from both sides of the flight track, should be obtained for a range of airplane heights as low as possible; in this case takeoffs may be necessary; however care should be taken to ensure that the airspeed is stabilized to at least V_2 + 10 kt (V_2 + 9 km/h) over the 10 dB-down period;

d) the airplane climbs over the reference point using takeoff power, speeds and configuration as described in B36.7(b)(3) and B.36.7(b)(4) of part 36;

e) the lateral certification noise level is obtained by finding the peak of the curve of noise level (EPNL) corrected to reference-day atmospheric absorption values and plotted against airplane height above the reference point (see Figure 35); this curve is described as a least-squares curve fit through the data points defined by the median values of each pair of matched data measured on each side of the track (i.e., the average of the two microphone measurements for a given airplane height); and

f) to ensure that the requirements of A36.5.4.2 of part 36 are met, the 90 percent confidence limits should be determined in accordance with paragraph 305.

402(b)(1)(D) Measurements at non-reference points [ETM 4.2.2.1.4]

In some instances, test measurement points may differ from the reference measurement points as specified in Appendix B. Under these circumstances an applicant may request approval of data that have been adjusted from actual measurements to the reference conditions for reasons described in 402(a)(1)(v).

Noise measurements collected closer to the test airplane than at the certification reference points are particularly useful for adjusting propeller noise data because they are dominated by low frequency noise. The spectra roll off rapidly at higher frequencies and are often lost in the background noise at frequencies above 5000 Hz. Section 306(c), describes a procedure for background noise adjustment.

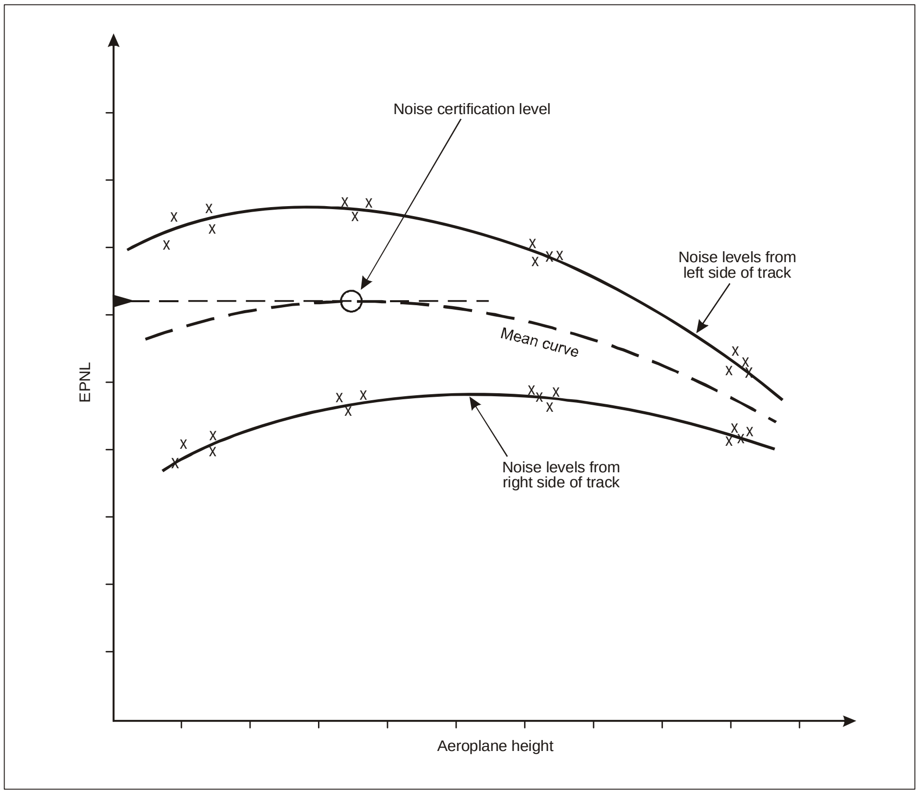


Figure 35. Typical lateral noise data plot for heavy propeller-driven airplanes

Non-reference measurement points may be used provided that measured data are adjusted to reference conditions in accordance with the requirements of A36.9 of part 36 and that the magnitude of the adjustments does not exceed the limits cited in B36.8(f) of part 36.

402(b)(2) Analytical procedures [ETM 4.2.2.2]

Equivalent analytical procedures rely upon the available noise and performance data of an airplane type. The generalized relationships between noise levels, propeller helical tip Mach number, and shaft horsepower, as well as the adjustment procedures for speed and height changes in accordance with the methods of Appendix A are combined with certificated airplane performance data in order to determine noise level changes resulting from type design changes. The noise level changes are then added to or subtracted from the certification noise levels that are demonstrated by flight test measurements for the "flight datum" airplane.

Certifications using analytical procedures have been approved for type design changes that result in predictable noise level differences. The type design changes include the following:

a) an increase or decrease in maximum takeoff and/or landing weight of the airplane from the originally certificated weight;

b) power increase or decrease for engines that are acoustically similar and fitted with propellers of the same type;

c) airplane engine and nacelle configuration changes, usually minor in nature, including derivative airplane models with changes in fuselage length and flap configuration; care is however needed to ensure that the existing noise sources are not modified by these changes (e.g., by changing the flow field into the propellers); and

d) minor airframe design changes that could indirectly affect noise levels because of an impact on airplane performance (e.g., increased drag); changes in airplane performance characteristics derived from aerodynamic analysis or testing have been used to demonstrate how these changes can affect the airplane flight path and consequently the demonstrated noise levels of the airplane.

402(b)(3) Ground static testing procedures [ETM 4.2.2.3]

402(b)(3)(A) General [ETM 4.2.2.3.1]

Unlike the case of a turbojet or turbofan powerplant, static tests involving changes to the propeller are not applicable for determining noise level changes in the development of a propeller-driven airplane /powerplant family because of changes in the aero-acoustic operating conditions of the propeller when run statically compared with conditions existing during flight. The propeller noise levels measured during a static test can include significant contributions from noise source components that are not normally important in flight. However, limited static tests on engines with propellers, which are used as engine loading devices, can be utilized to determine small noise changes, as described below.

402(b)(3)(B) Guidance on the test-site characteristics [ETM 4.2.2.3.2]

Guidance on the test-site characteristics, data acquisition and analysis systems, microphone locations, acoustical calibration and measurement procedures for static testing is provided in Reference T13 and is equally valid in these respects for propeller powerplants (see 402(a)(3)(iii)).

402(b)(3)(C) Static tests of the gas generator [ETM 4.2.2.3.3]

Static tests of the gas generator can be used to identify noise changes resulting from changes to the design of the gas generators, or to the internal structure of the engine, in the frequency ranges where:

a) there is a contribution to the airplane EPNL;

b) that part of the spectrum is clearly dominated by the gas generator; or

c) ancillary equipment under circumstances where the propeller and its aerodynamic performance remains unchanged.

Such circumstances where the propeller and its aerodynamic performance remain unchanged include, for example, changes to the compressor, turbine or combustor of the powerplant. The effect of such changes should be conducted under the same test, measurement, data reduction and extrapolation procedures as described in 402(a)(3) for turbojet and turbofan engines. The noise emanating from any propeller or other power extraction device used in static tests should be eliminated or removed analytically. For the purposes of airplane EPNL calculation, the measured “flight datum” airplane propeller contributions should be included in the computation process.

402(c) Helicopters [ETM 4.2.3]

The objective of a noise certification test is to acquire data for establishing an accurate and reliable definition of a helicopter’s noise characteristics (see Appendix H of part 36). This Appendix establishes a range of test conditions and procedures for adjusting measured data to reference conditions.

402(c)(1) Flight test procedures
[ETM 4.2.3.1]

402(c)(1)(A) Helicopter test speed
[ETM 4.2.3.1.1]

There are two requirements for helicopter test speeds. Firstly, the airspeed during the 10 dB-down period should be close to the reference speed (i.e., within ±5 kt (±9 km/h), (see H36.103(b) of part 36) in order to minimize speed adjustments for the three certification conditions of takeoff, flyover and approach.

The second speed requirement applies to the flyover case (see H36.105(c) & (d) of part 36). The number of level flyovers made with a headwind component must be equal to the number of flyovers made with a tailwind component. The objective is to minimize the effect of wind on the measured flyover noise levels. If, however, the absolute wind speed component in the direction of flight, as measured at a height of 33 ft (10 m) above ground, is less than ±5 kt (±2.6 m/s), then the effect of wind direction can be considered to be negligible. In this case, the measured flyover can be considered to be either a headwind or tailwind test run.

The applicant may find that although there are at least three valid flyovers with a headwind component and three valid flyovers with a tailwind component, there are more valid flyovers with one wind component than with another. In this case, the applicant will need to discuss with the FAA which flyovers are to be used in the determination of the final EPNL value for flyover. In many cases, preference may be given to using level flyovers performed in pairs in order that the meteorological conditions are as similar as possible for the two flyovers in each pair. Hence, there is merit in considering conducting flyovers in pairs for all wind speed conditions. Each pair should consist of two flyovers performed one after the other in opposite directions along the reference flight track.

The measurement of ground speed may be obtained by timing the helicopter as it passes over two points at a known distance apart on the helicopter track during the flyover noise measurements. These two points should straddle the noise measurement microphone array.

402(c)(1)(B) Atmospheric test conditions
[ETM 4.2.3.1.2]

The temperature, relative humidity and wind velocity limitations are contained in A36.2.2.2 of part 36. The parameters are measured at 33 ft (10 m) at a location subject to approval by FAA. For adjustment purposes the measured values of these parameters are assumed to be representative of the air mass between the helicopter and the microphones. No calculation procedures based on the division of the atmosphere into layers are required, but such a method of analysis could be accepted by the FAA.

402(c)(1)(C) Temperature and relative humidity measurements
[ETM 4.2.3.1.3]

Temperature and relative humidity measurements, as defined in H36.101(c) of part 36, have to be made at a height of 33 ft (10 m) above the ground. The measured values are used in the adjustment of the measured one-third octave band sound pressure levels for the effects of atmospheric absorption to account for the difference in the sound attenuation coefficients in the test and reference atmospheric conditions as given in H36.205(f) of part 36. The distances AL, AL_r, AM, AM_r, AN and AN_r in the equations of H36.205(f) refer to the distances between positions on the measured and reference flight paths corresponding to the PNLTM position and the noise measurement point.

As a consequence the procedure assumes that the difference between the temperature and relative humidity at 33 ft (10 m) and the PNLTM position is zero, or small, and that the atmosphere can be represented by the values measured at 33 ft (10 m) above the ground in the vicinity of the noise measurement point Data obtained from European and U.S. certification tests over a number of years and records provided by the United Kingdom meteorological office confirm that this assumption is valid over a wide range of meteorological conditions.

Noise certification measurements may be made under test conditions where significant changes in temperature and/or relative humidity with height are expected. Of particular concern are conditions when a significant drop in humidity with altitude is expected. Such special conditions might be encountered in desert areas shortly after sunrise where the temperature near the ground is lower and the relative humidity considerably higher than at the height associated with the PNLTM point. Measurements made under such conditions should be adjusted by using the average of the temperature and relative humidity measured at 33 ft (10 m) above the ground and at the height associated with the PNLTM point in order to eliminate errors associated with the use of data measured at 33 ft (10 m) only (see also 402(c)(1)(v)).

H36.101(c)(3) of part 36 limits testing to conditions where the sound attenuation rate in the 8 kHz one-third octave band is not more than 12 dB/100 m. If, however, the dew point and dry bulb temperature are measured with a device that is accurate to within ±0.5°C, it has been found acceptable by FAA to permit testing in conditions where the 8 kHz sound attenuation rate is not more than 14 dB/100 m.

402(c)(1)(D) Modifications or upgrades involving aerodynamic drag changes [ETM 4.2.3.1.4]

The use of drag devices, such as drag plates mounted beneath or on the sides of the "flight datum" helicopter, has proven to be effective in the noise certification of modifications or upgrades involving aerodynamic drag changes. External modifications of this type are made by manufacturers and aircraft "modifiers". Considerable cost savings are realized by not having to perform noise testing of numerous individual modifications to the same model series. Based on these findings it is considered acceptable to use the following as an equivalent procedure:

a) for helicopters to be certificated under Appendix H a drag device is used that produces the aerodynamic drag calculated for the highest drag modification or combination of modifications;

b) with the drag-producing device installed, an flyover test and, if considered appropriate by the FAA, takeoff and/or approach tests are performed by using the appropriate noise certification reference and test procedures;

c) a relationship of noise level versus change in aerodynamic drag or airspeed is developed by using noise data (adjusted as specified in Appendix H of part 36) of the "flight datum" helicopter and of the "high drag" configuration;

d) the actual airspeed of the modification to be certificated is determined from performance flight testing of the baseline helicopter with the modification installed; and

e) using the measured airspeed of the modification, certification noise levels are determined by interpolation of the relationship developed in item c).

Note.— Modifications or upgrades involving aerodynamic drag changes that do not require noise certification are described in 101(d)(4) of this AC.

402(c)(1)(E) Anomalous test conditions [ETM 4.2.3.1.5]

H36.101(c)(5) of part 36 requires that the tests be conducted under conditions where no anomalous meteorological conditions exist. The presence of anomalous atmospheric conditions can be determined to a sufficient level of certainty by monitoring the outside air temperature (OAT) with the use of the aircraft instruments. Anomalous conditions which could impact the measured levels can be expected to exist when the OAT at 492 ft (150 m) is higher by 3.6°F (2°C) or more than the temperature measured at 33 ft (10 m) above ground level. This check can be made in level flight at a height of 492 ft (150 m) within 30 minutes of each noise measurement.

Since the actual heights associated with the PNLTM points will not be known until the analysis is made, measurements of temperature and relative humidity can be made at a number of heights and the actual value determined from a chart of temperature and relative humidity versus height. Alternatively, since the influence of height is small, measurements at a fixed height in the order of 394 ft (120 m) and 492 ft (150 m) can be used depending on the flight condition and agreement of the FAA prior to the tests being conducted.

If tests are adjusted by using the "average" of the temperature and relative humidity measured at 33 ft (10 m) and the height associated with the PNLTM point (as described in the third paragraph of402(c)(1)(c)) then the provisions of the first paragraph of this section do not apply. The reason is that the impact of any anomalous meteorological conditions is taken into account by using the average of the temperature and relative humidity at 33 ft (10 m) and the height associated with the PNLTM point.

402(c)(1)(F) Helicopter test rotor speed [ETM 4.2.3.1.6]

Operational rotor speed modes (e.g., CAT A) can form part of the normal procedures of the RFM and are used under specific operational circumstances. They typically involve airspeed ranges below those of the certification reference procedures. However, in some cases, such as a high pilot workload in the final approach phase, combined with instrument flight rules (IFR) conditions, their use has been permitted at higher airspeeds which includes the reference speed for noise certification. Hence, the maximum normal operating rotor speed corresponding to the reference flight condition should take into account any relevant operational rotor speed mode. The decision on how and which operational rotor speed modes are to be applied for noise certification is normally coordinated with the flight test experts of the FAA and is dealt with on a case-by-case basis.

402(c)(1)(G) Helicopter test weight [ETM 4.2.3.1.7]

The weight of the helicopter during the noise certification demonstration (see H36.101(b)(6) & (8) of part 36) must lie within the range of 90 percent to 105 percent of the maximum takeoff weight for the takeoff and flyover demonstrations and between 90 percent to 105 percent of the maximum landing weight for the approach demonstration. For noise certification purposes the effect of change of weight is to change the test-day flight path for takeoff, and adjustments to the reference flight path should be made for spherical spreading and atmospheric attenuation as described in H36.205(f) of part 36.

In some cases, such as when the test aircraft weight is restricted to a value somewhat less than the anticipated final certification weight, the applicant may, subject to the approval by the FAA, apply specific adjustments for weight variations. The applicant may be approved to use a 10-log relationship adjustment or otherwise determine, by flight test, the variation of EPNL with weigh. In such a case, the weight tested should include the maximum allowable test weight.

Note.— A similar adjustment procedure may be acceptable when the certificated weight is increased by a small amount subsequent to the flight tests.

402(c)(1)(H) Helicopter approach [ETM 4.2.3.1.8]

H36.3(f)(ii) of part 36 constrains the approach demonstration to within ±0.5° of the reference approach angle of 6°. Adjustments of the noise data to the reference approach angle are required to account for spherical spreading effects and atmospheric attenuation as described in H36.205(f) of part 36.

402(c)(2) Analytical procedures [ETM 4.2.3.2]

402(c)(2)(A) Helicopter test window for zero adjustment for atmospheric attenuation [ETM 4.2.3.2.1]

There is currently a "test window" contained in H36.101(c) of part 36 which needs to be met before test results are acceptable to FAA. In addition if the test conditions fall within a "zero attenuation adjustment window" (see Figure 36), defined as the area enclosed by (2°C, 95 percent RH), (30°C, 95 percent RH), (30°C, 35 percent RH), (15°C, 50 percent RH) and (2°C, 90 percent RH), then the sound attenuation adjustment of the test data may be assumed to be zero.

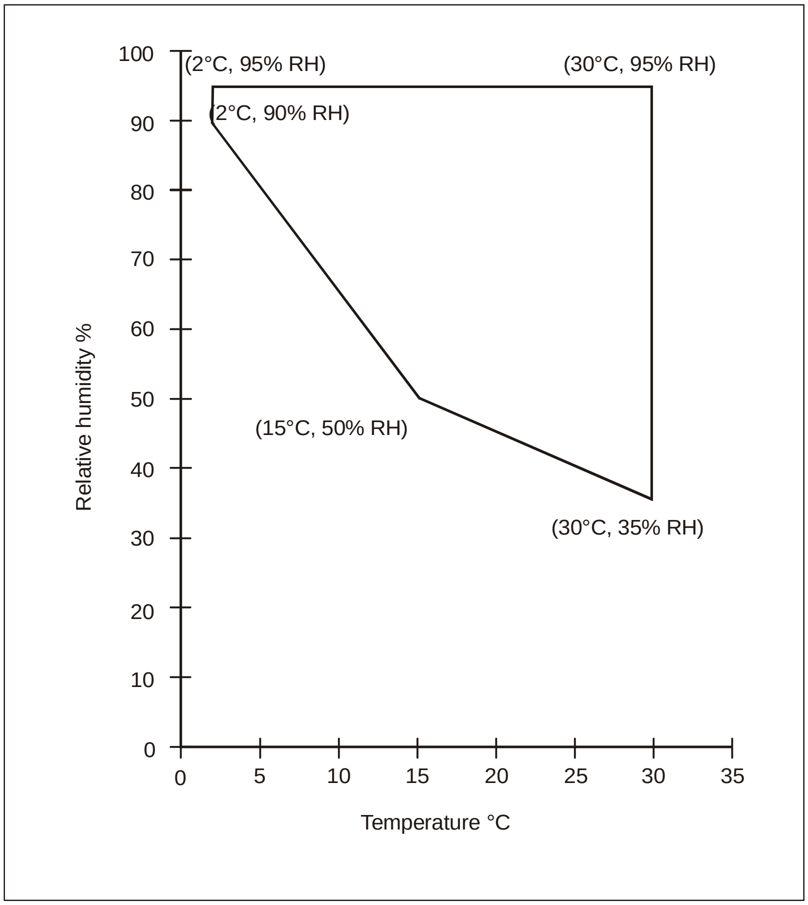


Figure 36. Appendix H zero attenuation adjustment window

Accordingly the terms:

$$0.01\,[\alpha(i) - \alpha(i)_0]\,\text{AL, and}$$

$$0.01\,\alpha(i)_0\,(\text{AL} - \text{AL}_r)$$

from the equation for $\text{SPL}(i)_r$ H36.205(f) of part 36 become zero and the equation for $\text{SPL}(i)_r$ becomes:

$$\text{SPL}(i)_r = 20 \log (\text{AL} / \text{AL}_r)$$

Furthermore, in this equation AL and AL_r may be replaced by the test and reference distances to the helicopter when the helicopter is over the center noise measuring point provided that all the measured points for a particular flight condition are:

a) flown in test conditions within the "zero attenuation adjustment window" defined in Figure 37;

b) for flyover, the height is 492 ± 30 ft (150 ± 9 m);

c) for approach, the height over the microphone is 394 ± 33 ft (120 ± 10 m)); and

d) for takeoff, the distance adjustment given in H36.111(c)(2) of part 36 is not greater than 2 EPNdB.

The total effect of both simplifications cited above is that the equation in H36.205(f) of part 36 becomes:

$$SPL(i)_r = SPL(i) + 20 \log (AF / A_rF_r)$$

and the duration adjustment term specified in H.36.205(g) becomes:

$$\Delta_2 = -7.5 \log (AF / AF_r) + 10 \log (V / V_r)$$

where AL is the measured distance from the helicopter to the noise measuring point when the helicopter is directly over the center noise measuring point and AL_r is the reference distance.

402(c)(2)(B) Procedure for the determination of source noise adjustment [ETM 4.2.3.2.2]

For demonstration of flyover reference certification noise levels, off-reference adjustments are normally made by using a sensitivity curve of PNLTM versus advancing blade tip Mach number deduced from flyovers carried out at different airspeeds around the reference airspeed. However, adjustment may be made by using an alternative parameter or parameters approved by the FAA. If the test aircraft is unable to attain the reference value of the advancing blade tip Mach number or the agreed reference noise correlating parameter, then an extrapolation of the sensitivity curve is permitted, provided that the data cover a range of values of the noise correlating parameter between test and reference conditions as agreed by the FAA. The advancing blade tip Mach number, or agreed noise correlating parameter, must be computed from as-measured data using true airspeed, on-board outside air temperature (OAT) and rotor speed. A separate curve of source noise versus advancing blade tip Mach number, or another agreed noise correlating parameter, must be derived for each of the three noise certification measurement points (i.e., centerline, left sideline and right sideline). Left and right sidelines are defined relative to the direction of the flight for each run. PNLTM adjustments are to be applied to each microphone datum using the appropriate PNLTM function.

In order to eliminate the need for a separate source noise adjustment to the flyover test results, the following test procedure is considered acceptable when the correlating parameter is the main rotor advancing blade tip Mach number (M_r).

Each flyover noise test must be conducted such that:

a) the adjusted reference true airspeed (V_{ar}) is the reference airspeed (V_r) specified in H36.105(c)(5) of part 36 adjusted as necessary to produce the same main rotor advancing blade tip Mach number as associated with reference conditions;

Note.— The reference advancing blade tip Mach number (M_r) *is defined as the ratio of the arithmetic sum of the main rotor blade tip rotational speed* (V_T) *and the helicopter reference speed* (V_r) *divided by the speed of sound* (c_r) *at 77°F (25°C) 1135.6T/s (346.1 m/s) such that:*

$$M_r = \frac{V_T + V_r}{c_r}$$

and the adjusted reference true airspeed (V_{ar}) *is calculated from:*

$$V_{ar} = c(\frac{V_T + V_r}{c_r}) - V_T,$$

where c is the speed of sound calculated from the on-board measurement of outside air temperature (see 308 of this AC).

b) the test true airspeed (V_T) must not vary from the adjusted reference true airspeed (V_{ar}) by more than ±3 kt (±5.5 km/h) or an equivalent approved variation from the reference main rotor advancing blade tip Mach number (M_r);

c) in practice, the tests will be flown to an IAS which is the adjusted reference true airspeed (V_{ar}) corrected for compressibility effects and instrument position errors; and

d) the on-board outside static air temperature must be measured at the flyover height just prior to each flyover.

Note 1.— The calculation of noise levels, including the adjustments, is the same as that described in Appendix H except that the need for source noise adjustment is eliminated. It should be emphasized that in the determination *of the duration adjustment* (Δ_2)*, the speed component of the duration adjustment is calculated as* 10 log(V_G/V_{Gr}) *where* V_G *is the test ground speed and* V_{Gr} *is the reference ground speed.*

Note 2.— The symbol V_G *is denoted as the symbol* V *and* V_{Gr} *as* V_r *in Appendix H*

403 TECHNICAL PROCEDURES INFORMATION [ETM 4.3]

403(a) Jet and Propeller-Driven Airplanes and Helicopters [ETM 4.3.1]

403(a)(1) Adjustment of measured noise data to reference conditions [ETM 4.3.1.1]

Sections A36.9.3 and A36.9.4 of part 36 provides for the use of either simplified or integrated methods for adjusting measured noise data to reference conditions. Criteria for selecting the adjustment method are given in A36.9.1.2 of part 36. Guidance in the form of technical procedures for performing each of these two adjustment methods is provided in the following sections.

403(a)(2) Determination of reference-condition noise geometry [ETM 4.3.1.2]

For either the simplified or integrated adjustment method, aircraft noise geometry must be determined in order to locate the aircraft position on the reference flight path.

The method described in this section illustrates the fundamental principles and key elements of aircraft noise geometry. It is not recommended as the only acceptable method. Other methods may be preferable depending on the techniques used for acquisition and adjustment of test data. Acceptable methods will though have within them key elements consistent with these principles. Note that all methods, including the method described in this section, and the manner in which they are implemented by the applicant, are subject to approval by the certificating authority.

The methodology presented is dependent on obtaining an average, straight-line flight path that represents the test aircraft position during noise measurements. This method is based on characterizing this average straight-line flight path by a set of single-point descriptors, which can be easily obtained from any method of aircraft TSPI measurement data. Geometry relative to each centerline (flyover and approach) and lateral microphone of interest is then determined for the test data, including sound emission coordinates (t, X, Y, Z) for each measured acoustic spectrum (k) in the acoustic spectral time-history data set. Once the sound emission coordinates have been identified, sound propagation distances and acoustic emission angles are calculated, which are used to determine the position of the aircraft on the reference flight path. For the integrated method of adjustment only, the series of positions on the reference flight path are then used to obtain the effective duration for each spectrum *k* for the reference condition acoustic data set.

403(a)(2)(A) Assumptions
[ETM 4.3.1.2.1]

a) The test aircraft position during noise measurements can be represented by a straight-line flight path;

b) the ground reference system used in the figures, a right-handed coordinate system, is assumed to be fixed to the surface of a flat earth with the X axis pointing along the reference ground track, the Y axis pointing to the left of the reference ground track, and the Z axis pointing up;

Note.— For airplanes the term "reference ground track" refers to the "extended centerline of the runway" or the "extended runway centerline" referred to in B36.3 of part 36.

c) the point on the ground directly beneath the centerline microphone is the origin of the XYZ coordinate system (X=0, Y=0, Z=0);

d) the X-coordinate value increases with time as the aircraft moves through the noise measurement test site;

e) the single-point flight path descriptors represent average values over the noise duration as defined in §36.9.4.2(b) of part 36; and

f) angular quantities are expressed in radians except where otherwise noted.

403(a)(2)(B) Steps involved
[ETM 4.3.1.2.2]

a) Characterization of a straight-line average test flight path based on descriptors for a single point (see 403(a)(2)(C));

b) determination of test aircraft position at time of sound emission of each acoustic spectrum (see 403(a)(2)(D));

c) calculation of the geometric minimum distance between the test flight path and the microphone (see 403(a)(2)(E));

d) determination of test aircraft noise geometry (sound propagation distance, acoustic emission angle) for each acoustic spectrum (see 403(a)(2)(F));

e) determination of reference flight path (see 403(a)(2)(G));

f) determination of reference sound propagation distance for each acoustic spectrum (see 403(a)(2)(H)); and

g) determination of effective duration for each acoustic spectrum for the integrated procedure (see 403(a)(2)(I)).

403(a)(2)(C) Characterization of a straight-line average flight path based on descriptors for a single point
[ETM 4.3.1.2.3]

A straight-line flight path can be defined knowing the aircraft position, speed, and three-dimensional direction (vector) at a single point in time (see Figure 37). For the method described in this section the "single-point" descriptors are:

— t_{OH} is the time at overhead (the time when the aircraft X coordinate = 0.0);

— X_{OH} is the X coordinate of the centre line microphone, X = 0.0;

— Y_{OH} is the lateral offset of the aircraft from the reference ground track at t_{OH} ;

— Z_{OH} is the aircraft height above the reference X-Y ground plane at t_{OH};

— V_G is the average groundspeed over the noise duration;

— γ is the average climb/descent angle; and

— χ is the average lateral cross-track angle.

Note.— The average ground speed, V_G, used in calculations for aircraft noise geometry is independent from any cockpit instrumentation, and is to be determined from the aircraft position measurements. For reference conditions, the reference groundspeed, V_{GR}, is to be determined from the reference climb/descent angle and its relationship to the reference true airspeed value, V_R.

Generate the straight-line average aircraft flight path t, X, Y, Z position time history from the single-point flight path descriptors at an appropriate sample rate (typically two times per second):

For any relative time, t(*p*):

$$X(p) = (t(p) - t_{OH})\,(V_G \cos(\chi)) + X_{OH}$$

$$Y(p) = (t(p) - t_{OH})\,(V_G \sin(\chi)) + Y_{OH}$$

$$Z(p) = (t(p) - t_{OH})\,(V_G \tan(\gamma)) + Z_{OH}$$

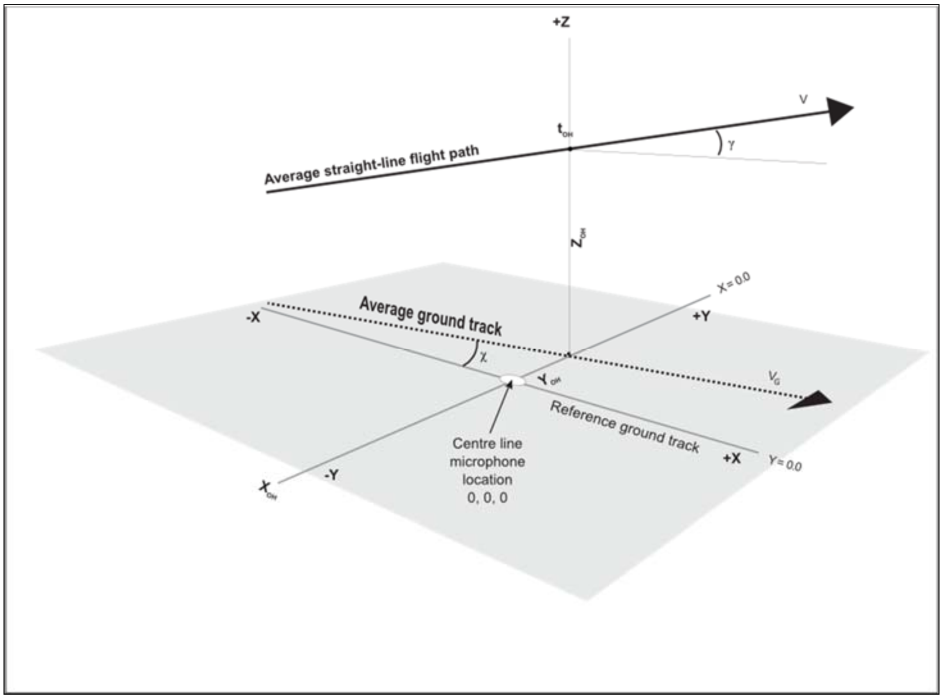


Figure 37. Single-point flight path descriptors

403(a)(2)(D) Determination of test aircraft position at time of sound emission of each acoustic spectrum [ETM 4.3.1.2.4]

Sound emitted from the aircraft takes a finite time to propagate prior to being received at the measurement microphone. During this time, the aircraft has travelled a finite distance along the flight path. Therefore, it is necessary to determine the time and position coordinates of the aircraft for the point of sound emission for each acoustic record *k* (see Figure 38).

The spectral time history of measured aircraft noise data includes a series of slow sample times as specified in A36.3.7.5 of part 36. For each of these measurement times, $t_m(k)$, the associated time of sound emission, $t_E(k)$, as well as the sound emission coordinates, $X_E(k)$, $Y_E(k)$, $Z_E(k)$, can be determined using information about the microphone, the measured aircraft position and time, and the test speed of sound (c).

The microphone position descriptors are:

— X_{MIC} is the longitudinal distance along the reference ground track, between microphone location and coordinate system origin (typically 0.0);

— Y_{MIC} is the lateral distance between microphone location and the reference ground track (typically 0.0 for centerline microphone, and ±492 ft (±150 m) or ±1476 ft (±450 m) for lateral microphones);

— Z_{MIC} is the height of ground at microphone location relative to the reference ground plane (typically 0.0); and

— H_{MIC} is the height of microphone above local ground (4 ft (1.2 m));

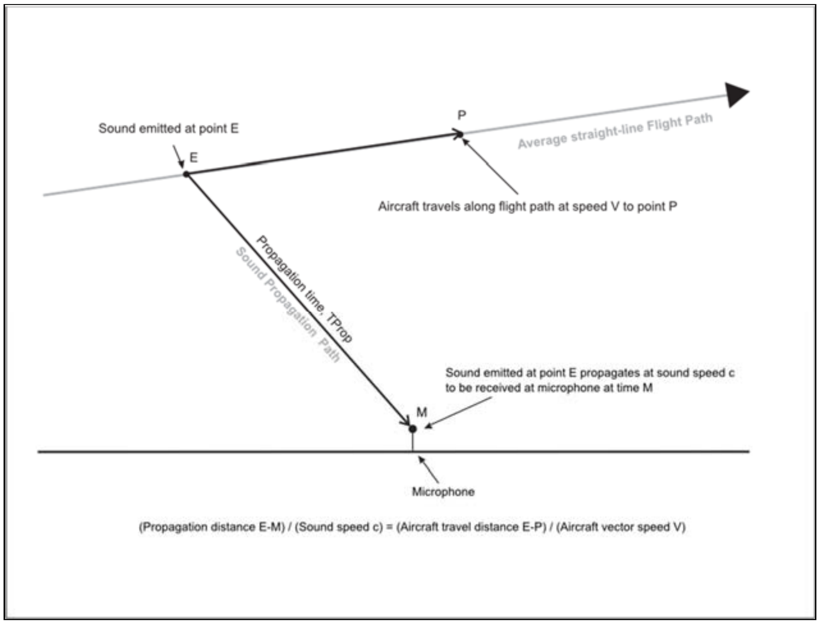


Figure 38. Aircraft position at time of sound emission

Using the average straight-line flight path position time history from 403(a)(2)(C) and the microphone position descriptors listed above, develop an emission/reception array for eventual determination of aircraft sound emission coordinates for each measured acoustic spectral data record, *k*, as follows:

a) Calculate sound speed (c) for test-day conditions (see 308);

b) For each *p*th aircraft position sample in the position time history, t(*p*), X(*p*), Y(*p*) and Z(*p*), calculate the following:

1) Slant range between the aircraft and the microphone:

$$SR(p) = [(X(p) - X_{MIC})^2 + (Y(p) - Y_{MIC})^2 + (Z(p) - (Z_{MIC} + H_{MIC}))^2]^{0.5}$$

2) Sound propagation time:

$$\delta t_{prop}(p) = SR(p) / c$$

3) Reception time:

$$t_{rec}(p) = t(p) + \delta t_{prop}(p)$$

c) The emission/reception array should now include the following for each aircraft position:

$$t(p), X(p), Y(p), Z(p) \text{ and } t_{rec}(p)$$

Using linear interpolation, determine the time of sound emission, $t_E(k)$, for each *k*th measured acoustic spectral data record in the spectral time history:

$$t_E(k) = t(p_2) + ([\ t(p_1) - t(p_2)]\ ([t_m(k) - t_{rec}(p_2)] / [t_{rec}(p_1) - t_{rec}(p_2)])) \text{ where:}$$

— $t_E(k)$ is the relative time when spectrum k was emitted;

— $t_m(k)$ is the acoustic measurement time for spectral record k (as per Section 3.7.6 of Appendix 2 of the Annex)

— p_1 is the aircraft position record where $t_{rec}(p)$ is > $t_m(k)$; and

— p_2 is the aircraft position record where $t_{rec}(p)$ is < $t_m(k)$.

Once the time of sound emission has been determined generate the sound emission coordinates $X_E(k)$, $Y_E(k)$ and $Z_E(k)$ for each kth measured acoustic spectral data record as follows:

$$X_E(k) = (t_E(k) - t_{OH})\,(V_G \cos(\chi)) + X_{OH}$$

$$Y_E(k) = (t_E(k) - t_{OH})\,(V_G \sin(\chi)) + Y_{OH}$$

$$Z_E(k) = (t_E(k) - t_{OH})\,(V_G \tan(\gamma)) + Z_{OH}$$

403(a)(2)(E) Calculation of the geometric minimum distance between the test flight path and the microphone [ETM 4.3.1.2.5]

Using the single-point flight path descriptors identified in 403(a)(2)(C) and the coordinates of the microphone identified in 403(a)(2)(D), calculate the geometrical minimum distance (closest point of approach or "CPA"), the line from the microphone of interest which intersects the straight line flight path at right angles:

$$CPA = (Gnorm^2 + GCPA^2)^{0.5}$$

Intermediate calculations for determination of CPA (see Figures 4-31 and 4-32) include:

a) Lateral distance from microphone to average ground track at t_{OH}:

$$Ydis = Y_{MIC} - Y_{OH}$$

b) Line on the ground from the microphone location which intersects the average ground track at right angles:

$$Gnorm = (Ydis) \cos(\chi)$$

c) Vertical distance of flight path above microphone:

$$Malt = Z_{OH} - (Z_{MIC} + H_{MIC})$$

d) Distance along average ground track between X=0.0 and intersection with Gnorm:

$$Ginc = (Ydis) \sin(\chi)$$

e) Vertical difference between G_{alt} and Z_{OH}:

$$Zinc = (Ginc) \tan(\gamma)$$

f) Vertical height of flight path above microphone at intersection of Gnorm and average ground track

$$Galt = Malt + Zinc$$

g) Line from the point at the microphone height (H_{MIC}) vertically above the point where Gnorm intersects the average ground track, which intersects the average straight line flight path at right angles

$$GCPA = (Galt) \cos(\gamma)$$

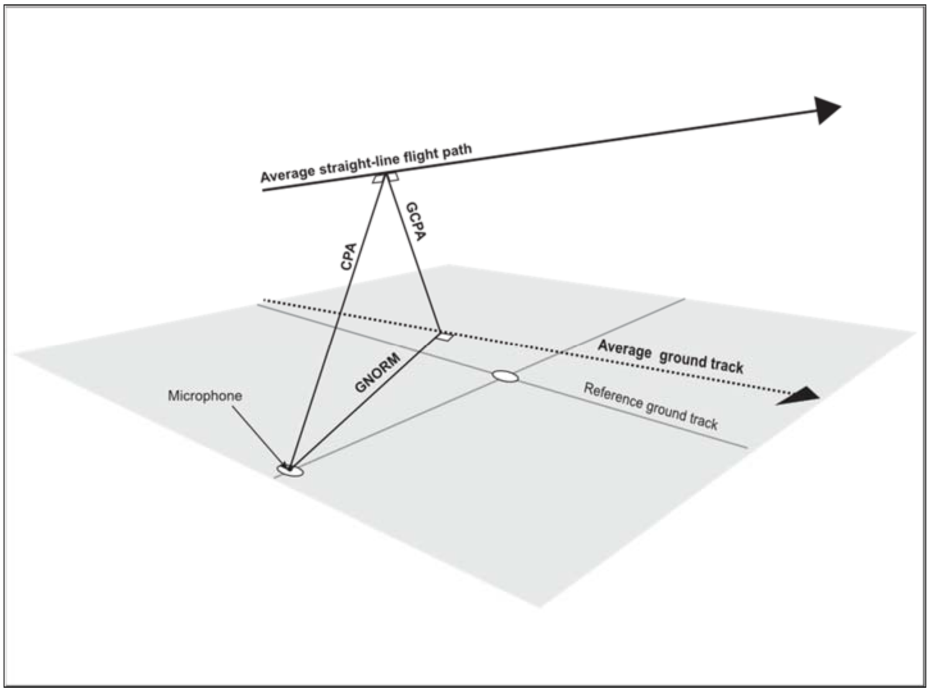


Figure 39. Basic CPA geometry

Note.— In contrast to the previous figure, the horizontal X-Y plane illustrated in this figure is now at the height of the microphone, not the reference ground plane where Z=0.0.

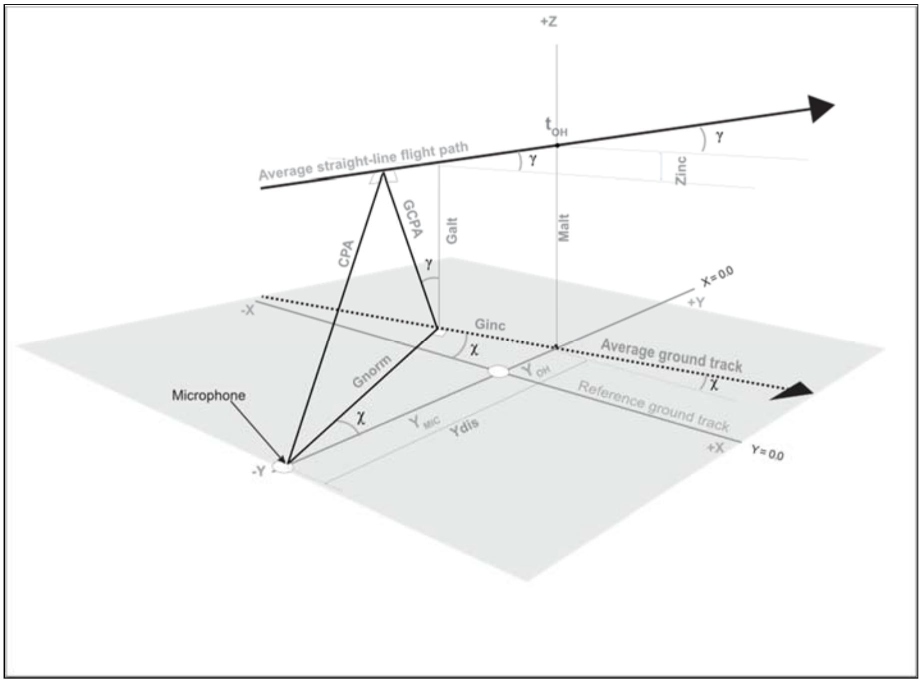


Figure 40. Detailed CPA geometry

Note.— This figure illustrates the CPA geometry for a lateral microphone, but also includes intermediate elements used in the calculation of Gnorm and G_{CPA} applicable to a centerline microphone. Also, the X-Y plane in this figure is at the height of the lateral microphone.

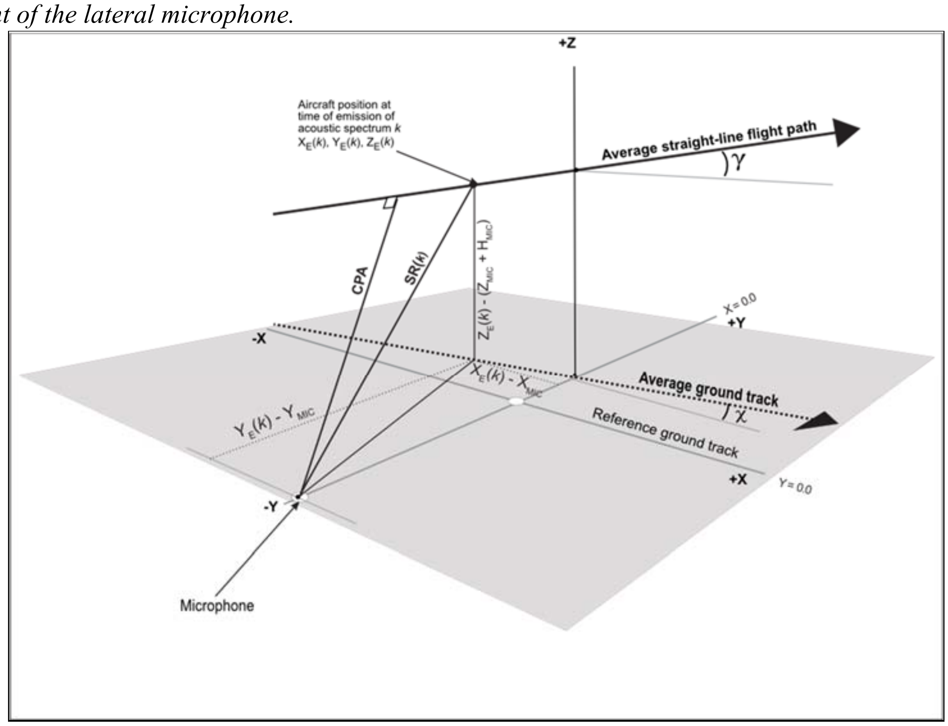


Figure 41. Sound propagation distance, SR(*k*)

403(a)(2)(F) Determination of test aircraft noise geometry (sound propagation distance and acoustic emission angle for each acoustic spectrum) [ETM 4.3.1.2.6]

Using the sound emission coordinates from 403(a)(2)(D) calculate slant range SR(k), the sound propagation distance between the aircraft and the microphone, for each spectrum k in the spectral time history (see Figure 41):

$$SR(k) = [(X_E(k) - X_{MIC})^2 + (Y_E(k) - Y_{MIC})^2 + (Z_E(k) - [\, Z_{MIC} + H_{MIC}])^2]^{0.5}$$

Using the sound propagation distance, SR(k), and the geometric minimum distance between the flight path and microphone, CPA, from 403(a)(2)(E), calculate the three-dimensional acoustic emission angle, θ, for each spectrum k (see Figure 42):

$\theta(k) = \arcsin(CPA / SR(k))$ when aircraft is positioned prior to CPA

$\theta(k) = \pi/2$ (i.e. 90 degrees) when aircraft is positioned at CPA

$\theta(k) = \pi - \arcsin(CPA / SR(k))$ when aircraft is positioned subsequent to CPA

The resulting noise geometry time history for each acoustic spectral data record k now includes:

- $t_m(k)$ is the acoustic measurement time for spectrum k;
- $t_E(k)$ is the sound emission time for spectrum k, received at the microphone at $t_m(k)$;
- $X_E(k)$ is the X-coordinate at time of sound emission for spectrum k;
- $Y_E(k)$ is the Y-coordinate at time of sound emission for spectrum k;
- $Z_E(k)$ is the Z-coordinate at time of sound emission for spectrum k;
- $S_R(k)$ is the sound propagation distance (slant range) for spectrum k; and
- $\theta(k)$ is the three-dimensional acoustic emission angle for spectrum k.

Note.— SR(k) is used for calculations of sound attenuation due to spherical spreading, as well as for sound attenuation due to atmospheric absorption, and for the distance-dependent portion of the Δ_2 duration adjustment term used in the simplified method; θ(k) is used for determining the aircraft position on the reference flight path when adjusting noise data to reference conditions.

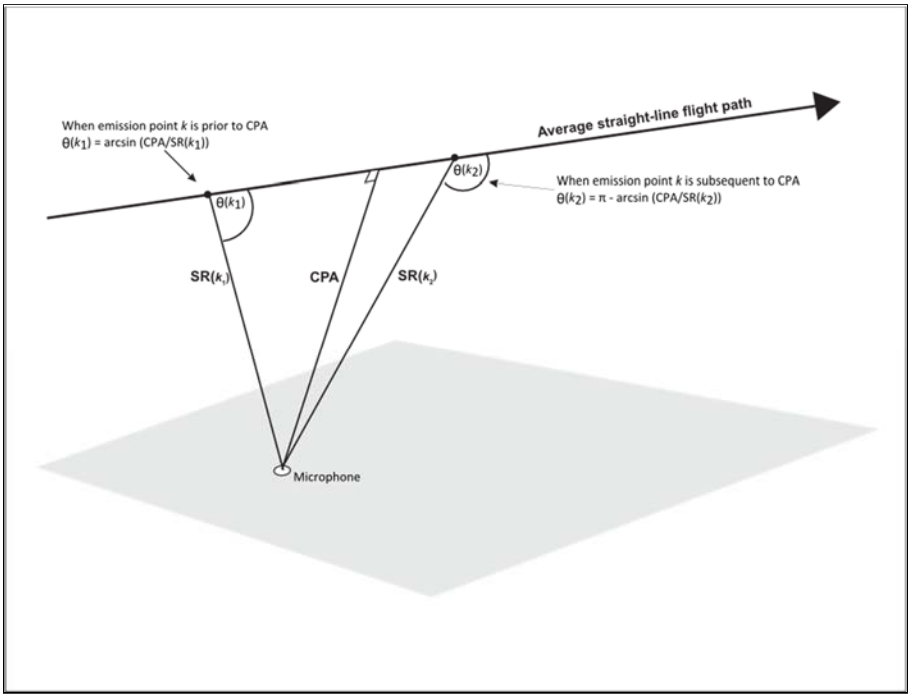


Figure 42. Acoustic emission angle, θ

403(a)(2)(G) Determination of reference flight path [ETM 4.3.1.2.7]

By definition, the reference flight path is a straight line with no lateral displacement. This makes the associated noise geometry relatively simple.

The reference flight path geometry has the following characteristics:

— Z_{OHR} is the vertical height of the reference flight path above the reference ground plane at t_{OH};

— V_{GR} is the reference groundspeed;

— c_R is the reference sound speed, 1135.5 ft/s (346.1 m/s) as per 308 of this AC;

— γ_R is the reference climb/descent angle;

— Y_{MICR} is the lateral distance between the reference microphone location and the reference ground track; and

— H_{MICR} is the height of the reference microphone (4 ft (1.2 m)) above the reference ground plane.

Calculate CPA_R, the reference flight path geometrical minimum distance, or closest point of approach to microphone (see Figure 43a & b):

$$CPA_R = (CPA_{OHR}^2 + Y_{MICR}^2)^{0.5} \text{ where:}$$

$$CPA_{OHR} = (Z_{OHR} - H_{MICR}) \cos (\gamma_R)$$

Note.— CPA_{OHR} is the minimum distance directly under the reference flight path between the reference flight path and the reference microphone height at the intersection of the reference ground track and the lateral microphone line. For centerline microphones, $CPA_R = CPA_{OHR}$.

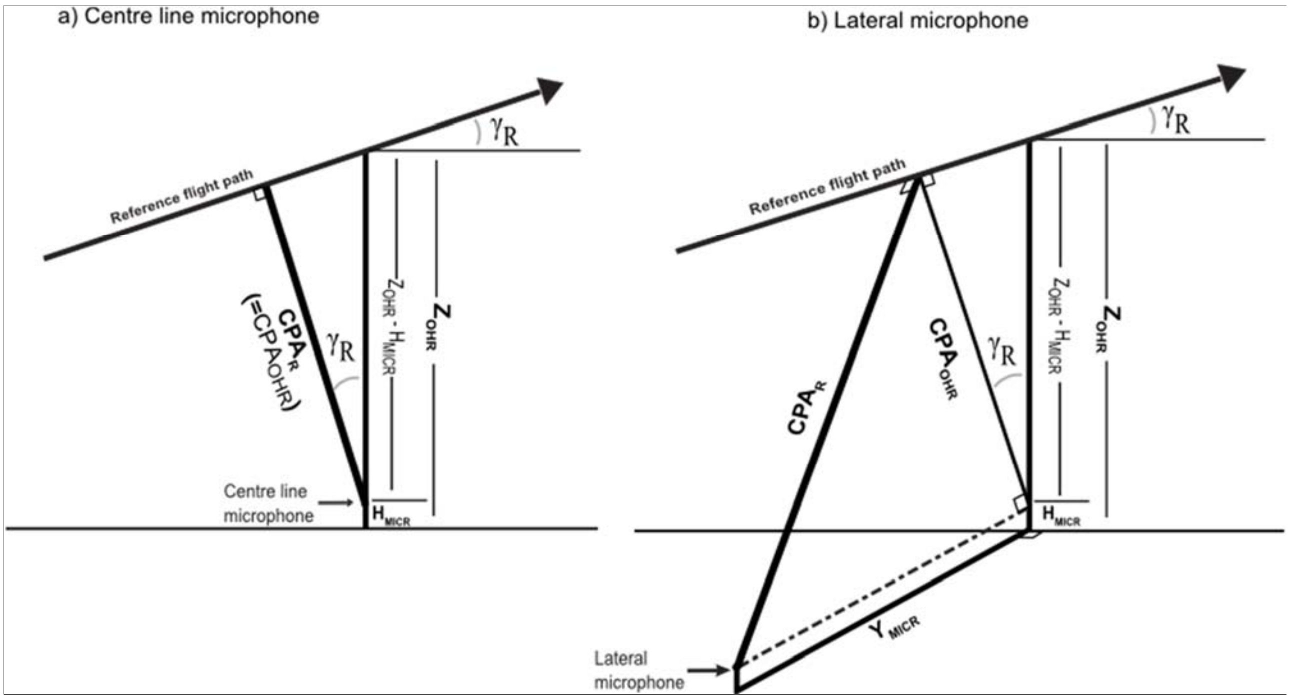


Figure 43. CPA_R for centre line and lateral microphones

403(a)(2)(H) Determination of reference sound propagation distance for each acoustic spectrum [ETM 4.3.1.2.8]

The reference sound propagation distance, $SR_R(k)$, can be determined from the geometric relationship between the acoustic emission angle, $\theta(k)$, which is kept constant between the test and reference cases, and the geometric minimum distance between the reference microphone and the reference flight path, CPA_R (see Figure 44):

$$SR_R(k) = CPA_R / \sin(\theta(k))$$

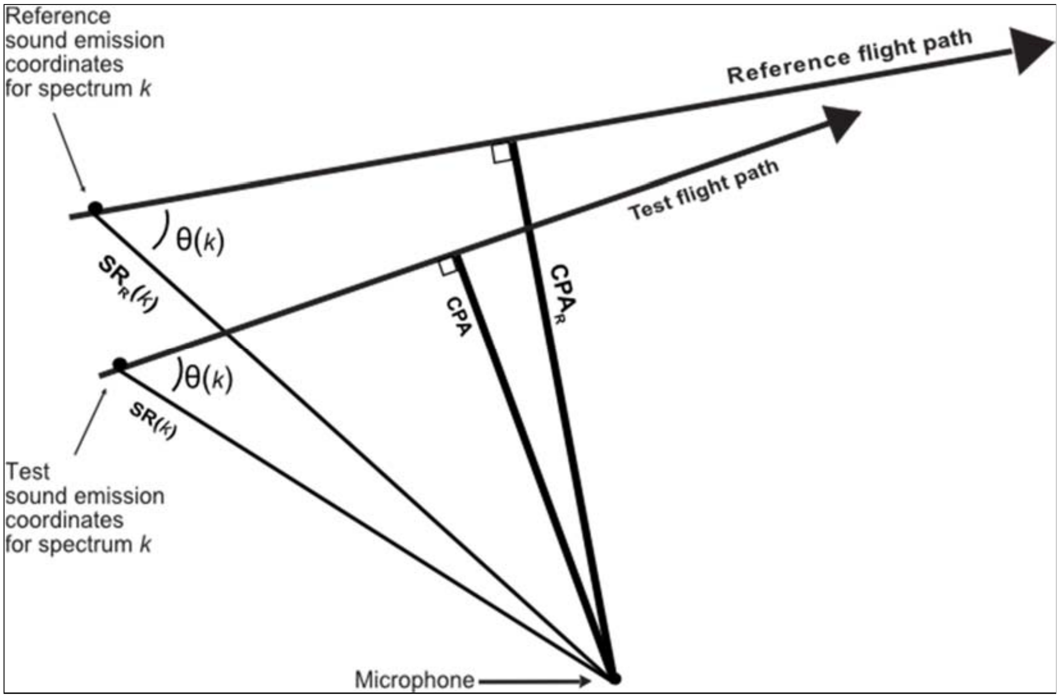


Figure 44. Determination of reference sound propagation distance, $SR_R(k)$

403(a)(2)(I) Determination of effective duration for each acoustic spectrum for the integrated procedure [ETM 4.3.1.2.9]

When using the integrated method of adjustment described in A36.9.4 of part 36, an effective duration ($\delta t_R(k)$) for each reference condition PNLT value must be determined for use in the calculation of EPNL. The uniform, one-half second time intervals between the samples of the measured test aircraft noise data become non-uniform when projected to the reference case, due to adjustments for differences between test and reference conditions. The effective duration represents the time interval between successive acoustic data samples that would have been measured at the reference microphone under reference conditions.

Two elements are involved in determining the "measurement" time for each reference condition acoustic data sample, *k*:

a) the time of sound emission, $t_{ER}(k)$; and

b) the sound propagation time, $\delta t_{propR}(k)$.

Determining the time of sound emission, $t_{ER}(k)$, for reference conditions requires calculation of three distances along the reference flight path, $FPDist(CPA_R)$, $FPInc_R(k)$, and $FPDist_R(k)$ (see Figure 45).

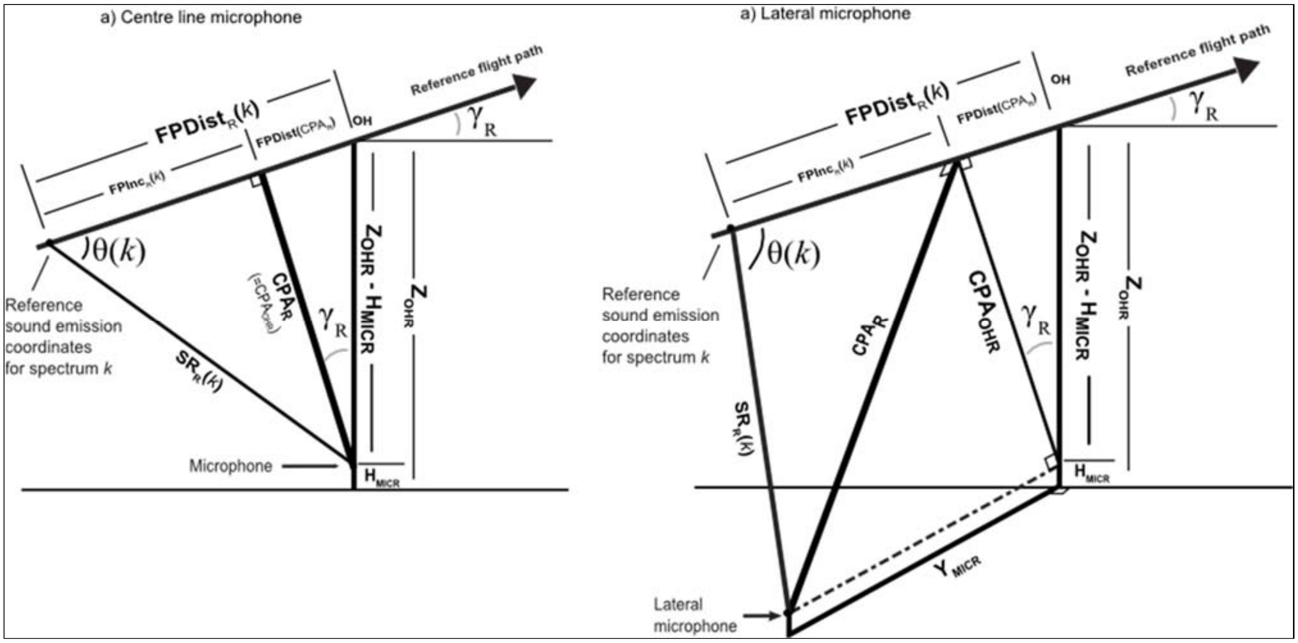


Figure 45. FPDist concept for centerline and lateral microphones

$FPDist(CPA_R)$ is the distance along the reference flight path from CPA_R to t_{OH} (taking its sign from the reference climb/descent angle, γ_R), such that:

$$FPDist(CPA_R) = (CPA_{OHR}) \tan(\gamma_R)$$

Note.— $FPDist(CPA_R)$ is positive when γ_R is positive.

$FPInc_R(k)$ is the distance along the reference flight path from sound emission point k to CPA_R, such that:

$FPInc_R(k) = CPA_R / \tan(\theta(k))$, taking its sign from acoustic emission angle $\theta(k)$ as follows:

a) $FPInc_R(k)$ is positive when $\theta(k) < \pi/2$ (i.e. < 90 degrees);

b) $FPInc_R(k) = 0$ when $\theta(k) = \pi/2$ (i.e. 90 degrees); and

c) $FPInc_R(k)$ is negative when $\theta(k) > \pi/2$ (i.e. > 90 degrees).

$FPDist_R(k)$ is the distance along the flight path from point k to the overhead point, such that:

$$FPDist_R(k) = FPDist(CPA_R) + FPInc_R(k)$$

Note.— $FPDist_R(k)$ is positive when k is before overhead.

$t_{ER}(k)$ is the time of sound emission for point k (found in this case by backing the aircraft along the flight path from t_{OH}), such that:

$$t_{ER}(k) = t_{OH} - (FPDist_R(k) / V_R)$$

Note.— V_R is the true airspeed for reference conditions.

$\delta t_{propR}(k)$ is the sound propagation time for sound emission point k, such that:

$$\delta t_{propR}(k) = SR_R(k) / c_R$$

$t_R(k)$ is the time of sound reception at the microphone for sound emitted at point k, such that:

$$t_R(k) = t_{ER}(k) + \delta t_{propR}(k)$$

Finally calculate $\delta t_R(k)$, the effective time duration for the sound received at the microphone at time $t_R(k)$, as specified in A36.9.4.2.1 of part 36 where:

$$\delta t_R(k) = [(t_R(k) - t_R(k\text{-}1)) + (t_R(k+1) - t_R(k))]/2$$

403(a)(3) Computation of EPNL by the simplified method of adjustment [ETM 4.3.1.3]

Section A36.9.3 of the part 36 provides specifications for the simplified adjustment method. The following procedure illustrates one method for meeting the requirements of this section.

403(a)(3)(A) Inputs required for performing the simplified method [ETM 4.3.1.3.1]

The following inputs are required for the simplified method:

a) The one-third octave band spectrum representing the measured test-day aircraft noise at the time of PNLTM, SPL(i, k_M), plus the spectra representing the measured test-day aircraft noise for any PNLT(k) values within 2 dB of the level of PNLTM (secondary peaks), SPL(i,k), determined in accordance with A36.9.3.2.2 of part 36. Additional guidance is provided in 401(c);

b) The average atmospheric absorption coefficients, $\alpha(i)$ for each one-third octave band, i, determined for test-day conditions, in dB per 100 metres, as determined from measured test-day meteorological data in accordance with A36.2.2.3 of part 36. Additional guidance is provided in 401(b)(2) (Calculation of sound attenuation coefficients for the effects of atmospheric absorption);

c) The atmospheric absorption coefficients, $\alpha(i)_0$ for each one-third octave band, i, determined for reference conditions in dB per 100 meters, as determined in accordance with A36.2.2.3 of part 36. Note that reference conditions for atmospheric absorption are specified in B36.7 of part 36 for airplanes being certified under Stage 3 or Stage 4 or Stage 5 requirements, and in H36.3(a) of part 36 for helicopters, as a homogenous atmosphere with temperature of 77°F (25°C) and relative humidity of 70%;

d) The sound propagation distance (in meters) between the aircraft and the microphone at the time of emission of the PNLTM noise data record, SR(k_M), and for each secondary peak record, SR(k), as determined in 403(a)(2);

e) The reference sound propagation distance (in meters) between the aircraft and the reference microphone at the time of emission of the $PNLTM_R$ noise data record, $SR_R(k_M)$, and of each secondary peak record, $SR_R(k)$, as determined in 403(a)(2);

f) The test-day bandsharing adjustment, Δ_B, as determined in A36.4.4.2 of part 36;

g) The test-day aircraft groundspeed, V_G, as determined from the measured aircraft tracking TSPI data from 403(a)(2);

h) The reference aircraft groundspeed, V_{GR}, as determined from 403(a)(2);

i) The test-day value for EPNL, as specified in A36.4 of part 36;

j) The test-day value for PNLTM, as specified in A36.4 of part 36; and

k) A source noise adjustment, Δ_3, as determined in A36.9.3.4.2 of part 36.

403(a)(3)(B) Adjustment of sound pressure levels to reference conditions [ETM 4.3.1.3.2]

Adjust each measured test-day one-third octave band SPL in the spectrum associated with PNLTM, and in the spectra associated with any secondary peaks, for spherical spreading (also known as "inverse square law") and the effect of the change in sound attenuation due to atmospheric absorption for differences between the test and reference flight paths, using the equation provided in A36.9.3.2.1 of part 36:

For the measured test-day acoustic data spectrum associated with PNLTM, k_M:

For all one-third octave bands, i:

$$\begin{aligned} SPL_R(i,k_M) = SPL(i,k_M) &+ 0.01\,[\alpha(i) - \alpha(i)_0]\,SR(k_M) \\ &+ 0.01\,\alpha(i)_0\,(SR(k_M) - SR_R(k_M)) \\ &+ 20 \log\,(SR(k_M)/\,SR_R(k_M)) \end{aligned}$$

For each measured test-day acoustic data spectrum associated with a secondary peak, k:

For all one-third octave bands, i:

$$\begin{aligned} SPL_R(i,k) = SPL(i,k) &+ 0.01\,[\alpha(i) - \alpha(i)_0]\,SR(k) \\ &+ 0.01\,\alpha(i)_0\,(SR(k) - SR_R(k)) \\ &+ 20 \log\,(SR(k)/\,SR_R(k)) \end{aligned}$$

403(a)(3)(C) Determination of reference-condition tone-corrected perceived noise levels [ETM 4.3.1.3.3]

Calculate the reference-condition tone-corrected perceived noise level, $PNLT_R(k_M)$ for the adjusted spectrum associated with PNLTM, k_M, and for each spectrum associated with a secondary peak, k, using the procedures specified in A36.4.6 of part 36, including calculation of perceived noise level, $PNL_R(k)$ and tone-correction factor, $C_R(k)$.

403(a)(3)(D) Application of test-day bandsharing adjustment to reference-condition maximum tone-corrected perceived noise level and determination of the Δ_1 simplified adjustment term [ETM 4.3.1.3.4]

In order to account for the presence of bandsharing in the measured test-day PNLTM and EPNL, the test-day bandsharing adjustment, Δ_B, as determined in A36.4.4.2 of part 36, is applied to the adjusted reference-condition $PNLT_R(k_M)$ value prior to determination of other adjustment factors, and subsequent calculation of the simplified reference-condition effective perceived noise level, $EPNL_R$ as specified in A36.9.3 of part 36:

$$PNLTM_R = PNLT_R(k_M) + \Delta_B$$

The simplified adjustment term Δ_1 is then calculated per A36.9.3.2.1 of part 36, by subtracting the test-day (bandsharing-adjusted) value for PNLTM (as determined in accordance with A36.4.4.2 of part 36) from the reference-condition (bandsharing-adjusted) value for $PNLTM_R$ obtained from the equation above:

$$\Delta_1 = PNLTM_R - PNLTM$$

403(a)(3)(E) Determination of the Δ_{Peak} simplified adjustment term to account for the effects of secondary peaks [ETM 4.3.1.3.5]

Using the bandsharing-adjusted reference-condition $PNLTM_R$ value as determined in 4.3.1.3.4, and the reference-condition values of $PNLT_R$ for each of the secondary peaks, as determined in 4.3.1.3.3, calculate the secondary peak adjustment term, Δ_{Peak}, specified in A36.9.3.3.2 of part 36 as follows:

a) Compare the $PNLT_R$ values for all of the secondary peaks to determine which has the maximum value of $PNLT_R$, and identify this secondary peak value as $PNLT_R(\mathit{MaxPeak})$.

b) If the value of $PNLT_R(\mathit{MaxPeak})$ exceeds that of $PNLTM_R$, then calculate the secondary peak adjustment term, Δ_{Peak}, by subtracting $PNLTM_R$ from $PNLT_R(\mathit{MaxPeak})$ such that:

$$\Delta_{Peak} = PNLT_R(\mathit{MaxPeak}) - PNLTM_R$$

403(a)(3)(F) Determination of the Δ_2 simplified adjustment term to account for change in noise level [ETM 4.3.1.3.6]

Section A36.9.3.3.1 of part 36 specifies that whenever the flight path and/or ground velocity of aircraft differ between test-day and reference conditions, then a duration adjustment should be determined and applied.

This duration adjustment term, Δ_2, comprising two components, accounts for the effects on the EPNL noise duration of differences between the test and reference distance and speed. These components are determined as follows:

$$\Delta_2 \text{ [distance component]} = -7.5 \log (SR(k_M) / SR_R(k_M)) \text{ where:}$$

k_M is the noise data point at which PNLTM occurred; and

$$\Delta_2 \text{ [speed component]} = +10 \log (V_G / V_{GR}) \text{ where:}$$

V_G and V_{GR} are the test and reference ground speeds of the aircraft, determined from aircraft tracking TSPI data, as determined in 403(a)(2).

The complete equation for the simplified duration adjustment is:

$$\Delta_2 = -7.5 \log (SR(k_M) / SR_R(k_M)) + 10 \log (V_G / V_{GR})$$

403(a)(3)(G) Determination of the Δ_3 simplified adjustment term to account for differences in source noise [ETM 4.3.1.3.7]

Section A36.9.3.4.2 of part 36 defines and describes various means of determining a Δ_3 adjustment term to be used in the calculation of reference-condition effective perceived noise level.

Determine the appropriate process, and calculate the value for Δ_3 per A36.9.3.4.2 of part 36, to account for the effects of differences in source noise between test-day and reference conditions.

Application of this adjustment term, Δ_3, is illustrated in 403(a)(3)(H).

403(a)(3)(H) Determination of the simplified reference-condition effective perceived noise level [ETM 4.3.1.3.8]

Compute the simplified reference-condition effective perceived noise level, $EPNL_R$, as specified in A36.9.3.1 of part 36 as follows:

$$EPNL_R = EPNL + \Delta_1 + \Delta_{Peak} + \Delta_2 + \Delta_3$$ where:

- EPNL is the test-day value for effective perceived noise level, determined in accordance with A36.4.6 of part 36;
- Δ_1 is the simplified adjustment term for the effects of adjusting the PNLTM spectrum to reference conditions as determined in 403(a)(3)(D);
- Δ_{Peak} is the secondary peak adjustment term as determined in 403(a)(3)(E);
- Δ_2 is the simplified adjustment term for duration effects as determined in 403(a)(3)(F); and
- Δ_3 is the adjustment term for source noise effects as described in 403(a)(3)(G).

403(a)(3)(I) Worked example calculations illustrating the simplified method [ETM 4.3.1.3.9]

4.3.1.3.9 *Worked example calculations illustrating the simplified method*

[Reserved]

403(a)(4) Computation of EPNL by the integrated method of adjustment [ETM 4.3.1.4]

Section A36.9.4 of part 36 provides specifications for the integrated method. The following procedure illustrates one method for meeting the requirements of A36.9.4.

403(a)(4)(A) Inputs required for performing the integrated method [ETM 4.3.1.4.1]

The following inputs are required for the integrated method:

a) the one-third octave band spectral time-history representing the measured test-day aircraft noise, SPL(i,k), encompassing at least the test-day EPNL noise duration as defined in A36.4.6 of part 36; additional guidance is provided in 401(c);

b) the average atmospheric absorption coefficients, $\alpha(i)$, for each one-third octave band, i, determined for test-day conditions, in dB per 100 meters, as determined from measured test-day meteorological data in accordance with A36.7 of part 36; additional guidance is provided in 401(b)(2) (Calculation of sound attenuation coefficients for the effects of atmospheric absorption);

c) the reference atmospheric absorption coefficients, $\alpha(i)_0$ for each one-third octave band, i, in dB per 100 metres, as determined in accordance with A36.7 of part 36; note that reference conditions for atmospheric absorption are specified in B36.7 of part 36 for airplanes being certified under Stage 3, Stage 4 or 5 requirements, and in H36.3(a) of Appendix H of part 36 for helicopters, as a homogenous atmosphere with temperature of 77°F (25°C), and relative humidity of 70%;

d) the series of sound propagation distances (in metres) between the aircraft and the microphone at the time of emission of each noise data record, $SR(k)$, as determined in 403(a)(2);

e) the series of reference sound propagation distances (in meters) between the aircraft and the reference microphone at the time of emission of each reference-condition noise data record, $SR_R(k)$, as determined in 403(a)(2); and

f) the series of effective durations, $\delta t_R(k)$ for the series of reference-condition noise data records, k, as determined in 403(a)(2).

403(a)(4)(B) Adjustment of sound pressure levels to reference conditions [ETM 4.3.1.4.2]

Adjust each measured test-day one-third octave band SPL in the spectral time history for the effect of spherical spreading (also known as "inverse square law") and the effect of the change in sound attenuation due to atmospheric absorption for differences between the test and reference flight paths, using the equation provided in A36.9.3.2.1 of part 36:

For all of the one-third octave bands, i, in each of the measured test-day acoustic data records, k:

$$\begin{aligned} SPL_R(i,k) = SPL(i,k) &+ 0.01\,[\alpha(i) - \alpha(i)_0]\,SR(k) \\ &+ 0.01\,\alpha(i)_0\,(SR(k) - SR_R(k)) \\ &+ 20\log\,(SR(k) / SR_R(k)) \end{aligned}$$

Note.— Sufficient spectra in the measured test-day spectral time history should be adjusted to encompass the integrated reference-condition EPNL noise duration, which may exceed the test-day EPNL noise duration due to adjustments to SPLs that may result in different first and last 10 dB-down points being selected.

403(a)(4)(C) Determination of reference-condition tone-corrected perceived noise level time history [ETM 4.3.1.4.3]

Calculate the reference-condition tone-corrected perceived noise level, $PNLT_R(k)$ for each adjusted spectrum, k, in the spectral time history using the procedures specified in A36.4.6 of part 36, including calculation of perceived noise level, $PNL_R(k)$ and tone-correction factor, $C_R(k)$.

403(a)(4)(D) Identification of integrated reference-condition maximum tone-corrected perceived noise level [ETM 4.3.1.4.4]

Using the reference-condition time history of $PNLT_R(k)$ obtained in 403(a)(4)(C), identify the record at which the maximum level occurs, $PNLT_R(k_M)$, and determine and apply the integrated reference-condition bandsharing adjustment, Δ_{BR}, as described in A36.4.4.2 of part 36, to obtain the bandsharing-adjusted reference $PNLTM_R$:

$$PNLTM_R = PNLT_R(k_M) + \Delta_{BR}$$

Note that due to adjustments for differences between test-day and reference conditions, it is possible that the acoustic data record at which $PNLTM_R$ occurs will be different from the record at which the measured test-day PNLTM occurred. It is also possible that the bandsharing adjustment determined from the integrated reference-condition data set. Δ_{BR}, will be different from the bandsharing adjustment determined from the measured test-day data set, Δ_B.

403(a)(4)(E) Identification of integrated reference-condition EPNL Noise Duration [ETM 4.3.1.4.5]

Using the reference-condition time history of $PNLT_R(k)$ obtained in 403(a)(4)(C), but including the bandsharing-adjusted value for $PNLTM_R$ obtained in 403(a)(4)(D), identify the limits of the reference-condition EPNL noise duration in accordance with A36.9.4.3.1 of part 36.

Note that due to adjustments for differences between test-day and reference conditions, the first and last reference-condition 10 dB-down points, k_{FR} and k_{LR} will quite likely be different from the first and last 10 dB-down points for the measured test-day EPNL noise duration, k_F and k_L.

403(a)(4)(F) Summation of integrated reference-condition EPNL [ETM 4.3.1.4.6]

Compute the integrated reference-condition effective perceived noise level, $EPNL_R$, by summing the $PNLT_R(k)$ "energy" between the limits, k_{FR} and k_{LR}, of the integrated reference-condition EPNL noise duration, obtained in 4.3.1.4.5, as follows:

$$EPNL_R = 10\log[(\frac{1}{T_0})\sum_{K_{FR}}^{K_{LR}}(10^{0.1PNLT_R(k)})(\delta t_R(k))]$$ where:

— the series of $PNLT_R(k)$ values is obtained in 4.3.1.4.3 (substituting as necessary the bandsharing-adjusted value of $PNLTM_R$ in place of the value for $PNLT_R(k_M)$); and

— the effective durations, $\delta t_R(k)$, is obtained in 4.3.1.2.

In practice the adjusted EPNL value takes into account the contributions of sound energy associated with each individual time increment (record), and is calculated from a summation from the first 10 dB-down point, k_{FR}, to the last 10 dB-down point, k_{LR}. Note that due to the effects of the adjustment for differences between test and reference conditions the effective duration, $\delta t_R(k)$, associated with each record, is not likely to be uniform. Table 14 provides an example of how this calculation may be performed.

403(a)(4)(G) Worked example calculations illustrating the integrated method [ETM 4.3.1.4.7]

Table 14. Example calculation of adjusted EPNL value when using the integrated method of adjustment.

Labels	$PNLT_R(k)$	$\delta t_R(k)$ s	"Energy"= $(10^{0.1PNLT_R(k)})(\delta t_R(k)$
-	84.62	0.3950	-
-	85.84	0.3950	-
-	85.37	0.3951	-
k_{FR}	88.57	0.3951	284254291.2
-	88.82	0.3952	301173624.8
-	88.03	0.3953	251146317.4
-	88.76	0.3954	297191692.3
-	87.06	0.3956	201027875.5
-	86.92	0.3957	194700044.3
-	90.39	0.3960	433206721.0

Labels	$PNLT_R(k)$	$\delta t_R(k)$ s	"Energy"= $(10^{0.1PNLT_R(k)})(\delta t_R(k)$
-	89.89	0.3963	386388393.4
-	91.00	0.3967	499415710.9
-	90.08	0.3973	404686358.5
-	89.71	0.3981	372384998.9
-	89.61	0.3992	364914006.0
-	90.21	0.4009	420761559.6
-	91.14	0.4033	524358390.8
-	92.10	0.4066	659427985.6
-	93.68	0.4108	958584572.0
-	94.89	0.4153	1280447955.7
-	95.87	0.4196	1621195835.7
-	97.06	0.4231	2150022601.5
PNLTM	97.40	0.4256	2338845959.1
-	96.23	0.4273	1793630138.6
-	94.73	0.4285	1273358894.6
-	92.30	0.4294	729225824.4
-	88.75	0.4299	322379520.6
k_{LR}	86.96	0.4304	213733335.2
-	85.41	0.4307	-
-	83.88	0.4309	-
-	83.01	0.4311	-
-	-	Total energy	18276462607.5
-	EPNL = 10 log (total energy) – 10		92.61892

403(b) Jet Airplanes
[ETM 4.3.2]

403(b)(1) Control of noise certification computer program software and documentation related to static-to-flight projection processes
[ETM 4.3.2.1]

403(b)(1)(A) General
[ETM 4.3.2.1.1]

Procedures for computer program software control must be developed, approved by the FAA, and maintained and adhered to by each applicant utilizing static-to-flight equivalencies (SFEs).

The procedures must consist of four key elements which, when implemented by the noise certification applicant, will result in documentation which properly describes and validates the applicable SFE noise certification computer program and data output. Throughout the development of a given airplane type, adherence to these procedures will enable the tracking of critical computer programs in order to verify that the initial software design has not been changed without substantiation.

The four key elements of configuration index, software control plan, design description, and verification process are described in 403(b)(1)(ii).

403(b)(1)(B) Software control procedures — four key elements [ETM 4.3.2.1.2]

403(b)(1)(B)(i) Configuration index [ETM 4.3.2.1.2.1]

A configuration index must be established for each unique SFE software system. It will include all applicable elements of the software system and provide historic tracking of documents and software under control. Where appropriate, the index may be maintained in a general database.

403(b)(1)(B)(ii) Software control plan [ETM 4.3.2.1.2.2]

A procedure for SFE software change management must be established that includes the baseline design identification, a software change control system and a method of reviewing and auditing software changes and maintaining a status accounting of changes.

Control of software changes must be maintained by establishing baselines within the verification process described below and by documenting modifications to the baseline case that result from program coding changes. Review and auditing procedures will be established within the verification process to allow the validity of the program coding changes for the “modified” configuration to be assessed relative to the “baseline” configuration.

The configuration index must be updated to reflect, historically, the changes made to the software system.

403(b)(1)(B)(iii) Design description [ETM 4.3.2.1.2.3]

A technical description of the methods used to accomplish the SFE certification must be provided, including an overview and a description of the software system design to accomplish the technical requirements. The software design description should include the program structure, usage of subroutines, program flow control and data flow.

403(b)(1)(B)(iv) Verification process [ETM 4.3.2.1.2.4]

The validation process for the SFE software system, or modifications to it, must include a procedure to verify that the calculations described in the documentation are being performed properly by the software. The process may include manual calculations compared to computer output, stepwise graphical displays, software audits, diagnostic subroutines that generate output of all relevant variables associated with the modifications, or other methods to establish confidence in the integrity of the software. The process results must be monitored and tracked relative to software calculation changes.

403(b)(1)(C) Applicability [ETM 4.3.2.1.3]

Although the software control plan is applicable to all SFE-specific computer program software and documentation established through the specific procedures and processes of each applicant, it may not be necessary to review and audit ancillary software such as, but not limited to, subroutines dealing with the sound attenuation coefficients for the effects of atmospheric absorption, noy calculations and tone corrections for each main program source code change.

403(b)(2) Identification of spectral irregularities [ETM 4.3.2.2]

403(b)(2)(A) Introduction [ETM4.3.2.2.1]

Spectral irregularities that are not produced by aircraft noise sources may cause tone corrections to be generated when the procedures of A36.4.3 of part 36 are used. These spectral irregularities may be caused by:

a) the reflected sound energy from the ground plane beneath the microphone mounted at 4 ft (1.2 m) above it, interfering with the direct sound energy from the aircraft (The reinforcing and destructive effects of this interference are strongest at lower frequencies, typically 100 Hz to 200 Hz and diminish with increasing frequency. The local peaks in the one-third octave spectra of such signals are termed pseudo-tones; above 800 Hz this interference effect is usually insufficient to generate a tone correction when the part 36 tone correction procedure is used.);

b) small perturbations in the propagation of aircraft noise when analyzed with one-third octave bandwidth filters; or

c) the data processing adjustments such as the background noise adjustment method and the adjustment for sound attenuation due to atmospheric absorption. (In the case of the latter, the sound attenuation coefficients, a, given in Reference T16 ascribe values at 4 kHz to the center frequency of the one-third octave band whereas at 5 kHz the value of "a" is ascribed to the lower pass frequency of the one-third octave. This difference is sufficient in some cases to generate a tone correction).

The inclusion of a tone correction factor in the computation of EPNL accounts for the subjective response to the presence of pronounced spectral irregularities. Tones generated by aircraft noise sources are those for which the application of tone correction factors is appropriate. Tone correction factors that result from spectral irregularities (i.e., false tones produced by any of the causes cited above) may be disregarded. This section describes methods which have been approved for detecting and removing the effects of such spectral irregularities. Approval of the use of any of these methods however remains with the FAA.

403(b)(2)(B) Methods for identifying false tones [ETM 4.3.2.2.2]

403(b)(2)(B)(i) Frequency tracking [ETM 4.3.2.2.2.1]

Frequency tracking of flyover noise data is useful for the frequency tracking of spectral irregularities. The observed frequency of airplane noise sources decreases continuously during the flyover due to Doppler frequency shift, f_{DOPP}, where:

$$f_{DOPP} = \frac{f}{1-M\cos\lambda},$$

where:

— f is the frequency of the noise at source;

— M is the Mach number of the airplane; and

— λ is the angle between the flight path in the direction of flight and a line connecting the source and observer at the time of sound emission.

Reflection-related effects in the spectra (i.e., pseudo-tones) decrease in frequency prior to, and increase in frequency after, passing overhead or abeam the microphone. Spectral irregularities caused by perturbations during the propagation of the noise from the airplane to the microphone tend to be random in nature, in contrast to the Doppler effect. These differing characteristics can be used to separate source tones from false tones.

403(b)(2)(B)(ii) Narrow-band analysis [ETM 4.3.2.2.2.2]

Narrow-band analysis with filter bandwidths narrower than those of one-third octave is useful for identifying false tones. For example, when the analysis is produced such that the spectral noise levels at an instance are presented in terms of image intensity on a line, the overall flyover analysis clearly indicates the Doppler-shifted airplane tones and those due to reflection as described above.

403(b)(2)(B)(iii) Microphone mounting height [ETM 4.3.2.2.2.3]

Comparison of one-third octave spectra of measurements taken using the 4 ft (1.2 m) high microphone and corresponding data obtained from a neighboring microphone mounted flush on a hard reflecting surface (a configuration similar to that described in A36.4.4 of part 36 or at a height substantially greater than 4 ft (1.2 m), such as 33 ft (10 m), may be used to identify false tones. Changes to the microphone height alter the interference spectra irregularities from the frequency range of data from the 4 ft (1.2 m) high microphone, and when a comparison is made between the two data sets collected at the same time, noise source tones can be separated from any false tones which may be present.

403(b)(2)(B)(iv) Inspection of noise time-histories [ETM 4.3.2.2.2.4]

Spectral irregularities which arise following data adjustment as described in this section will occur in the frequency range of between 1 kHz to 10 kHz, and the resulting false tone corrections will normally vary in magnitude between 0.2 dB to 0.6 dB. Time-histories of PNLs and PNLTs, which exhibit constant level differences, are often indicative of the presence of false tone corrections. Supplementary narrow-band analysis is useful in demonstrating that such tone corrections are not due to airplane -generated noise.

403(b)(2)(C) Treatment of false tones [ETM 4.3.2.2.3]

When spectral irregularities give rise to false tones that are identified by, for example, the methods described in this section their values, when computed according to Step 9 of the tone correction calculation described in A36.4.3 of part 36, may be set to zero.

403(b)(3) Noise data adjustments for tests at high altitude test sites [ETM 4.3.2.3]

403(b)(3)(A) Introduction [ETM 4.3.2.3.1]

Jet noise generation is somewhat suppressed at higher altitudes due to the difference in the engine jet velocity and jet velocity shear effects resulting from the change in air density. The use of a high altitude test site for the noise test of an airplane model that is primarily jet-noise dominated should include making the following adjustments. These jet source noise adjustments are in addition to the standard pistonphone barometric pressure adjustment of about 0.3 dB/1000 ft (0.1 dB/100 m) which is normally used for test sites not approximately at sea level. The jet source noise adjustments are applicable to tests conducted at sites at or above 1200 ft (366 m) mean sea level (MSL).

403(b)(3)(B) Jet source noise adjustment [ETM 4.3.2.3.2]

Flight test site locations at or above 1200 ft (366 m) MSL, but not above 4000 ft (1219 m) MSL, may be approved provided certain criteria are met (see Figure 46) and the source noise adjustments are applied.

Alternative criteria or adjustments require the approval by the FAA.

403(b)(3)(B)(i) Criteria
[ETM 4.3.2.3.2.1]

Jet source noise altitude adjustments are required for each one-half-second spectrum when using the integrated procedure and, for the PNLTM spectrum, when using the simplified procedure (see A36.9.3 and A36.9.4 of part 36) and are to be applied in accordance with the criteria described in Figure 46.

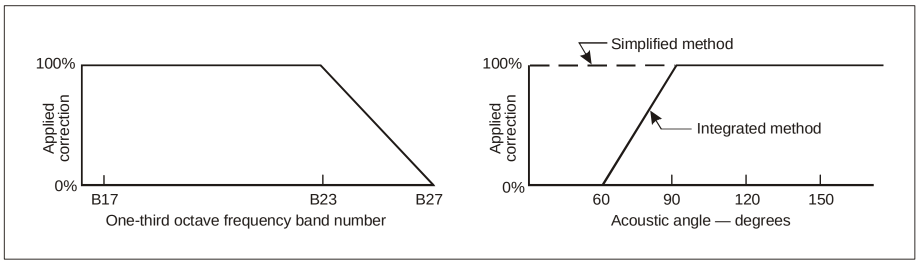


Figure 46. Criteria for jet source noise correction

403(b)(3)(B)(ii) Adjustment procedures
[ETM 4.3.2.3.2.2]

An acceptable jet source noise adjustment is as follows:

a) adjust each one-half-second spectrum or PNLTM one-half-second spectrum, as appropriate, in accordance with the criteria of 403(b)(3)(ii)(A) by using the following equation:

$$\Delta SPL = [10 \log (d_R/d_T) + 50 \log (c_T/c_R) + 10k \log (u_R/u_T)] \text{ [F1] [F2]}$$

where:

— subscript T denotes conditions at the actual airplane test height above MSL under standard atmospheric conditions (i.e., ISA + 18°F (ISA + 10ºC) and 70 percent relative humidity);

— subscript R denotes conditions at the airplane reference height above MSL (i.e., airplane test height above MSL minus the test-site altitude) under standard atmospheric conditions (i.e., ISA + 18°F (ISA + 10ºC) and 70 percent relative humidity);

— SPL denotes sound pressure level;

— d_R is the density for standard atmosphere at the airplane reference height in lb/ft^3 (kg/m^3) ;

— d_T is the density for standard atmosphere at the airplane test height in lb/ft^3 (kg/m^3);

— c_R is the speed of sound corresponding to the absolute temperature for a standard atmosphere at the airplane reference height in ft/s (m/s)

— c_T is the speed of sound corresponding to the absolute temperature for a standard atmosphere at the airplane test height in ft/s (m/s)

— $k = 8$, unless an otherwise empirically derived value is substantiated;

— $u = (v_e - v_a)$ is the equivalent relative jet velocity in ft/s (m/s);

where:

— v_e is the equivalent jet velocity as defined in Appendix C of Reference T12 and obtained from the engine cycle deck in ft/s (m/s);

— v_a is the aircraft velocity in ft/s (m/s);

— u_R is the equivalent relative jet velocity in ft/s (m/s) where v_e is determined at $N1C_{TEST}$ for standard atmosphere at the airplane reference height;

— u_T is the equivalent relative jet velocity in ft/s (m/s) where v_e is determined at $N1C_{TEST}$ for standard atmosphere at the airplane test height;

— N1C is the corrected engine rpm $N_1/\sqrt{\theta_{t2}}$;

— F1 is a factor corresponding to the percentage of applied adjustment related to acoustic angle in Figure 46 (values range from 0.00 to 1.00); and

— F2 is a factor corresponding to the percentage of applied adjustment related to the one-third octave band in Figure 46 (values range from 0.00 to 1.00);

b) for each one-third octave band SPL, arithmetically add the height jet noise adjustment in 403(b)(3)(ii)(B) a)to the measured SPLs to obtain the altitude jet source noise adjusted SPLs for the derivation of PNL described in A36.4.1.3 a) of part 36; and

c) the height adjustment is to be applied to all measured test data including approach conditions unless it can be substantiated that the jet noise during approach does not contribute significantly to the total aircraft noise.

Chapter 5

GUIDELINES FOR PROPELLER-DRIVEN SMALL AIRPLANES AND PROPELLER-DRIVE COMMUTER CATEGORY AIRPLANES EVALUATED UNDER APPENDIX G OF 14 CFR PART 36

CHAPTER TABLE OF CONTENTS

501 EXPLANATORY INFORMATION [ETM 5.1]

See 301 of this AC for technical procedures generally applicable for noise certification tests of all aircraft types including those evaluated under the provisions of Appendix G of part 36. Procedures specific to Appendix G are presented in the following section.

501(a) Noise Measurements [ETM 5.1.1]

501(b) Noise Certification Test and Measurement Conditions [ETM 5.1.2]

501(b)(1) Meteorological conditions GM §G36.101(b) [ETM GM A6 2.2.2]

(1) *Atmospheric conditions*

Atmospheric conditions can affect the generation and propagation of sound for non-reference helical tip Mach numbers (see G36.201 of part 36). Propellers generate higher noise levels at higher propeller helical tip Mach numbers. Usually the actual tip velocity is close to reference propeller-tip velocity, but the speed of sound is a function of air temperature which is often different than the reference value. Off-reference tip Mach numbers can occur because of off-reference air temperature. Part 36 specifies the need for correction for non-reference tip Mach numbers under most circumstances. However, limiting the permissible test temperature range reduces the potential magnitude of this correction. Corrections are also required to account for non-reference atmospheric absorption of sound. The magnitude of this correction is also limited by restricting the range of permissible temperature and relative humidity.

(2) *Non-uniform atmosphere*

The atmosphere between the source (i.e., airplane, propeller and/or exhaust) and the microphone is not uniform. There can be strong temperature gradients, positive and negative, variations in relative humidity and variations in wind. Turbulence is also associated with strong winds, which can cause irregular sound propagation. Corrections are not required to account for wind. The wind limits provide only a means of determining the acceptability of the data.

(3) *Weather monitoring*

Based on the above considerations, weather conditions should be monitored. Procedures used in the noise certification process for transport category airplanes and turbojet-powered airplanes call for measurement of the weather conditions between the ground and the height at which the airplane is flying (see A36.2.2.2(b) of part 36). The absorption of sound in air can then be computed based on these measurements. This process requires an appreciable investment of time and resources. For light propeller-driven airplanes, the magnitude of the adjustment for atmospheric absorption is less than that for jet airplanes. An adjustment procedure based on measurements of the weather near the surface is therefore considered sufficient and more appropriate for airplanes covered by this section.

(4) *Temperature inversions*

The effects of inversions and anomalous wind conditions are difficult to quantify. When temperature inversions are present (i.e., when the air temperature increases with height over any portion of the atmosphere between the ground and the airplane) flight conditions may be unstable, which hampers the ability of the pilot to set up a consistent, stabilized climb within the permitted operational tolerances. Also, under these conditions, it is possible to have a situation in which the surface temperature and relative humidity meet the permissible test criteria but the conditions aloft are much drier, with consequent high sound absorption characteristics and the possibility of underestimating the noise level. The noise spectrum of propeller-driven airplanes contains relatively less high frequency noise than that of jet airplanes, so the effects may not be very significant unless there is a severe inversion.

501(b)(2) Atmospheric measurements
AMC §G36.101(b) [ETM AMC A6 2.2.2]

(1) *General weather measurements*

The applicant should measure weather conditions near the surface and in the vicinity of the noise measuring point. The acceptability of noise data is contingent on the conditions being within the specified limits of G36.101(b) of part 36. These measurements are to be made at a height between 4 ft (1.2 m) and 33 ft (10 m) above ground level. This allows the use of hand-held equipment but does not preclude the use of more complex equipment of the type identified in Appendix A of part 36 if the applicant so chooses. The weather data may be recorded on a chart, or a record of the observations, witnessed by the FAA, may be kept.

(2) *Wind*

Consistent with the less complex requirements for small propeller-driven airplanes, wind measurements may be made using a hand-held device if its specifications are similar to instrumentation that the FAA would approve for use in testing under Appendix A of part 36. If the device used does not provide enough information to compute the crosswind, then the wind in any direction should be limited to the crosswind limit of 5 kt (2.6 m/s). The wind limits are based on a 30-second average.

(3) *Temperature and relative humidity limits*

Noise data are acceptable only if the air temperature is in the range of 36°F (2°C) to 95°F (35°C), and the relative humidity is in the range of 20 to 95 percent. Temperature and relative humidity may be measured with a psychrometer, a device that measures wet and dry bulb temperatures of the air. Relative humidity is then computed from these temperatures. Sufficient measurements should be made to determine all adjustments specified by Appendix G of part 36. Persons responsible for performing the test should be alert to changes in the conditions. At a minimum, measurements should be made immediately before the first run in a series and immediately after the last run. This interval should not exceed more than one hour because of the requirement for adjustment of the airplane test weight due to fuel loss. In marginal or changing conditions, shorter intervals would be more appropriate.

(4) *Anomalous winds*

The presence of anomalous wind conditions may be assessed by noting the airspeed variation as the airplane climbs. If the wind is uniform or changes speed or direction slowly with altitude, there is no difficulty in maintaining a constant climb speed. If there are strong variations in the wind (i.e., wind shear) or rising and descending air, there will be variations in airspeed that are not easily controllable. Variations of ±5 kt (±2.6 m/s) during the flyover relative to the reference velocity (V_y) are permitted by Appendix G of part 36, and this criterion may be used to evaluate the presence of anomalous wind conditions.

(5) *Air temperature measurements versus altitude*

At the beginning of the test and, if considered necessary, at intervals during the test, an observer on the test airplane may consider monitoring the air temperature during a climb. This climb may be a noise data–recording climb or may be dedicated to temperature measurement. The information must be assessed if a judgment is to be made about the acceptability of the conditions for noise measurements. The presence of anomalous wind conditions can be assessed during the data acquisition.

501(b)(3) Airplane flight path
GM §G36.111 [ETM GM A6 2.3.5]

(1) *Airplane position*

Appendix G of part 36 specifies determination of the noise level at a single location relative to the start of takeoff roll. Limits on the permissible deviation from the reference flight path are specified for the flight tests. These limits are based on the ability to obtain consistent, representative results, without placing excessive restrictions on the flight test. The initial takeoff weight should be equal to the maximum approved takeoff weight, and after an hour of flight time, the weight is to be increased back to maximum to account for fuel burn. This procedure ensures that the flight parameters, primarily angle-of-attack, do not vary significantly from the reference. The airplane position is to be approved by the FAA for each test flyover.

501(c) Noise Unit Definition
[ETM 5.1.3]

501(c)(1) A-weighting
GM §G36.105(e) [ETM GM A6 3.0]

(1) *Basis of measurement*

The A-weighting correction curve has been precisely defined by national and international standards for the measurement of sound, such as environmental noise, and is a standard feature in sound level meters and other sound analysis equipment used for noise assessments.

501(d) Measurement of Airplane Noise Received on the Ground
[ETM 5.1.4]

501(d)(1) Recording systems
GM §G36.105 [ETM GM A6 4.3.1]

(1) *Audio recorders*

An audio recorder can be used to preserve a complete acoustical record of the events. If there are questions about the data observed during the tests, the recorded data can be replayed, multiple times if necessary, to verify the results. A more detailed analysis of the airplane noise signal may also be useful to the applicant for research and development purposes.

(2) *Graphic level recorders*

A graphic level recorder can be used to provide a permanent record of the noise levels, but no replay or reproduction of the acoustical signal is possible.

(3) *Sound level meters*

The record that results from the use of a sound level meter depends on the design features of the instrument. The least complex instrument uses an electromechanical metering mechanism, requiring the operator to observe the highest level indicated by the moving needle in the meter display during each event. Other, more complex instruments can be set to hold the maximum noise level reached during each event and show this level on a digital display. Some currently available digital units are capable of storing entire time-histories of noise levels for multiple runs. These histories can be recalled to the instrument's display, transmitted to a printer or downloaded to a computer.

501(d)(2) Recording systems
AMC §G36.105(a) [ETM AMC A6 4.3.1]

(1) *Audio recorders*

One method is to record each noise event using an audio recorder. This recorded data can be played back and analyzed as much as necessary to verify that consistent results have been obtained.

(2) *Other methods*

Other methods include the following:

a) reading graphic level recorder charts;

b) reading a sound level meter in the field as the event occurs and keeping a handwritten log in ink; and

c) printing, or transferring to a personal computer, the entire time history after the test has been completed.

Appropriate measures should be taken to ensure the validity of the data, and their use is subject to approval by the FAA.

501(d)(3) Noise characteristics
GM §G36.105(e) [ETM GM A6 4.3.4]

(1) *Filtered noise level and meter response speed*

The noise level from each flyover test should be measured in terms of the maximum A-weighted sound level, in decibel (dB(A)) units, using an A-weighting filter with dynamic characteristics (meter response characteristics) designated as "S" (for "slow") as defined in Reference T3 and specified in G36.105(e) of part 36. The slow response results in an effective two-second averaging period (i.e., one-second time constant), which should be used in Appendix G noise tests.

(2) *Maximum sound level*

The measured or indicated A-weighted sound level will increase as the airplane approaches the measurement site and will decrease after the airplane passes over the site. The highest value of the A-weighted sound level that occurs during the flyover is called the maximum A-weighted sound level. This is the value that should be measured during each test.

Note.— This maximum value may not occur at the exact moment when the airplane is directly over the microphone. It usually occurs slightly before or after the airplane reaches the overhead position due to the directivity characteristics of propeller, engine and exhaust noise emissions.

501(d)(4) Measurement system sensitivity
GM §G36.107(b) [ETM GM A6 4.3.5]

(1) *Noise level variability*

There can be variability in the noise levels indicated by the test equipment, primarily due to environmental factors and the internal warm-up that is required by most types of equipment. Occasionally, there may be other changes due to cable problems or even equipment damage. Proper use of acoustic calibration devices can help identify such occurrences.

501(d)(5) Calibration process
AMC §G36.107(b) [ETM AMC A6 4.3.5]

(1) *Equipment calibration*

A suitable sound calibrator should be used to provide a reference sound level. This is usually accomplished by placing the calibrator on the microphone and adjusting the gain of the measuring system so that the reading corresponds to the known sound level of the calibrator. Initial, final and periodic calibrations should be used to verify that any changes in sensitivity are identified. It is important that the manufacturer's recommended system warm-up time be observed in the field prior to equipment calibration. Calibration equipment should be identified in the test plan and is to be approved by the FAA.

501(d)(6) Microphone configuration
GM §G36.107(a) [ETM GM A6 4.4.1]

(1) *Ground plane microphone*

The specified ground plane microphone configuration greatly minimizes the interference effects of reflected sound waves inherent in pole-mounted microphone installations. For a 4 ft (1.2 m) microphone, such effects typically occur in the frequency region that is most significant for propeller-driven aircraft noise.

(2) *Microphone sensitivity*

The specified ground plane configuration places the microphone diaphragm into an effective sound pressure field for the frequency range of interest. Microphones designed for uniform pressure response are appropriate for use in such installations.

501(d)(7) Microphone configuration
AMC §G36.107(a) [ETM AMC No. 1 A6 4.4.1]

(1) *Inverted microphone*

The inverted microphone setup shown in Figure 47 is an example of the design and construction of the microphone holder and the ground plate. The legs of the microphone holder should be firmly attached to the plate so that the microphone holder does not vibrate during the test. The plate should be painted white to reflect the sun's rays, as such reflection will reduce the thermal effects on the microphone-sensing element. A metal spacer is a practical tool to use in setting the space between the microphone diaphragm and the ground plate. The spacer thickness should be 7 mm minus the space between the microphone protective grid and the microphone diaphragm.

(2) *Microphone placement*

The spacing of the microphone diaphragm relative to the plate is critical, since it should be inserted completely within the effective sound pressure field, and the depth of this field varies with frequency and sensor size. For frequencies of interest, 7 mm spacing has been determined to provide the best compromise of associated technical considerations.

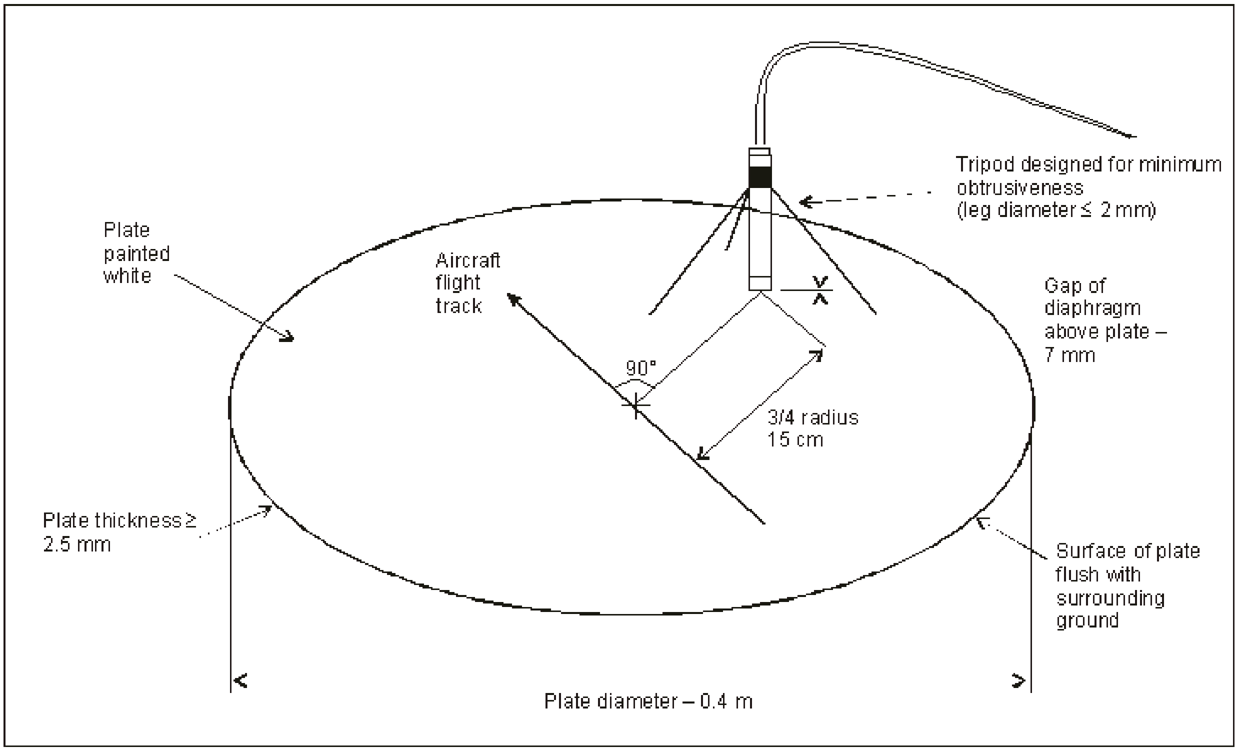


Figure 47. Configuration for one-half-inch inverted microphone

501(d)(8) Microphone installation
AMC §G36.107(a) [ETM AMC No. 2 A6 4.4.1]

(1) *Plate installation in local ground surface*

Care should be taken during installation to ensure that the ground surface beneath the plate is level and contains no voids or gaps. One way to achieve this is by pressing the plate into the ground surface at the desired location, applying slight pressure, then removing the plate to determine if any areas under the plate are recessed. These recesses can then be filled in with loose material, such as sand or soil, to obtain a level, uniform underlying surface. Care should also be taken to ensure that the edges of the plate are flush with the surrounding ground surface. This is especially important for plates that are thicker than the specified minimum of 2.5 mm.

In some cases it may be appropriate to moisten the soil with water immediately before installation to allow the surface to mould itself around the plate. In such cases, acoustical measurements should not be performed until the ground has dried.

(2) *Design and construction of microphone support*

The support should be designed so that it minimizes any potential interference with sound waves from the aircraft arriving in the vicinity of the microphone. If a spider-like structure such as that in Figure 47 is used, the number of legs should be limited to three or four. As specified in the figure, the legs should be no larger than 2 mm diameter. Ideally the support collar should be as small as possible, and it should also implement some sort of tightening device, such as a set screw, to facilitate adjustment of the microphone diaphragm height above the plate. The support should be stable and should orient the microphone in such a way that the diaphragm is parallel to the plate.

(3) *Cable support*

In some cases, it may be desirable to provide additional support to the microphone cable as it leads away from the plate. A metal rod or similar sort of support may be used for this purpose. Any such support should be as small as possible and located as far away from the plate as is practical. The microphone cable should lead directly away from the plate without crossing above any more of the plate's surface than is necessary.

(4) *Windscreens*

Consideration should be given to using windscreens when wind speed exceeds 5 kt (2.6 m/s) (see 502(b) of this AC).

501(d)(9) Background noise alleviation
AMC §G36.107(c) [ETM AMC A6 4.4.4]

(1) *Increased airplane noise*

If a site with lower noise levels cannot be used, it may be necessary to fly the airplane so that the target height over the microphone is less than it would be at the reference microphone station (8202 ft (2500 m) from the start of the takeoff roll). In this case, the airplane height at the microphone location is likely to be outside the ±20 percent tolerance specified in G36.111(a) of part 36. Adjustment of data to reference conditions should be performed in an approved manner.

501(e) Adjustment to Test Results
[ETM 5.1.5]

501(e)(1) Atmospheric absorption adjustment
GM §G36.201(b) [ETM GM A6 5.2.1 a)]

(1) *Atmospheric absorption*

The temperature and relative humidity of the air affect the sound propagation. This correction accounts for the difference in atmospheric absorption along the sound propagation path that occurs between temperature and relative humidity under noise certification test conditions and temperature and relative humidity under reference conditions 59°F (15ºC) and 70 percent relative humidity (see G36.201 of part 36 for additional atmospheric absorption correction information).

501(e)(2) Noise path adjustment
GM §G36.201(d) [ETM GM A6 5.2.1 b)]

(1) *Noise path length*

The airplane test limitations are that the height over the microphone must be within ±20 percent of the reference height and that the lateral position must be within ±10° of the vertical. The noise path length correction adjusts the measured noise levels for the difference in noise path length between actual noise test conditions and reference conditions (see G36.201 of part 36 for additional path length correction information).

501(e)(3) Noise source adjustment
GM §G36.201(d)(3) [ETM GM A6 5.2.1 c)]

(1) *Helical tip Mach number*

The noise generated by a propeller-driven airplane depends on the rotational speed of the tip of the propeller, more specifically the helical tip Mach number. Data corrections are based on the relationship between the helical tip Mach numbers determined for test and reference conditions (see 502(d)).

Note.— The reference helical tip Mach number, M_R, *is the one corresponding to the reference conditions above the measurement point.*

501(e)(4) Noise source adjustment
GM §G36.201(d)(4) [ETM GM A6 5.2.1 d)]

(1) *Engine power*

Corrections are required to account for non-reference engine power settings that are used during noise certification tests. The procedures for determining the engine power to be used in the calculations depend on the design characteristics of the engine-propeller combination. In most cases, this power is not published and does not have to be determined for airworthiness purposes. It is therefore necessary to determine the power for noise certification purposes (see 502(d)).

501(f) Reporting of Data to the FAA and Validity of Results
[ETM 5.1.6]

501(f)(1) Reporting of meteorological data
GM §G36.109(d) [ETM GM A6 6.1.3]

(1) *Interpretation of "each test"*

For clarification, this refers to each test series (i.e., test) and each test flyover (i.e., run). The meteorological measurements should be made at the time of each test run, since each noise measurement will be corrected by use of the meteorological data.

(2) *Wind measurement*

The provisions of G36.101(b)(4) of part 36 set the limits on testing, based on a 30-second average wind speed, not to exceed 10 kt (5.1 m/s), with a 5 kt (2.6 m/s) crosswind limitation. There are no additional limitations based on the surface wind.

501(f)(2) Reporting of airplane information
AMC §G36.109(g)(5) [ETM AMC A6 6.1.5]

(1) *Equipment calibrations*

All equipment utilized to determine the required parameters should be calibrated, and the calibrations are to be applied before being reported to the FAA in the test report and before being used to make reference airplane corrections. The temperature at the airplane height should be acquired for tip Mach number correction.

(2) *Mechanical tachometers*

Separate validation of the in-flight reading should be made if a mechanical tachometer is used because mechanical tachometers are subject to potential indicating errors as a result of the cable drive system.

501(f)(3) Reference noise levels/confidence intervals
AMC §G36.203 [ETM AMC A6 6.2.1]

(1) *Average noise level calculations*

Calculation of average noise and associated confidence intervals should be accomplished as described in 305.

When the 90 percent confidence limit calculated using data from six or more test flights is within ±1.5 dB(A), then the average corrected noise level $(L_{Amax})_{avg}$ resulting from the validated data can be used to determine conformity with the maximum noise levels specified in G36.301 of part 36.

501(f)(4) Confidence limit compliance GM §G36.203(b) [ETM GM A6 6.2.2]

(1) *Confidence limit exceedance*

If the 90 percent confidence limit does not satisfy the ±1.5 dB(A) standard, additional test data points should be obtained, increasing the number of events until the confidence limit is reduced to ±1.5 dB(A). The variability of data obtained under controlled conditions should be substantially less than ±1.5 dB(A). If the 90 percent confidence interval is near or above the permitted limit, the approved test procedures and/or correction procedures should be carefully reviewed.

502 EQUIVALENT PROCEDURES INFORMATION [ETM 5.2]

The procedures described in this chapter have been used as equivalent in stringency for propeller-driven airplanes with maximum certificated takeoff weight not exceeding 19,000 lb (8618 kg), as provided in Appendices F and G of part 36.

502(a) Installation of Add-on Silencers (Mufflers) [ETM 5.2.1]

Installation of an add-on silencer (muffler) may be an effective method for reducing the noise levels of a propeller-driven airplane powered by a reciprocating engine. However, an add-on silencer (muffler) may also degrade the performance of the airplane and therefore adversely affect the aircraft's noise characteristics.

The airplane performance characteristics must be re-evaluated after the installation of the add-on silencer (muffler). The type design change represented by the silencer (muffler) installation can be accepted as an NAC for compliance with Appendix F or G of part 36 if the following conditions are verified to the satisfaction of the FAA:

a) for aircraft certificated according to Appendix F of part 36, the airplane's takeoff and climb performance, as determined by the performance correction defined in F36.201 of part 36, is not adversely affected; or

b) for aircraft certificated according to Appendix G of part 36, the airplane's takeoff and climb performance, as determined by the reference height calculated in accordance with G36.111 of part 36, is not adversely affected.

In either case, the add-on silencer (muffler) has no significant effect on the engine performance (i.e., power and rotational speed).

502(b) Guidance on Use of a Windscreen [ETM 5.2.2]

For noise certification tests conducted according to Appendix G of part 36, the microphone must be installed in accordance with G36.107(a) of part 36, which describes how the microphone is mounted in an inverted position so that the microphone diaphragm is 0.25 in (7 mm) above and parallel to a circular metal plate. With this configuration, the FAA has approved the use of a windscreen in order to minimize wind- and turbulence-induced pseudo-sound levels and to protect the microphone during the test.

A windscreen prepared and used in the following manner will cause no significant effect on the test result. The windscreen must be made from a commercially available spherical foam windscreen cut into a hemispherical shape in order to accommodate the microphone over the plate. In preparing the hemispherical windscreen, the following points must be ensured:

a) the cut surface of the windscreen must not be damaged by the cutting process; and

b) with the microphone properly inserted into the hemispherical windscreen and mounted over the ground plate, the microphone diaphragm must be at the specified distance from the plate's surface.

502(c) Takeoff Test and Reference Procedures [ETM 5.2.3]

Note.— In planning a test program for noise certification according to the provisions of Appendix G of part 36, it is helpful to note the differences between test-day flight procedures and the standardized takeoff reference profile.

The takeoff reference profile is used to compute the altitude and speed of the aircraft passing over the microphone on a standard day. The requirements for this profile are contained in G36.111(c) of part 36. They require that the first segment be computed by using airworthiness approved data, assuming takeoff power is used from the brake-release point to 50 ft (15 m) above the runway. The second segment is assumed to begin precisely at the end of the first segment with the airplane in a climb configuration, with gear up and climb flaps, and operating at the certificated speed for best rate of climb (V_y) (see Figure 48).

A worked example of the calculation of reference flyover height and reference conditions for correction of source noise for airplanes certificated according to the Standards of Appendix G of part 36 is presented in 503(a).

The requirements for airplane test procedures are contained in G36.111(a) of part 36. It basically refers only to test tolerances and approval of test plans by the FAA.

Figure 48 illustrates the difference between the test and reference procedures. Note that the actual flight test path need not include a complete takeoff from a standing condition. Rather, it assumes that a flight path intercept technique is used. As with the turbojet and helicopter standards, the airplane should be flown to intersect the second phase (i.e., segment) climb path at the right speed and angle of climb when going over the microphone within 20 percent of the reference height.

The takeoff reference procedure defined in Appendix G of part 36 requires that the second phase of the procedure be flown at the best rate of climb speed (V_y). The airplane testing procedures described in Appendix G of part 36 require that the flight test be conducted at V_y. The reference height to which the measured noise levels are to be corrected is calculated from the climb rate corresponding to V_y. Recent changes to the airworthiness requirements have eliminated the need to determine V_y for small propeller-driven airplanes. In this case applicants will nevertheless have to determine V_y for the purpose of showing compliance with Appendix G of part 36. If the minimum airworthiness approved climb speed is greater than V_y then this speed must be used and noted in the AFM.

Applicants may alternatively show compliance with Appendix G of part 36 at the climb speed for which the AFM performance information is calculated provided they demonstrate, to the satisfaction of the FAA, that the resulting noise level is not less than would have been obtained using V_y.

502(d) Source Noise Adjustments [ETM 5.2.4]

Source noise adjustment data for propeller-driven light airplanes may be obtained by flying the test airplane with a range of propeller speeds for fixed pitch propellers and a range of torque or manifold air pressure (MAP) values for variable pitch propellers.

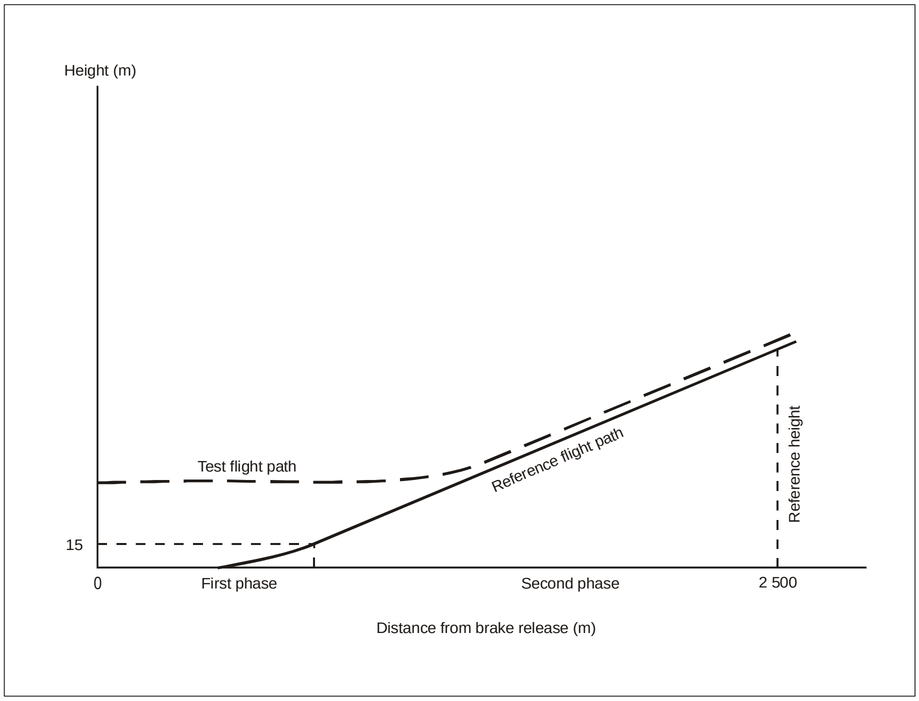


Figure 48. Typical test and reference profiles

502(d)(1) Fixed pitch propellers [ETM 5.2.4.1]

For airplanes fitted with fixed pitch propellers demonstrating compliance with Appendix F of part 36, source noise sensitivity curves are developed from data taken by measuring the noise level for the airplane flying at 1000 ft (300 m) (see F36.111(a) of part 36) at the propeller speed for maximum continuous power (N_{MCP}).

Airplanes demonstrating compliance with Appendix G of part 36 should be flown according to G36.111(c) of part 36. In this way, the aircraft overflies the microphone at the reference height (H_{REF}) defined in G36.111(c) of part 36, the best rate of climb speed (V_y) and at the propeller speed (N_{MAX}) corresponding to that defined in G36.111(c)(iv) of the "second phase" of G36.111(c) of part 36.

For both Appendix F and Appendix G airplanes, noise measurements are repeated at two lower propeller speeds, typically 200 rpm and 400 rpm lower than N_{MCP} or N_{MAX}. For Appendix G airplanes, these should be flown at speed V_y. The maximum A-weighted noise peak noise level (L_{Amax}) is plotted against the propeller helical tip Mach number (M_H) in order to obtain the curve from which the source noise correction may be derived.

For fixed pitch propellers, it is generally not possible to separate the two significant noise generating parameters, helical tip Mach number and the power absorbed by the propeller, by using flight tests. A sensitivity curve of Mach number versus noise level derived from flight tests of a fixed pitch propeller, either level flyovers or fixed-speed climbs, will therefore include, within the curve, the effects not only of the Mach number but also the power. Under these circumstances, it is not appropriate to apply a separate power correction.

502(d)(2) Variable pitch propellers [ETM 5.2.4.2]

For variable pitch propellers, the source noise sensitivity curves are developed from data taken with the aircraft flying over a range of propeller speeds, typically three, at a fixed torque or MAP in a manner similar to that described in 502(d)(1) where N_{MCP} or N_{MAX} would in this case be the maximum propeller speed at the maximum permitted torque or MAP. This is repeated for two lower torque or MAP values in order to establish a carpet plot of maximum A-weighted noise levels against propeller speed and torque, MAP or SHP.

A plot of maximum A-weighted noise level (L_{Amax}), helical tip Mach number (M_H) and torque or MAP is developed. This plot is then used to derive the source noise adjustment (L_{Amax}) which is the difference between reference and test conditions at the noise certification power.

Generally the test and reference engine SHP can be derived from the engine manufacturer's performance curves. However, where such curves are not available, a correction should be applied to the manufacturer's published engine SHP, which is normally presented for a range of engine speeds under ISA and sea level conditions, in order to establish the engine power level under the test conditions of ambient temperature and air density. The correction is as follows:

a) for normally aspirated engines:

$P_T = P_R|(T_R/T_T)^{\frac{1}{2}}|[(\sigma - 0.117)/0.883]_,$;and

b) for turbo-charged engines:

$P_T = P_R|(T_R/T_T)^{\frac{1}{2}},$

where:

— P_T and P_R are the test and reference engine powers;

— T_T and T_R are the test and reference ambient temperatures; and

— $\sigma$is the air density ratio.

Note.— In this context reference denotes the reference conditions for which the engine SHP is known.

502(e) No-Acoustical Change Guidance for Derived Versions of Propeller-Driven Airplanes Certificated According to Appendix G [ETM 5.2.5]

After the certification in their basic configuration, small propeller-driven airplanes are often modified, either by a TC change of the TC holder or by an STC from a supplier. These changes can be of a different nature such as weight increase/decrease, engine change, power change, propeller change, installation of vortex generators, fitting of winglets or external mounted equipment (cargo boxes, floats, etc.). With regard to noise and depending on their nature, some changes might have to demonstrate compliance with the applicable requirements by a new flight test, others by re-evaluation of the original noise flights or by demonstrating a no acoustical change.

The propeller and the engine are the main noise sources of small propeller-driven airplanes. Parameters like the diameter, the number of blades, the rpm, the pitch, the blade tip shape or the geometry could have an impact on the propeller noise signature. As for the engine, noise signature could change by modifying the rotor assembly or the exhaust.

Several sections refer to the determination of a new reference height due to a change in performance data, here D_{50}, V_y and RC. New performance data are accepted for the recalculation only if they are established by a method approved by the FAA.

The following sections are intended to provide guidance for applicants concerning an NAC demonstration.

502(e)(1) No-acoustical change guidance for airplanes fitted with fixed pitch propellers [ETM 5.2.5.1]

(Reserved)

Note.— This guidance is limited to variable pitch propellers only. According to G36.111(c)(2)(iv) of part 36, takeoff rpm must be maintained throughout the noise test runs. During climb at the best rate of climb speed, the fixed pitch propeller can generally not reach its maximum operating rpm value. Therefore the reference propeller speed is defined to be the average propeller rpm calculated from all valid runs. Changing the performance (e.g., due to an engine change or a change in weight) might change the average rpm adversely. Currently the amount of change in the propeller rpm for a fixed pitch propeller cannot be estimated analytically.

502(e)(2) No-acoustical change guidance for airplanes fitted with variable pitch propellers [ETM 5.2.5.2]

502(e)(2)(A) Engine change without power change [ETM 5.2.5.2.1]

The engine is one of the main noise sources of the airplane. Changes to the engine can take many forms. They vary from small changes within one engine family, normally addressed by different characters within the engine designation, to a complete re-engine. In the latter case the compliance demonstration can in general be achieved only by new noise flight tests. In the former case it is often obvious that the change has no acoustical impact, and a simple statement should suffice to demonstrate that the change is not acoustically significant.

502(e)(2)(B) Power increase without changing the propeller rpm [ETM 5.2.5.2.2]

Increasing the power output of an engine without changing the takeoff weight will increase the engine noise level at source but also improve the takeoff performance. A method subject to the approval by the FAA can be applied to evaluate the increase in engine noise source. This increase in engine noise source may be offset by the higher reference height. Takeoff distance is shortened, the climb rate is increased and therefore the flyover height over the microphone is increased. If it can be shown that this increase in reference flyover height offsets the increase in engine source noise, the change in engine power may be considered as an NAC.

An NAC is acceptable if it can be demonstrated that a minimum of six valid flights are within the “new” height window.

The effect of angle-of-attack changes may be included in the analysis by a method approved by the FAA. The method must be robust enough to account for the effects of performance and angle-of-attack changes on noise levels. If the analysis method shows that the noise level does not increase then the noise level of the unmodified airplane can be applied. Otherwise new testing should be required.

Note.— Section G36.111(c)(2)(iv) of part 36 defines that the microphone has to be passed at maximum takeoff power. If source noise sensitivity curves are established in accordance with the procedure laid down in 502(d) of this chapter the noise level can be adjusted up to the highest power covered by the sensitivity curve. In such a case the power correction determined by the sensitivity curve should be used instead of the general adjustment $\Delta_3 = K_3 \log (P_R/P_T)$.

502(e)(2)(C) Change in weight [ETM 5.2.5.2.3]

According to G36.111(a) of part 36, the flight tests must be initiated at the maximum takeoff weight. Only increases in takeoff weight up to the maximum actually flown during the original flight tests can be accepted without new flight tests. If it can be demonstrated that a further weight increase and the corresponding loss of performance do not adversely affect the noise level by more than 0.10 dB(A), the certificated noise level may be assigned to this weight without additional flight tests.

A change in the weight of the aircraft will lead to different performance characteristics. A new reference height with the new performance parameters has to be determined to demonstrate the influence on the noise level. Possible impact on the propeller speed should be taken into account.

Similar to the previous section, the effect of angle-of-attack changes may be included in the analysis by a method approved by the FAA.

502(e)(2)(D) Drag change [ETM 5.2.5.2.4]

While a change in drag generally has no direct impact on the noise at source, it may have an indirect effect on noise level through a change in performance.

A drag change will in general be introduced by modifications such as the fitting of cargo pods or external fuel tanks, larger tires, floats, etc. In most cases, the change in aerodynamic noise can be shown to be negligible for small propeller-driven airplanes. However, there may be cases where the aerodynamic noise generated by the modification has to be addressed. The drag change might change the performance characteristics of the aircraft D_{50}, V_y and/or RC leading to a change in reference flyover height. The performance characteristics defined in the AFM are approved by the performance experts of the FAA. In some cases the performance experts agree to apply the former performance parameters to the modified aircraft if the applicant can demonstrate that the performance is not worse than the one for the basic aircraft. Three different situations have to be considered:

a) the performance characteristics are better than those of the parent aircraft;

b) the performance characteristics are identical to those of the parent aircraft; and

c) the performance characteristics are worse than those of the parent aircraft.

With regard to noise these three situations should be dealt with as follows:

a) in the case of situation a), independent of whether the applicant decides to maintain the old performance data or to document the better performance in the AFM, an NAC can be granted and the noise level for the parent version can be applied to the modified aircraft;

b) in the case of situation b), the noise level for the parent version can be applied to the modified aircraft without further investigation; and

c) in the case of situation c), in general a new flight test is required.

502(e)(2)(E) Different blade count propeller [ETM 5.2.5.2.5]

The effect of changing the number of the propeller blades on the noise level is difficult to determine by analytical procedures. Typically the applicant is obliged to perform a new flight test. Propeller noise prediction routines are highly sophisticated requiring extensive data sets which can in general be provided only by the propeller manufacturer. The use of such propeller noise prediction routines has to be acceptable to the FAA to demonstrate an NAC.

502(e)(2)(F) Different blade tip shape [ETM 5.2.5.2.6]

In general rounded tips are quieter than squared ones. The change from squared to rounded blade tips can be accepted as an NAC if the rpm and diameter remain the same.

503 TECHNICAL PROCEDURES INFORMATION [ETM 5.3]

503(a) Worked Example of Calculation of Reference Flyover Height and Reference Conditions for Source Noise Adjustments (Appendix G) [ETM 5.3.1]

503(a)(1) Introduction [ETM 5.3.1.1]

The reference flyover height for an airplane certificated to Appendix G of part 36 is defined at a point which is 8202 ft (2500 m) from the start-of-roll beneath a reference flight path determined according to the takeoff reference procedure described in G36.111(c) of part 36. An expression for the reference flyover height in terms of commonly approved performance data and an example of how such an expression may be worked are presented in this section. The relationship between the reference height and the conditions to which source noise corrections are to be made is also explained.

503(a)(2) Takeoff reference procedure [ETM 5.3.1.2]

The takeoff reference procedure for an airplane certificated to Appendix G is defined in G36.111(c) of part 36 under sea level, ISA conditions, at maximum takeoff weight for which noise certification is requested. The procedure is described in two phases:

a) the first phase commences at “brakes release” and continues to the point where the aircraft reaches a height of 50 ft (15 m) above the runway; the point of interception of a vertical line passing through this point with a horizontal plane 50 ft (15 m) below is often referred to as “reference zero”; and

b) the second phase commences at the end of the first phase and assumes the airplane is in normal climb configuration with landing gear up and flap setting normal for “second segment” climb.

Note.— The reference “acoustic” flight path ignores the “first segment” part of the flight path, during which the aircraft accelerates to normal climb speed and, where appropriate, landing gear and flaps are retracted.

503(a)(3) Expression for reference height [ETM 5.3.1.3]

The reference flyover height is defined according to the takeoff reference flight path at a point 8202 ft (2500 m) from the start-of-roll for an airplane taking off from a paved, level runway under the following conditions:

a) sea level atmospheric pressure of 1013.25 hPa;

b) ambient air temperature of 59°C (15°C) (i.e., ISA);

c) relative humidity of 70 percent; and

d) zero wind.

This height can be defined in terms of the approved takeoff and climb performance figures for the conditions described above as follows:

$$H_R = (8203 - D_{50}) * \tan[\sin^{-1}(\frac{RC}{101.4V_y})] + 50,$$

where:

- D_{50} is the sea level, ISA takeoff distance in feet to a height of 50 ft at the maximum certificated takeoff weight and maximum certificated takeoff power;
- RC is the sea level, ISA best rate of climb (ft/s) at the maximum certificated takeoff weight and the maximum power and engine speed that can be continuously delivered by the engine(s) during this second phase; and
- V_y is the speed (kt) for the best rate of climb.

The performance data in many flight manuals are often presented in terms of SI units. Typically the takeoff distance, expressed in meters, is given to a height of 15 m and the rate of climb and airspeed are expressed in meters per second (m/s). In such instances, the expression for reference flyover height, H_R in meters becomes:

$$H_R = (2500 - D_{15}) * \tan[\sin^{-1}(\frac{RC}{V_y})] + 15,$$

where:

- D_{15} is the sea level, ISA takeoff distance in meters to a height of 15 m at the maximum certificated takeoff weight and maximum certificated takeoff power;
- RC is the sea level, ISA best rate of climb (m/s) at the maximum certificated takeoff weight and the maximum power and engine speed that can be continuously delivered by the engine(s) during this second phase; and
- V_y is the speed (m/s) for the best rate of climb.

The performance figures can normally be found in the performance section of an AFM or pilot's handbook. Note that for certain categories of aircraft, a safety factor may be applied to the takeoff and climb performance parameters presented in the flight manual. In the case of multi-engine aircraft, it may be assumed that one engine is inoperative during part of Phase 1 and during Phase 2. For the purpose of calculating the "acoustic" reference flight path, the takeoff distance and rate of climb should be determined for all engines operating by using gross (i.e., without the factor applied) data.

In addition, the best rate of climb speed, V_y, used in the equation for H is defined as the true airspeed (TAS). However in the flight manual, speed is normally presented in terms of IAS. This should be corrected to the calibrated airspeed (CAS) by applying the relevant position error and instrument corrections for the airspeed indicator. These corrections can also be found in the flight manual. For an ISA day at sea level, the TAS is then equal to the CAS.

503(a)(4) Reference conditions for source noise adjustments [ETM 5.3.1.4]

Sections G36.201(c) and G36.201(d) of part 36 describe how corrections for differences in source noise between test and reference conditions must be made.

The reference helical tip Mach number and engine power are defined for the reference conditions above the measurement point (i.e., the reference atmospheric conditions at the reference height, H_R)

The reference temperature at the reference height (H_R) is calculated under ISA conditions (i.e., for an ambient sea level temperature of 59°F (15°C) and assuming a standard temperature lapse rate of 3.566°F (1.98°C) per 1000 ft).

The reference temperature, T_R°C, can be defined as:

$$T_R = 15 - 1.98(H_R/1000)$$

The reference atmospheric pressure, P_R hPa, is similarly calculated at the reference height (H_R) for a standard sea level pressure of 1013.25 hPa, assuming a standard pressure lapse rate such that:

$$P_R = 1013.25[1 - (6.7862 * 10^{-6} H_R)]^{5325}.$$

503(a)(5) Worked example for the calculation of reference flyover height and the associated reference atmospheric conditions [ETM 5.3.1.5]

503(a)(5)(A) For reference flyover height calculation [ETM 5.3.5.1]

In Table 15 extracts are presented from the performance section of a flight manual for a typical light, single-engine propeller-driven airplane.

The introduction contains a statement to the effect that the information is derived from "measured flight test data" and includes "no additional factors".

The sea level, ISA takeoff distance in feet to a height of 50 ft at the reference conditions cited in Appendix G of part 36 can be read from the table of takeoff distances presented for a paved runway at the maximum certificated takeoff weight of 1920 lb. Thus D_{50} is 1370 ft.

The rate of climb (RC) at the reference conditions can similarly be read from the RC table. Thus RC is 1000 ft/min.

The climb speed associated with the RC figures is given as 80 knots indicated airspeed (KIAS). The corresponding true airspeed at the reference conditions cited in Appendix G of part 36 is equal to the IAS, corrected according to the airspeed calibration table at the appropriate flap setting of 0°. Thus V_y is 81 knots true airspeed (KTAS).

Entering these parameters into the equation for reference height expressed in feet (H_R ft) given in 503(a)(3) gives:

$$H_R = (8203 + 1370) * \tan|sin^{-1}(1000/101.4 * 81)| + 50$$

and so H_R = 888 ft.

Table 15. Example of flight manual performance section

SECTION 5. PERFORMANCE

1. INTRODUCTION

The data processed in this section enable flight planning to be carried out for flights between airfields with various altitudes, temperatures and field lengths. The information is derived from measured flight test data using CAA-approved methods and factors to cover all the conditions shown. The data assume average pilot skill and an aircraft engine and propeller in good condition.

No additional factors are included, and it is the pilot's responsibility to apply safety factors which must not be less than those …

6. AIRSPEED CALIBRATION

	0° flap	KIAS KCAS		60 61	70 71	80 81	90 91	100 101	110 111	120 121	130 131	180 181	
	15° flap	KIAS KCAS	50 51	60 61	70 71	80 81	85 86	—	—	—	—	—	
	35° flap	KIAS KCAS	50 50	60 59	70 69	80 79	85 84	—	—	—	—	—	

TAKEOFF DISTANCE PAVED RUNWAY (1) — CONDITIONS

Flaps — 15°
Weight — 1920 lb
Power — Full throttle

Rotation speed — 53 KIAS
Speed at 50 ft — 65 KIAS

Airfield height (ft)	ISA – 20°C		ISA – 10°C		ISA		ISA + 10°C		ISA + 20°C		ISA + 30°C	
	Ground roll	Total to 50 ft	Ground roll	Total to 50 ft	Ground roll	Total to 50 ft	Ground roll	Total to 50 ft	Ground roll	Total to 50 ft	Ground roll	Total to 50 ft
Sea level	530	1230	565	1290	600	1370	700	1580	750	1715	840	1900
5000	1045	2835	1065	2435	1090	2580	1170	2670	1295	2840	1290	2905
10,000	10,465	3335	1490	3390	1510	3435	1575	3560	1610	3695	1670	3790

RATE OF CLIMB — CONDITIONS

Flaps up
Weight — 1920 lb

Full throttle
Speed — 80 KIAS

Pressure altitude (ft)	Rate of climb (ft/min)			
	ISA – 20°C	ISA	ISA + 10°C	ISA + 20°C
Sea level	1035	1000	915	825
1000	980	945	860	770
2000	925	890	805	720
3000	870	830	750	665
4000	815	775	695	610
5000	765	720	640	560
6000	700	665	585	505
7000	635	605	560	450
8000	570	550	475	395
9000	495	480	410	335
10,000	415	405	335	270

KIAS = knots indicated airspeed
KCAS = knots calibrated airspeed

503(a)(5)(B) For calculation of reference atmospheric conditions [ETM 5.3.1.5.2]

a) The reference temperature at the reference height, H_R, is given by the equation for T_R in 503(a)(4):

$$T_R = 15 - 1.98(\frac{888}{1000})$$

and so T_R = 13.24°C.

b) The reference pressure at the reference height is given by the equation for P_R in 503(a)(4):

$$P_R = 1013.25[1 - (6.7862 * 10^{-6} * 888)]^{5325}$$

and so P_R = 981 hPa.

Chapter 6

GUIDELINES FOR HELICOPTERS NOT EXCEEDING 7000 LB EVALUATED UNDER APPENDIX J OF 14 CFR PART 36

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601 EXPLANATORY INFORMATION [ETM 6.1]

601(a) General [ETM 6.1.1]

Helicopters not exceeding 7000 lb (3175 kg) can be certificated under either Appendix H or J of the part 36. Helicopters exceeding 7000 lb (3175 kg) can be certificated only under Appendix H of part 36. Guidelines for helicopters certificated using Appendix H of part 36 are provided in Chapter 4 of this AC.

Unlike Appendix H of part 36 which requires takeoff, flyover and approach tests with noise measurements being made at three measuring points, compliance with Appendix J of part 36 is based on flyover tests only, with the noise data being obtained only at one microphone located under the flight track. Flight path adjustments are simplified and the final results determined in terms of SEL instead of EPNL.

Also since the Appendix J procedure is based on flyover tests only, there are no trade-off provisions between flight conditions as allowed in Appendix H of part 36. However, if a helicopter not exceeding 3175 kg (7000 lb) fails to comply with the noise limit of Appendix J of part 36, certification of the helicopter under the Appendix H procedures is allowed.

601(b) Noise Measurements
[ETM 6.1.2]

See 301 of this AC for technical procedures generally applicable for noise certification tests of all aircraft types including those evaluated under the provisions of Appendix J of part 36. Procedures specific to Appendix J are presented in the following section.

601(c) Noise Certification Test and Measurement Conditions
[ETM 6.1.3]

601(c)(1) Atmospheric test conditions
AMC §J36.101(c)(2), (4), and (6) [ETM AMC No. 2 A4 2.2.2]

(1) *Temperature/relative humidity test window*

Tests are permitted over the range of temperature and relative humidity specified in J36.101(c)(2) of part 36 and shown in Figure 49.

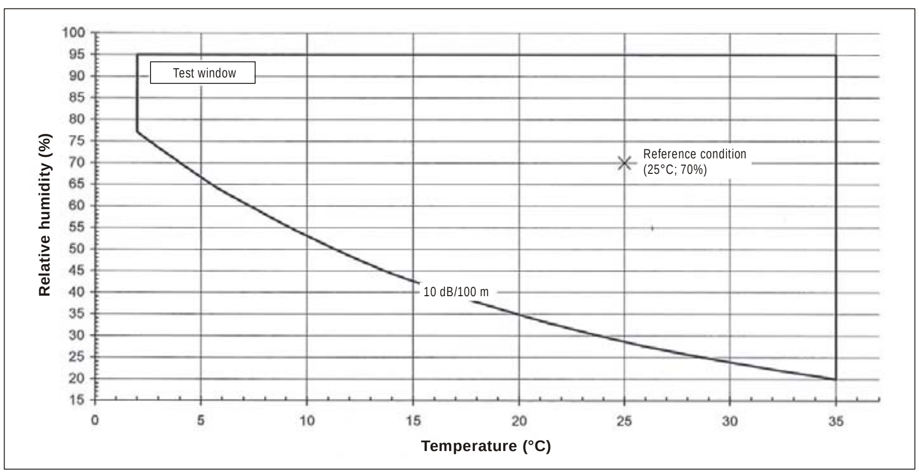

Figure 49. Appendix J temperature/relative humidity test window

(2) *Testing outside the temperature and relative humidity window*

If the limits of J36.101(c)(2) of part 36 cannot be met, but the tests can be conducted within the temperature/relative humidity limits specified in H36.101(c) of part 36, then the applicant may alternatively elect to use the equivalent procedure defined in 602(b)(2).

(3) *Meteorological measurements*

Measurements of the meteorological conditions are required to be made using equipment approved by the FAA. The temperature, relative humidity and wind measurements are required to be made in the vicinity of the noise measurement point at a height between 4 ft (1.2 m) and 33 ft (10 m). This allows the use of hand-held equipment but does not preclude the use of more complex measuring systems. Temperature and relative humidity may be measured by a hand-held psychrometer. This device measures the wet and dry bulb temperatures from which the relative humidity is obtained. Similarly wind measurements may be made using a hand-held device if its specifications comply with the provisions of J36.101(c) of part 36.

(4) *Temperature and relative humidity*

Measurements of temperature and relative humidity should be made at intervals of not more than one hour to ensure that the test conditions remain in the required limits. It is advisable to make measurements for each flight in case it is required at a later time to verify the test conditions.

Section 6.2.2.2 provides an equivalent procedure to the specifications for temperature and humidity measurement given in J36.101(c)(2) of part 36.

601(c)(2) Anomalous meteorological conditions
AMC §J36.101(c)(5) [ETM AMC No. 3 A4 2.2.2]

(1) *OAT differential*

The presence of anomalous meteorological conditions can be reasonably determined by monitoring the outside air temperature (OAT) using the helicopter on-board temperature gauge. Anomalous conditions that could impact the measured levels can be expected to exist when the OAT at 492 ft (150 m) is higher than the temperature measured at a height between 4 ft (1.2 m) and 33 ft (10 m) above the ground by more than 2°C (3.6°F). This check should be made in level flight at a height of 492 ft (150 m) within 30 minutes of each noise measurement.

601(c)(3) Wind speed
AMC §J36.101(c)(3) and (4) [ETM AMC No. 4 A4 2.2.2]

(1) *Wind speed limitations*

Wind speed measurement points and limits are given in J36.101(c) of part 36. Wind speed measurement system specifications are given in J36.101(c)(3) of part 36. Measurements should be taken frequently and, if near the limit, at least prior to each flight to confirm that the requirements are met. Particular attention should be given to the crosswind component since this can often be the limiting factor during testing. If feasible, the reference flight path direction can be changed to reduce the impact of this requirement. These wind speeds should be recorded and included in the report of the noise certification program. Wind limits are intended to minimize the adverse effects of wind on helicopter noise generation and sound propagation.

601(c)(4) Anomalous wind conditions
AMC §J36.101(c)(5) [ETM AMC No. 5 A4 2.2.2]

(1) *Identification of anomalous winds*

Anomalous winds are difficult to quantify but, providing the helicopter can be easily flown within the flight path and airspeed limits defined in part 36, there is no excessive side slip or yawing of the helicopter and no indication of rough air, then the flights can be considered acceptable. In the case where wind effects are anticipated to be a likely problem, an agreement between the applicant and the FAA or designated observer should be reached prior to testing to determine the acceptability criteria. Normally such issues arise only with gusty wind conditions near the 10 kt (5.1 m/s) wind speed limit, high crosswind conditions or the presence of strong thermals.

601(c)(5) Flight test conditions
GM §J36.105(b) [ETM GM A4 2.4]

(1) *Flyover height*

A reference flyover height of 492 ± 50 ft (150 ± 15 m) above the ground at the noise measurement point is specified as indicated in Figure 50. The measured noise data must be adjusted for the effects of spherical spreading between the helicopter test flight path and the reference flight path, and between reference airspeed and adjusted reference airspeed as specified in J36.205(b) of part 36.

(2) *Flight path measurement*

The helicopter flight path is also required to be within ±10° of the vertical above the noise measurement point (see Figure 50). This requirement, along with the height test window, means that the helicopter has to fly through a height/off-track test window located directly above the noise measurement point. There is no requirement to determine the magnitude of the off-track distance, but it is necessary to show that the helicopter is within the required height and angular limits. The applicant may therefore find merit in recording the off-track values for subsequent confirmation of compliance.

(3) *Flight track: markings*

The helicopter has to fly on a straight path and be within ±10° of the vertical overhead the noise measurement point as shown in Figure 50. In order for this to be successfully accomplished the applicant should consider marking on the ground, in a manner that can be readily seen from the helicopter, the intended track and associated lateral limits. Brightly colored or day-glow markers or lights to mark the flight track are advisable. These markings will be very important in the case of a small helicopter where the on-board equipment may be the minimum required to comply with the airworthiness certification.

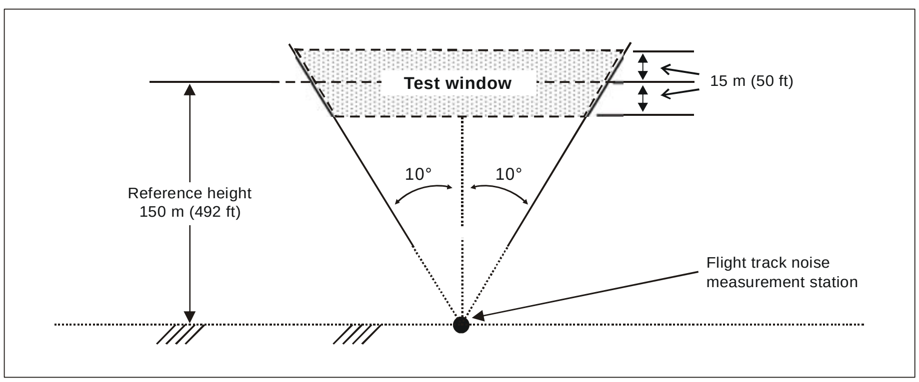

Figure 50. Flight boundaries for flyover test condition

(4) *Number of test runs*

A minimum of six flyovers, with an equal number of flights with headwind and tailwind components over the noise measurement point, are required. These test runs should be conducted in pairs, since the aim is to minimize the influence of wind speed and direction on the measured SEL. The tests in each pair should be conducted immediately one after another in order that the meteorological conditions are as similar as possible for the two test runs. It should be possible to determine immediately after each test run if it meets the necessary requirements and thus relatively easy to establish when three pairs of valid test runs have been made. The applicant would also be advised to conduct one or two additional pairs of test runs to ensure that after all the test parameters have been examined a minimum of three valid pairs of test run results are available. If additional valid pair(s) of test runs are obtained these will be required to be included in the analysis to determine the arithmetic average SEL.

(5) *Landing gear position*

If the helicopter has a retractable landing gear, the landing gear position for noise tests needs to be that used for the cruise configuration.

601(c)(6) Flight test conditions
AMC §J36.105(c), (d) and (e) [ETM AMC A4 2.4]

(1) *Test period*

The test conditions have to be maintained, or held constant, over an adequate distance (time interval) to encompass the 10 dB-down period. The maximum A-weighted sound pressure level, dB(A) or L_{Amax}, will normally occur when the helicopter is at, or just prior to, the position directly above the noise measuring point. Pre-test flights should be conducted to determine the 10 dB-down period and ensure this period is adequately captured by the noise measurement system. It is advisable that the helicopter flight test conditions are stabilized well in advance of the initial 10 dB-down point and maintained until well after the second 10 dB-down point to ensure a valid noise measurement is obtained.

(2) *Maximum normal operating rotor speed*

In order that the noise levels are representative of normal operation, the rotor speed used must be the maximum normal value associated with flyover at the reference conditions. Also, since on most helicopters small changes in rotor speed occur during a stabilized flight, a ±1 percent rpm variation is allowed.

(3) *Test weight*

Fuel, together with the weight of the pilot, flight observers and ballast, are normally used to set the weight of the test helicopter within the required test range of +5 percent/–10 percent of the maximum takeoff weight. Fuel burn (i.e., decrease in fuel weight) should be documented to determine the actual test value. Care must be taken regarding the location of ballast to ensure it does not have any adverse impact on the applicable center of gravity limits.

Unlike in Appendix H, there is no requirement to conduct any test run above the maximum takeoff weight. Note that variation of the flyover noise levels within the allowable weight limits is small and for this reason no adjustments for difference in test weights are required. The helicopter weight, or the quantity of fuel from which the weight of the helicopter can be calculated, should be recorded for each flight.

Note.— Conducting the tests as near as possible to the upper weight limit of +5 percent can also be useful in supporting noise certification of future increases in maximum gross weight of the helicopter by minimizing the likelihood of having to conduct new tests.

(4) *Background noise*

Some initial pre-test flyovers should be performed to confirm helicopter noise levels exceed background noise by 15 dB(A) as specified in J36.109(f)(3) of part 36. The FAA has generally accepted that the requirement has been met if the maximum helicopter noise level exceeds background noise levels by 15 dB(A). If this requirement cannot be met when the flyover test is conducted at 492 ft (150 m), a lower flyover height approved by the FAA may be used. This normally will be required only in the case of lightweight/small helicopters or those that generate extremely low noise levels.

Variations in measured noise levels of up to ±1.5 dB(A) from flight to flight may typically occur. The applicant should therefore ensure that the difference between background noise and helicopter noise levels is adequate for the quietest flyover noise measurements anticipated. Such information may also be useful for adjusting the sensitivity of the noise measurement system. The level of background noise may be influenced by the location of the test site.

601(c)(7) Flight test conditions
GM §J36.105(c)(1) [ETM GM A4 2.4.2]

(1) *Adjusted reference airspeed*

The flyover adjusted reference airspeed (V_{ar}) is defined as the value at the test temperature that gives the same advancing main rotor blade tip Mach number (M_{AT}) as associated with the reference temperature of 25°C (77ºF). On most helicopters the controlling noise source is dependent on the advancing blade tip Mach number. The advancing blade tip Mach number is dependent on the temperature and thus the sound level varies with temperature. To avoid the need to make a source noise correction, as would be required for the flyover tests under Appendix H of part 36 unless an equivalent procedure is used, tests to meet the requirements of Appendix J of part 36 are required to be conducted at an adjusted reference airspeed, V_{ar}, which gives the same advancing blade tip Mach number at the time of the test as would occur if the test were conducted under the reference conditions. The speed of sound increases with absolute temperature so that tests conducted in temperatures below the reference value of 25°C (77ºF) at the reference flyover height will result in a higher advancing blade tip Mach number, and a reduction in test airspeed will be required to obtain the reference advancing blade tip Mach number. Similarly when the air temperature at flyover reference height is higher than 25°C (77ºF), the flyover test speed must be increased. This requires knowledge of the OAT measured on-board the aircraft at the time of the test. The applicant should note that it is essential to test at the required airspeed value since there is no provision for the adjustment of data obtained at the wrong Mach number.

601(c)(8) Flight test conditions
AMC §J36.105(c)(1) [ETM AMC No. 1 A4 2.4.2]

(1) *Test speed for light helicopters*

For the purposes of compliance with Appendix J of part 36, the helicopter should be flown at the test speed (V_{ar}) that will produce the same advancing blade Mach number (M_R) as the reference speed at reference conditions given in J36.3(a) and J36.3(c) of part 36.

The reference advancing blade Mach number (M_R) is defined as the ratio of the arithmetic sum of the main rotor blade tip rotational speed (V_{TIP}) and the helicopter true airspeed (V_{REF}) divided by the speed of sound (c) at 25°C (346.1 m/s) such that:

$$M_R = \frac{V_{REF} + V_{TIP}}{c}$$

The test airspeed (V_{ar}) is calculated from:

$$V_{ar} = c_T\left(\frac{V_{REF} + V_{TIP}}{c}\right) - V_{TIP}$$

where c_T is the speed of sound obtained from the on-board measurements of outside air temperature.

Since the ground speed obtained from the flyover tests will differ from that for reference conditions, an adjustment, Δ_{J3}, of the form

$$\Delta_{J3} = 10 \log (V_{ar}/V_{REF})$$

will need to be applied. Δ_{J3} is the increment in decibels that must be added to the measured SEL.

There are two additional requirements for light helicopter test speed. First, the airspeed during the 10 dB-down period should be close (i.e., within ±3 kt (±5.5 km/h)) to the adjusted reference speed (see J36.105(c)(1)(ii) of part 36).

The second speed requirement states that the level flyovers must be made in equal numbers with a headwind component and tailwind component (see J36.105(b) of part 36). For practical reasons, if the absolute wind speed component in the direction of flight, as measured at a height between 4 ft (1.2 m) and 33 ft (10 m) above ground (see J36.101(c)(4) of part 36), is less than 5 kt (2.6 m/s), then the effect of wind can be considered to be negligible. In this case, the measured flyover may be used to satisfy a test run in either the headwind or tailwind direction if the flyovers are conducted in pairs. Each pair should consist of two flyovers performed one after the other in opposite directions over the reference flight track.

Any changes in rotor speed, which may occur with the flight airspeed, will also need to be taken into account in the above calculations to determine the adjusted reference airspeed. If this is likely to occur then this topic should be reviewed with the FAA to determine if any additional adjustments to the flight test speed are required. Normally this is not a concern, since the rotor speed will be independent of flight speed.

The applicant should also note that the calculated adjusted reference airspeed (V_{ar}) is the adjusted true airspeed (TAS). Additional information will be required to determine the IAS for use by the pilot. This will normally be based on calibration charts or adjustments for the airspeed measurement system showing the IAS/TAS relationship.

601(c)(9) Flight test conditions
AMC §J36.105(c)(2) [ETM AMC No. 2 A4 2.4.2]

(1) *Rotor speed*

The rotor speed can be varied on some helicopters, and on others variations in the rotor speed can occur with flight speed. In order that the noise levels are representative of normal operation, the rotor speed used must be the maximum normal value associated with flyover at the reference conditions.

Note.— It is not the intent to require noise measurements at any value but the maximum used during normal operations, and thus testing at the maximum tolerance rotor speed is not required.

On some helicopters two distinct rotor speed values are available. If both can be used for normal operations then the noise certification has to be conducted at the higher rotor speed. If the higher of the two speeds is restricted to special operations, or if the helicopter is configured so that it cannot be used at the reference conditions and/or during lower altitude flight, then, subject to approval by the FAA, testing at the lower rotor speed may be allowed.

On some helicopters it may be possible for the rotor speed to be changed by pilot action. In these cases noise certification will require the highest rotor speed specified in the RFM for the flyover flight condition at the maximum takeoff weight to be used.

For most turbine-engine-powered helicopters the rotor speed is automatically linked by the engine control/ governor system to the flight condition. If this results in a different rotor speed at the adjusted reference airspeed to that associated with the reference airspeed, then additional adjustments may be required to ensure the correct advancing blade tip Mach number is used for the tests. If this situation is likely to occur, FAA approval of the rotor speed and/or adjusted reference airspeed to be used should be obtained.

On some recently designed helicopters the use of lower rotor speeds has been certificated for operations at low altitudes and/or in cruise flight. Since these lower rotor speeds are defined in the RFM and, if higher rotor speed values cannot be used at the reference conditions, except possibly in an emergency, noise certification is conducted at the certificated lower rotor speed, subject to approval by the FAA. If, however, the helicopter simply incorporates a two-speed or multi-speed system, and either can be selected by the pilot, then the highest value is required to be used for noise certification.

601(d) Noise Unit Definition
[ETM 6.1.4]

601(d)(1) Units
GM §J36.109(b) [ETM GM 3.1]

The noise levels are to be determined in terms of the SEL metric. The SEL is the time-integrated A-weighted sound level over the 10 dB-down period. This metric takes into account both the duration and the level of the sound.

601(e) Measurement of Helicopter Noise Received on the Ground
[ETM 6.1.5]

601(e)(1) Noise measurement system
AMC §J36.109(c) [ETM AMC A4 4.3]

(1) *System and calibration requirements*

The noise measurement system and system calibration requirements are specified in J36.109(c) through J36.109(e) of part 36 for compliance with Appendix J of part 36. The noise demonstration compliance test plan must include a description of the system to be used for the noise measurement. The FAA must approve the measurement system and calibration procedures in order to ensure that accurate measurements and results are obtained.

601(e)(2) Noise measurement procedures
AMC §J36.109(e) [ETM AMC A4 4.4]

(1) *Sound level integration period*

The A-weighted sound pressure level must be integrated over the 10 dB-down period. When using an integrating sound level meter where the start and stop times are selected manually, the actual test integration period should be slightly longer than the true 10 dB-down period. This will not have any significant impact on the SEL value, providing the integration period is only a few seconds longer, since the noise levels will be more than 10 dB(A) below the maximum sound level value.

601(f) Adjustment of Test Results
[ETM 6.1.6]

601(f)(1) Data adjustments
AMC §J36.205(b) and (c) [ETM AMC A4 5.0]

(1) *Height adjustment*

In order to account for the differences between the test heights (H) and reference height of 492 ft (150 m), which influence both the spherical spreading of the noise and the duration of the 10 dB-down period, the Δ_1 adjustment is applied.

(2) *Airspeed adjustment*

In order to account for the differences between the adjusted reference airspeed (V_{ar}) and reference airspeed (V_{REF}), which influence the duration of the 10 dB-down period, the Δ_2 adjustment is applied. Variations in the ground speed, and hence duration, as a result of wind at the test height also occur, but since test runs are to be made with equal numbers with headwinds and tailwinds (see J36.105(b) of part 36), this effectively cancels out this effect and no additional adjustments for duration are required.

601(g) Reporting of Data to the FAA
[ETM 6.1.7]

601(g)(1) Data reporting
AMC §J36.111 [ETM AMC A4 6.0]

(1) *Reporting requirements*

Noise certification data reporting requirements are detailed in J36.111 of part 36. Compliance with stabilized test conditions, including test airspeed, average rotor speed and flyover height, should be reported for the 10 dB-down period. If an acoustic data recording is made, information about the recorder, including frequency bandwidth and sample rate and operating mode, should be recorded.

(2) *Lateral position flight track data*

There is no requirement to determine the lateral off-track position directly above the noise measurement point, since it is necessary to show only that it is within the requirements defined in J36.105(b)(3) of part 36. Even so, an applicant may find merit in determining and reporting the lateral off-track distance, with the height information that is required, as a way to show compliance.

602 EQUIVALENT PROCEDURES INFORMATION
[ETM 6.2]

602(a) General
[ETM 6.2.1]

The objective of a noise certification demonstration test is to acquire data for establishing an accurate and reliable definition of a helicopter's noise characteristics. In addition, part 36 establishes a range of test conditions and procedures for adjusting measured data to reference conditions.

602(b) Procedures for the Determination of Changes in Noise Levels
[ETM 6.2.2]

Changes in noise levels determined by comparison of flight test data for different helicopter model series have been used to establish certification noise levels of modified or newly derived versions by reference to the noise levels of the baseline or "flight datum" helicopter model. These noise changes are added to or subtracted from the noise levels obtained from individual flights of the "flight datum" helicopter model. The confidence intervals of the new data are statistically combined with the "flight datum" data to develop overall confidence intervals (see 305 of this AC).

602(b)(1) Modifications or upgrades involving aerodynamic drag changes
[ETM 6.2.2.1]

The use of drag devices, such as drag plates mounted beneath or on the sides of the "flight datum" helicopter, has proven to be effective in the noise certification of modifications or upgrades involving aerodynamic drag changes. External modifications of this type are made by manufacturers and aircraft "modifiers". Considerable cost savings are realized by not having to perform noise testing of numerous individual modifications to the same model series. Based on these findings, it is considered acceptable to use the following as an equivalent procedure:

a) for helicopters to be certificated under Appendix J of part 36, a drag device is used that produces the aerodynamic drag calculated for the highest drag modification or combination of modifications;

b) with the drag-producing device installed, a flyover test is performed by using the appropriate noise certification reference and test procedures;

c) a relationship of noise level versus change in aerodynamic drag or airspeed is developed by using noise data, adjusted as specified in Appendix J of part 36, of the "flight datum" helicopter and of the "high drag" configuration;

d) the actual airspeed of the modification to be certificated is determined from performance flight testing of the baseline helicopter with the modification installed; and

e) using the measured airspeed of the modification, certification noise levels are determined by interpolation of the relationship developed in item c).

602(b)(2) Testing of light helicopters outside Appendix J temperature and humidity limits [ETM 6.2.2.2]

With the approval by the FAA, it may be possible to conduct testing of light helicopters in compliance with the temperature and relative humidity test limits specified in H36.101(c) of part 36 (see Figure 51) instead of the limits specified in J36.101(c)(2) of part 36. Temperature and relative humidity measurements must be made between 4 ft (1.2 m) and 33 ft (10 m) above ground as specified in J36.101(c)(2) of part 36 and within 30 minutes of each noise measurement as required by H36.101(c)(7) of part 36. In such circumstances, it will be necessary to conduct a one-third octave band analysis of a noise recording of each flyover. The measured value of SEL must be adjusted from the test values of temperature and relative humidity to the reference conditions defined in J36.3(a) of part 36. The adjustment procedure must be similar to that defined in H36.205(f)(2) of part 36 with the propagation distances QK and Q_rK_r, respectively replaced by H, the height of the test helicopter when it passes over the noise measurement point, and the reference height, 492 ft (150 m).

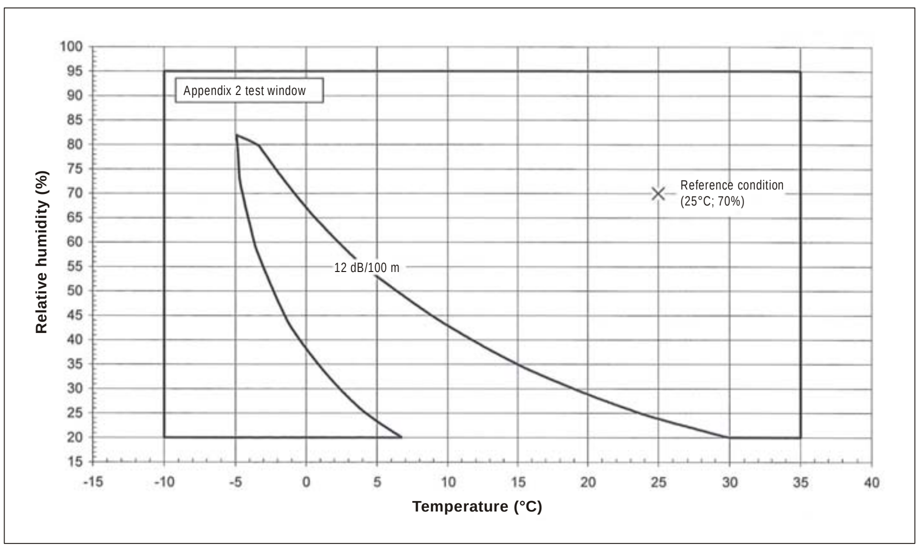

Figure 51. Optional Appendix H Temperature/relative humidity test window

Chapter 7

GUIDELINES FOR TILTROTOR AIRCRAFT EVALUATED UNDER APPENDIX K OF 14 CFR PART 36

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701 EXPLANATORY INFORMATION [ETM 7.1]

701(a) Background [ETM 7.1.1]

701(a)(1) Applicability GM §36.1(5) [ETM GM ATT F 1]

(1) *Intent of Appendix K requirements*

The prescribed test requirements for the noise certification of tiltrotor aircraft is presented in Appendix K of part 36. It was adopted in the USA following the ICAO development effort by the CAEP5 Tiltrotor Task Group that specifically addressed the noise certification of the Bell/Agusta BA609, the first example of a civil tiltrotor aircraft, which was renamed the AW609 in 2011. Initially developed as ICAO guidelines, it is becoming the basis for noise certification of tiltrotor aircraft in the USA. The explanatory material in this chapter is intended to provide an insight as to how the guidelines were developed. Its use is anticipated for AW609 noise certification and will become an ICAO standard within the Annex after its initial application.

(2) *Scope of Appendix K*

In anticipation of the AW609 becoming the first civil tiltrotor aircraft, these guidelines are being adopted in the USA as applicable standards. The ICAO Annex 16, Volume 1, Attachment F guidelines, published in 2002, provides a noise certification compliance testing methodology for tiltrotor aircraft that promotes uniform and consistent environmental protection for aviation.

When Working Group 1 (Noise) was originally task for developing tiltrotor guidelines, it was decided after careful deliberations, that the current Standards of Chapter 8 for helicopter in Annex 16 would offer a good basis for the guidelines since the helicopter configuration would characterize the worst case (noisiest) condition.

a) The noise from tiltrotors will be most prominent during departure and approach. In these situations tiltrotors will normally operate in or near the “helicopter mode”.

b) In the development of the guidelines, the noise of the Bell XV-15 tiltrotor aircraft (a prototype of the AW609) was observed. It was concluded that the character of the noise of this aircraft was much like that of a normal helicopter.

c) In horizontal flyover, the "helicopter mode" will normally be the noisiest configuration.

d) The proposed guidelines are confined to tiltrotors that can only take off vertically, excluding those with STOL characteristics. They will operate much like normal helicopters, with relatively steep takeoff and approach paths.

e) The level of available noise abatement technology for tiltrotors is considered to be the same as for helicopters.

f) Tiltrotor operations will often mix with helicopter operations from the same heliport. Therefore there will be a desire to compare the noise from tiltrotors and helicopters.

(3) *Transition phase noise-test point evaluation*

One item of strong interest is the transition from one nacelle angle to the other, which may be associated with particular noise-generation mechanisms. For example, when one considers the tiltrotor transition from airplane mode to helicopter mode while decelerating, there is a phase in which the component of the speed vector that is perpendicular to the rotor changes from "top to bottom" to "bottom to top". It would be conceivable that sometime during the transition phase, blade vortices would be ingested or another non-stationary effect would create additional noise.

A number of flyovers of the Bell XV-15 were listened to, one of which was especially set up to study the noise during transition. In this run, the tiltrotor (Bell XV-15) passed overhead at 492 ft (150 m) while transitioning from airplane to helicopter mode. No special phenomena were heard during this flight. In addition, during the other runs, in which there were demonstrations of hover, hover turns, sideward flight, takeoff, level flyovers at various speed/nacelle angle combinations, and approaches at 6° and 9°, no particularities were heard other than normal blade vortex interaction noise during both the 6° and 9° approaches. During the procedures to set the aircraft up for the various runs, several transitions were made from helicopter to airplane mode and back, which were listened to from different positions relative to the aircraft. No particular noise was heard.

Based on this experience and the arguments stated as follows, it has been decided not to attempt to define a special test point aimed at catching transition noise of tiltrotors.

The arguments for this are:

a) Experienced observers from industry claim they have never noticed any particular noise phenomena associated with the transitional phase. This was backed up by the specific observations of the Bell XV-15 referred to above.

b) The conversion rate is relatively slow, which means that during the whole conversion process, the flow field also changes very slowly.

c) If there were to be a transitional noise, it would probably be related to some form of blade-vortex interaction. This phenomenon is covered under the approach procedure, and it might be hard to justify adding a measurement point to get some additional information.

d) Defining a reproducible and practicable procedure to catch the transition noise which nobody has ever noticed is virtually impossible.

e) If in the future there is a design that has clear transitional noise characteristics, the effect could be studied and, if deemed necessary, an amendment to the guidelines could be proposed.

701(b) General Information
[ETM 7.1.2]

701(b)(1) Terms used in tiltrotor noise certification procedures
GM §36.1(i) [ETM GM ATT F 6]

Airplane mode means a configuration with nacelles on the down stops (axis aligned horizontally) and rotor speed set to cruise revolutions per minute (RPM).

Airplane mode RPM means the lower range of rotor rotational speed in RPM defined for the airplane mode cruise flight condition.

Fixed operation points mean designated nacelle angle positions ("gates") selected for airworthiness reference. These are default positions used to refer to normal nacelle positioning operation of the aircraft. The nacelle angle is controlled by a self-centering switch. When the nacelle angle is 0 degrees (airplane mode) and the pilot moves the nacelle switch upwards, the nacelles are programmed to automatically turn to the first default position (for example, 60 degrees) where they will stop. A second upward move of the switch will tilt the nacelle to the second default position (for example, 75 degrees). Above the last default position, the nacelle angle can be set to any angle up to approximately 95 degrees by moving the switch in the up or down direction. The number and position of the fixed operation points may vary on different tiltrotor configurations.

Nacelle angle is defined as the angle between the rotor shaft centerline and the longitudinal axis of the aircraft fuselage.

Tiltrotor means a class of aircraft capable of vertical takeoff and landing, within the powered-lift category, with rotors mounted at or near the wing tips that vary in pitch from near vertical to near horizontal configuration relative to the wing and fuselage.

Vertical takeoff and landing (VTOL) mode means the aircraft state or configuration having the rotors orientated with the axis of rotation in a vertical manner (i.e., nacelle angle of approximately 90 degrees) for vertical takeoff and landing operations.

$\mathbf{V_{CON}}$ is defined as the maximum authorized speed for any nacelle angle in VTOL/Conversion mode.

$\mathbf{V_{MCP}}$ is defined as the maximum level flight airspeed for airplane mode corresponding to minimum specification engine power corresponding to maximum continuous power available for sea level pressure of 1013.25 hPa, at 77° F (25° C) ambient conditions at the relevant maximum certificated weight.

$\mathbf{V_{MO}}$ is defined as the maximum airspeed in airplane mode that may not be deliberately exceeded.

VTOL/Conversion mode is all approved nacelle positions where the design operating rotor speed is used for hover operations.

VTOL mode RPM means highest range of RPM that occur for takeoff, approach, hover, and conversion conditions.

701(c) Information on Specific Appendix K Texts
[ETM 7.1.3]

701(c)(1) Definitions
GM §36.K1 [ETM GM ATT F Note 1]

(1) *Definition*

The definition was proposed by the International Coordinating Council of Aerospace Industries Associations (ICCAIA). It focuses on the fundamental difference between tiltrotors and other aircraft.

701(c)(2) Applicability
GM §36.K1 [ETM GM ATT F Notes 1 and 2 and Section 1]

(1) *Applicability*

An applicability section promotes uniform application of the guidelines. The reference to derived versions means that no measurements are required on aircraft that are quieter than their parent aircraft due to the definition of derived versions though addressed as an acoustical change. The regulation is effective upon completion of the US rulemaking.

701(c)(3) Noise evaluation measure
GM §36.K2 [ETM GM ATT F Section 2]

(1) *Noise evaluation measure*

In view of the commonality with helicopters, the same units used in Appendix H of part 36 are proposed. It is proposed that no new appendix for tiltrotors be created, since the current Appendix H of part 36 is considered to be appropriate.

The FAA encourages that additional data be made available for land-use planning purposes. With the exception of flyovers in airplane mode discussed later in this chapter, the intention of this section of the guidelines is to require only data that can be gathered through additional analysis of the data that have already been measured for certification purposes. Which data should be provided is to be determined between the FAA, or other authorities, and the applicant, since the needs of different authorities in this respect may differ. As a minimum, data in units of SEL and L_{Amax} as defined in Appendix 4 of part 36 should be made available for approval by the FAA. This data may be presented in the noise section of the RFM as supplemental information (see 201(d) of this AC discussing §36.1581(b) of part 36).

701(c)(4) Reference noise measurement points
GM §36.K3 [ETM GM ATT F Section 3]

(1) *Reference noise measurement points*

In view of the desired commonality with helicopters, the same reference noise measurement points used for Appendix H of part 36 are prescribed.

701(c)(5) Maximum noise levels and trade-offs
GM §36.K4 and §36.K5 [ETM GM ATT F Sections 4 and 5]

(1) *Maximum noise levels and trade-offs*

In view of the desired commonality with helicopters, it was determined that the Stage 2 limits of H36.305(a)(2) and the trade-offs of H36.305(b) of part 36 would serve as a good starting point for use in this regulation. In the helicopter mode, both the lift technology and operating environment are similar to those of a helicopter. For the flyover case, a limit is specified only for the helicopter mode, since this is normally the noisiest configuration and also the configuration most likely to be used when flying the circuit pattern.

(2) *Noise levels in airplane mode*

There is no maximum noise level for the tiltrotor in airplane mode. However, it is recommended that noise levels be measured as per the reference procedures defined in 36.K6 and reported as supplemental data in the noise section of the RFM as this configuration will be used when transiting between points.

701(c)(6) Noise certification reference procedures
GM §36.K6 [ETM GM ATT F Section 6]

(1) *General*

The capability to change the nacelle angle and the two (possibly more) different rotor speeds required additional criteria relative to the current helicopter reference procedures of Appendix H of part 36.

(2) *Rotor speed*

In Appendix H of part 36, the rotor speed required is linked to the corresponding flight condition. This means that for takeoff, approach and flyover in the helicopter mode, the higher rotor speed will have to be used, while for the flyover in airplane mode, the lower rotor speed has to be used.

(3) *Nacelle angle*

a) *Takeoff*

During takeoff, the choice of the nacelle angle is left to the applicant. This is in line with the philosophy of part 36 where the choice of the configuration is left to the applicant. It is also in line with the requirement in Appendix H of part 36 to use the aircraft's best rate of climb speed, Vy, since the applicant will normally choose the nacelle angle that is close to the nacelle angle which corresponds to the overall best rate of climb. Note that for each nacelle angle there is a speed that gives the best rate of climb, which is normally not the same numerical value for different nacelle angles. There will be one nacelle angle that gives the highest overall rate of climb, but this is usually not an angle that corresponds to a fixed operation point.

b) *Flyover in helicopter mode*

In the case of flyover in helicopter mode, the definition of the nacelle angle to be used was one of the more difficult problems. Initially it was proposed to use a nacelle angle of 90°, comparable to a helicopter. This was however unsatisfactory because a tiltrotor will normally not fly at this angle at the high speed required for noise certification. Normally the rotor will be tilted to get more forward thrust without tilting the fuselage forward, and to do this, a nacelle angle of approximately 80° is selected. It was agreed that this unique capability of the tiltrotor should be incorporated into the reference procedure. On the other hand the requirement should prevent the applicant from choosing a nacelle angle that would be close to 0° since this would give unrealistically low noise figures. Note that tilting the rotor will reduce the advancing blade tip Mach number. After long deliberations, a satisfactory solution was found. For a tiltrotor there will normally be a nacelle angle below which hover is no longer possible and for which flight with zero airspeed is not permitted. It was decided to fix the nacelle angle for the flyover in helicopter mode to the fixed operation point closest to that angle.

c) *Flyover in airplane mode*

In flyover in airplane mode, the nacelle angle is defined as on the down-stop, the position that will normally be used for cruise and high speeds. Two conditions are measured:

— one is with the high rotor speed and the same speed as used in the helicopter mode flyover. This condition is intended to make it possible to make comparisons between the helicopter mode and airplane mode flyover; and

— the other condition is with the cruise rotor speed and speed V_{MCP} or V_{MO}, as defined in 701(b), which is intended to represent a worst-case cruise condition.

d) *Approach*

For the approach reference configuration, the nacelle angle for maximum approach noise should be used. This is consistent with the philosophy of Appendix H and other parts of part 36 that require the noisiest configuration for approach. This will normally require testing several different nacelle angles in order to determine which is noisiest.

In the tiltrotor aircraft design, the flap angle varies with airspeed so the pilot may manually set flaps or may use auto flap control in order to reduce the pilot's workload. In this latter case, the flap angle for noise certification will be the flap angle that is normal for the approach configuration and approach condition flown. For a design with pilot-controlled flap angle, the applicant should use the flap angle designated for approach and will have to prove that the noisiest configuration is used for noise certification.

701(c)(7) Test procedures
GM §36.K7 [ETM GM ATT F Section 7]

(1) *Test procedures*

The test procedures are the same as in Appendix H of part 36. Where appropriate, the helicopter guidance provided in Chapter 4 of this AC is equally applicable to tiltrotors.

Note that this means that, as a minimum, all noise measurements are taken and evaluated with the microphone at 4 ft (1.2 m), including any voluntary data taken for land-use planning purposes. This is proposed in order to maintain commonality with Appendix H numbers and to reduce costs for the applicant. If, for land-use planning or other purposes, the gathering of data at other microphone positions (i.e., at ground plane) were desired, this would of course be allowed but would have to be agreed between the applicant and the FAA.

Chapter 8

GUIDELINES ON FLIGHT TEST WINDOWS AND ADJUSTMENT OF LAND-USE PLANNING NOISE DATA MEASURED IN ACCORDANCE WITH ATTACHMENT H TO ANNEX 16, VOLUME I

CHAPTER TABLE OF CONTENTS

801 EXPLANATORY INFORMATION [ETM 8.1]

801(a) Background [ETM 8.1.1]

801(a)(1) General [ETM GM ATT H 1]

At CAEP/6, guidelines for the provision of rotorcraft noise data for land-use planning (LUP) purposes were approved as Attachment H to Annex 16, Volume 1. The objective of Attachment H is the provision of noise data, in metrics suitable for LUP purposes, at the noise certification flight conditions and/or at alternative flight conditions representing normal operating procedures or other flight procedures for noise abatement or heliport-specific requirements.

Detailed guidance on flight test windows and adjustments of LUP data to reference conditions for alternative flight procedures specifically designated for LUP data provision is provided in this chapter. To be consistent with noise certification data and provide comparable accuracy, the detailed guidance is based, to the fullest extent practical, on the flight test windows and data adjustment procedures utilized for noise certification flight procedures.

In developing these flight test windows and data adjustment procedures, the needs associated with LUP data provision have been balanced against the test costs in acquiring LUP data, with the intent of encouraging additional optional flight testing and measurements by applicants.

The guidance on test windows for alternative flight procedures is provided in 801(b). Guidance on adjustment of LUP data to reference conditions is provided in 801(c) and 803(a), with 801(c) addressing reference conditions and 803(a) providing specific guidance on adjustment procedures.

Note.— The test windows and adjustments to data provided in this chapter address constant airspeed and flight path conditions only. Varying airspeed and flight path conditions may require additional guidance not yet provided in this chapter.

801(b) Test Windows
[ETM 8.1.2]

801(b)(1) Alternative constant airspeed and flight path conditions
[ETM GM No. 1 ATT H 2.1 and 2.2]

The flight test windows and procedures for alternative constant flight conditions for LUP are provided in Table 16 together with the existing requirements for noise certification. “No change” in Table 16 denotes the recommended use of the corresponding test window or procedure of Appendix H or J of part 36.

Table 16. Flight test windows and procedures for alternative constant flight conditions for LUP

Annex 16/Doc 9501 reference	*Test window/procedure*	*Noise certification*	*LUP flight conditions*
8.7.4	Total adjustments	Takeoff: 4 EPNdB/2 EPNdB Approach and flyover: 2 EPNdB	No change for integrated noise metrics
8.7.5	Rotor speed (N_r)	±1 percent	No change
8.7.6	Airspeed	±5 kt (±9 km/h)	±7 kt (±13 km/h)
8.7.7	Flyovers with headwind/tailwind	Equal numbers	No change
8.7.8	Angle from the vertical	±10° or ±65 ft (±20 m)	No change
8.7.9	Flyover height at overhead	±30 ft (±9 m)	No change
8.7.10	Approach angle	± 0.5° “Wedge”	No change
8.7.11	Weight	90 percent to 105 percent	No change
App 2, 2.2.2.2 b)	Temperature at 10 m (33 ft)	14°F to 95°F (–10°C to 35°C)	No change
App 2, 2.2.2.2 b)	RH at 10 m (33 ft)	20 to 95 percent	No change
App 2, 2.2.2.2 c)	8 kHz sound attenuation coefficient	12 dB/100 m	No change
App 2, 2.2.2.2 e)	Wind at 10 m (33 ft)	10 kt (5.1 m/s)	No change
App 2, 2.2.2.2 e)	Crosswind at 10 m (33 ft)	5 kt (2.6 m/s)	No change

Annex 16/Doc 9501 reference	*Test window/procedure*	*Noise certification*	*LUP flight conditions*
App 2, 3.5.2	Microphone height	4 ft (1.2 m)	4 ft (1.2 m) (Note 1)
App 2, 5.4.2	Number of test runs	6	4
App 2, 5.4.2	90 percent CI — 3 microphone average (Note 2)	±1.5 EPNdB	±1.5 dB SEL
	90 percent CI — each metric at each microphone	N/A	To be reported
Doc 9501, 4.2.3.2.1	No adjustment window	Equivalent to <0.3 dB delta	No change (Note 3)
Doc 9501, 4.2.3.2.2	Airspeed for equivalent Mach number	3 kt (±5.5 km/h)	No change
Doc 9501, 8.1.2	Airspeed (VT and V(x)) — decelerating	N/A	±7 kt (±13 km/h) of reference airspeed schedule
11.6.5	Total adjustments	2 dB(A)	No change
11.6.6	Rotor speed (Nr)	±1 percent	No change
11.6.7	Airspeed — constant	±3 kt (±5.5 km/h)	±5 kt (±9 km/h) (Note 4)
11.6.4	Headwind/tailwind	Equal numbers	No change
11.6.8	Angle from the vertical	±10°	No change
11.5.2.1 a)	Height at overhead	±50 ft (±15 m)	No change
	Approach angle	N/A	±0.5° “Wedge”
11.6.9	Weight	90 percent to 105 percent	No change
App 4, 2.2.2.2 b)	Temperature at 33 ft (10 m)	14 ºF to 95ºF (–10°C to 35°C)	No change
App 4, 2.2.2.2 b)	RH at 33 ft (10 m)	20 to 95 percent	No change
App 4, 2.2.2.2 b)	8 kHz sound attenuation coefficient	10 dB/100 m	No change
App 4, 2.2.2.2 c)	Wind at 10 m (33 ft)	10 kt (5.6 m/s)	No change
App 4, 2.2.2.2 c)	Crosswind at 10 m (33 ft)	5 kt (2.6 m/s)	No change
App 4, 4.4.2	Microphone height	1.2 m (4 ft)	1.2 m (4 ft) (Note 1)
App 4, 6.3.1	Number of test runs	6	4
App 4, 6.3.2	90 percent CI	±1.5 dB SEL	No change
	90 percent CI — each metric at each microphone	N/A	To be reported
Doc 9501, 4.2.3.2.1	Equivalent Mach number	±3 kt (±5.5 km/h)	No change
Doc 9501, 8.1.2	Airspeed (VT and V(x)) — decelerating	N/A	±7 kt (±13 km/h) of reference airspeed schedule

1. LUP measurements at other heights should be adjusted to 1.2 m (4 ft) using an approved method.
2. The three-microphone average is based on the three noise certification measurement points.
3. No change for Appendix H noise certification measurement points. Other measurement points to be evaluated.
4. Can use ±7 kt (±13 km/h) if velocity term, □2, of Appendix H is used.

Many of the flight test windows and procedures currently used for noise certification testing can be applied when acquiring noise data for LUP purposes. Thus the flight test windows and procedures detailed in Table 16 make as much use of current adjustment procedures of Appendix H and J of part 36 as practical. In addition, it should be noted that the “zero attenuation adjustment window” as defined in 402(c)(2)(A), may be used.

Table 16 includes, relative to the noise certification requirements, an expanded airspeed tolerance of ±7 kt (±13 km/h) for Appendix H helicopters and ±5 kt (±9 km/h) for Appendix J helicopters (or ±7 kt (±13 km/h) if the Appendix H Δ2 adjustment is used), and a minimum number of 4 test runs. The 90 percent confidence interval limit of ±1.5 EPNdB currently applied to the three-microphone average of EPNL in Appendix H is also applied to the corresponding three-microphone average of SEL. In the case of Appendix J helicopters, the current 90 percent confidence interval requirement for SEL at the flight track microphone is retained. In addition, the 90 percent confidence interval calculated for each time-integrated and maximum noise level metric at each microphone should be reported.

These guidelines primarily address the balance between LUP data needs and test costs for applicants providing data under Attachment H. In particular, increasing the airspeed test window by 2 kt (3.7 km/h) will reduce test costs while having little impact on the final results. Reducing the required minimum number of test runs from 6 to 4 also reduces test costs while the needed accuracy of the data is maintained by the 90 percent confidence interval limit.

801(b)(2) Multi-segmented flight path conditions at constant airspeed — no climb segments [ETM GM No. 2 ATT H 2.1 and 2.2]

The flight test windows and procedures provided for alternative constant flight conditions for LUP in Table 16 can be applied for the case of approaches with multiple reference flight path segments, each having a different constant descent angle or level flight condition. In particular, the test tolerances in Table 16 for total adjustments, rotor speed, airspeed, angle from the vertical, height at overhead, approach angle and test weight are applicable to each flight path segment as appropriate.

Note.— Changes in reference flight path angle between two segments should be completed as quickly as possible in order to remain within flight path tolerances for each flight segment. This may necessitate initiating the transition prior to the reference transition point.

801(b)(3) Multi-segmented flight path conditions at constant airspeed with climb segments [ETM GM No. 3 ATT H 2.1 and 2.2]

(Reserved)

801(b)(4) Non-constant airspeed and flight path conditions [ETM GM No. 4 ATT H 2.1 and 2.2]

(Reserved)

801(b)(5) Approaches with constant deceleration and flight path conditions [ETM GM No. 5 ATT H 2.1 and 2.2]

The flight test windows and procedures provided for alternative constant flight conditions for LUP in Table 16 can be applied for the case of approaches with constant deceleration and flight path (glide slope) conditions with some adjustments to account for the constant variation of airspeed with time. Specifically, a reference airspeed “schedule” (i.e., reference airspeed as a function of position along the reference flight track) needs to be derived from the reference deceleration rate for the reference condition of zero wind speed. The airspeed tolerance of ±7 kt (±13 km/h) should be applied both to airspeed as a function of time and as a function of position along the reference flight track as illustrated in Figure 52 and Figure 53.

801(b)(6) Other non-constant airspeed and flight path conditions [ETM GM No. 6 ATT H 2.1 and 2.2]

(Reserved)

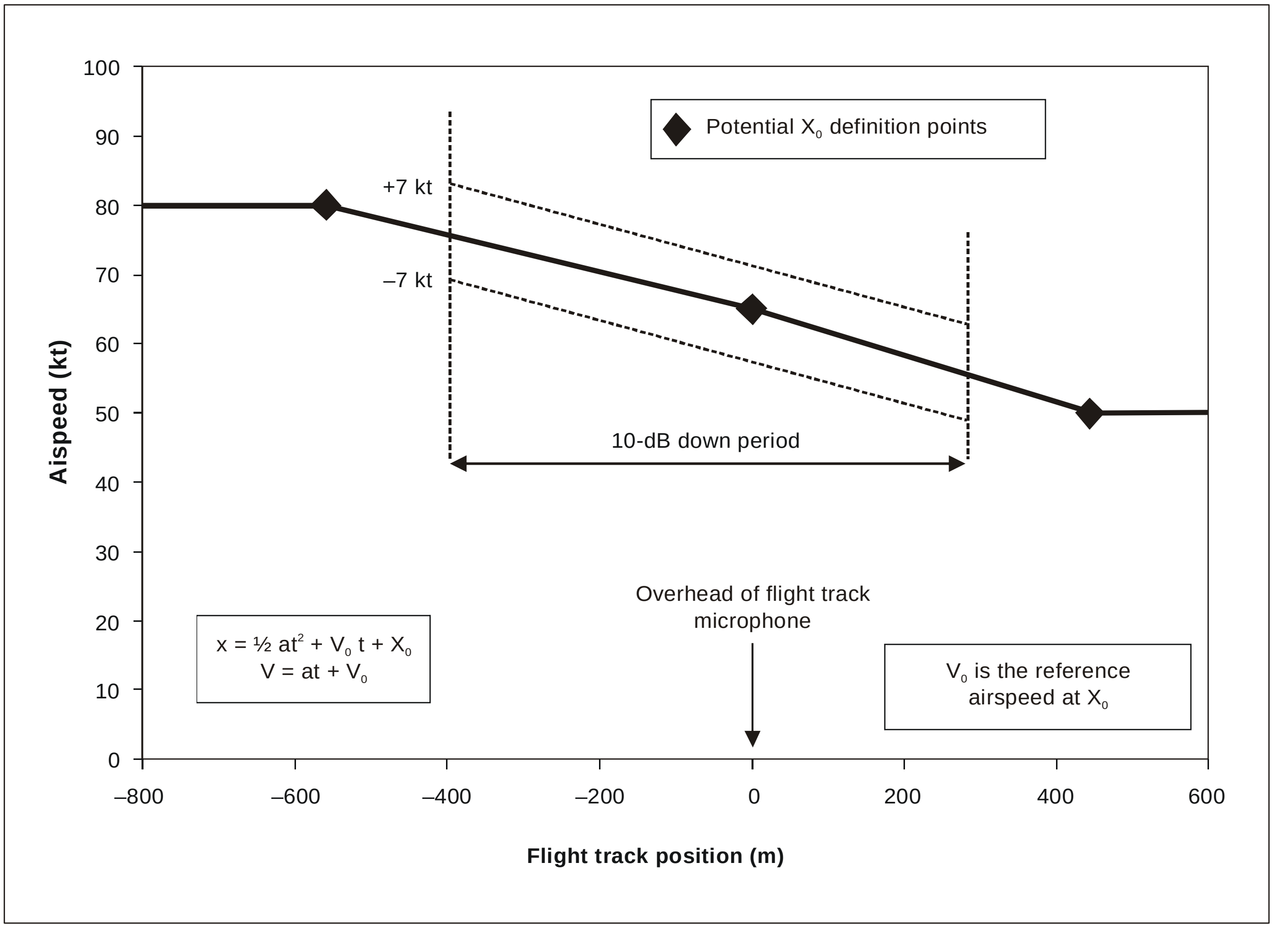

Figure 52. Example of a reference airspeed profile versus flight track position for a constant deceleration from 80 kt to 50 kt at 1 kt/s

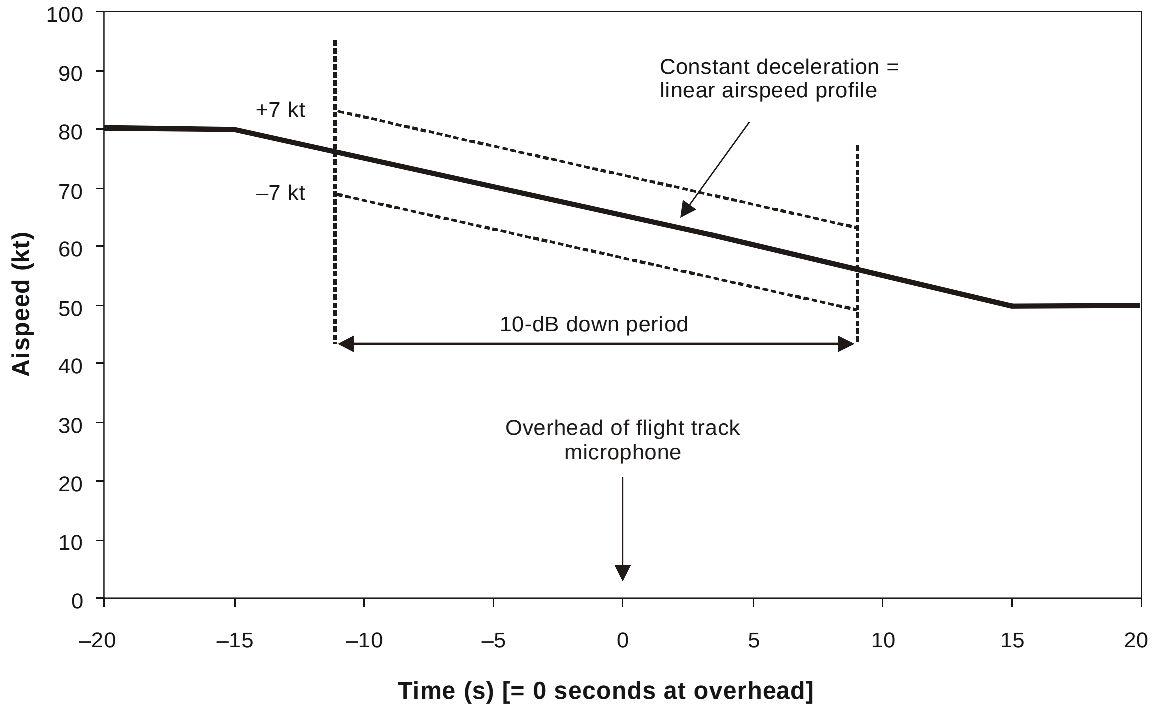

Figure 53. Example of a reference airspeed profile versus time

for a constant deceleration from 80 kt to 50 kt at 1 kt/s

801(c) Reference Conditions [ETM 8.1.3]

801(c)(1) General [ETM GM No. 1 ATT H 2.3]

Flight procedures designed to represent normal or noise abatement operations can vary from simple fixed flight path and airspeed procedures similar to noise certification test conditions to complex non-constant flight path and/or non-constant airspeed procedures. The resulting reference flight procedures and data adjustment procedures should be submitted to the FAA for approval.

The primary reference test conditions that affect adjustments to the noise data are the reference atmospheric conditions, the reference helicopter flight path, and the reference helicopter airspeed. For acquiring noise data for LUP purposes, the reference atmospheric conditions should be the same as those specified in H36.3(a) and J36.3(a) of part 36.

In the process of developing flight profiles for LUP and noise abatement procedures, a reference flight path and/or reference airspeed procedure may not have been determined prior to obtaining a set of noise data suitable for LUP purposes. In such cases, the flight path and airspeed test data may be used to derive appropriate reference values. The method used should be approved by the FAA.

801(c)(2) Predefined constant flight path and constant airspeed [ETM GM No. 2 ATT H 2.3]

If a predefined reference constant flight path and constant speed conditions similar to, but different from, those defined for noise certification testing under Appendix H of part 36 are used, the same adjustment procedures defined in Appendix H can be used with the new reference conditions substituted in the adjustment procedures as appropriate and the adjustment procedures modified as necessary to give results in terms of adjusted sound exposure level, L_{AE}, and any other metrics selected by the applicant.

801(c)(3) Derived constant flight path [ETM GM No. 3 ATT H 2.3]

If a reference flight path is not predefined, a reference path needs to be derived or otherwise determined from the flight test data. One method to define the reference path is to determine the mean of the test runs by calculating the path of each test run using a least-squares linear fit of the aircraft position data, defined in terms of X, Y and Z coordinates, between the 10 dB-down points and averaging the calculated results.

An example is the case where, as a result of flight testing multiple glide slopes, a fixed glide slope approach is deemed appropriate for pilot acceptability. If the selected flight path is repeated as necessary to obtain a statistically valid set of noise levels, the flight path data can be averaged to define the reference flight path.

801(c)(4) Derived constant airspeed [ETM GM No. 4 ATT H 2.3]

If the reference airspeed, V_r, is not predefined, a value of V_r needs to be derived or otherwise determined from the measured data. One method to define V_r is to determine the mean of the test runs by averaging the true airspeeds (TAS) of each test run that meets the test window criteria.

An example of this is the case where the sensitivity of noise level with airspeed and rate of descent is of interest. The test program might incrementally test a range of fixed IAS for one or more rates of descent, with the reference airspeed for a LUP flight profile subsequently defined after the flight test program.

For the special case of determining V_r for the flyover condition when using the equivalent Mach number method (see section 10 of 401(h)(8), 402(c)(2)(B) and J36.105(c) of this AC) to adjust for source noise, a separate method is described in 801(c)(7).

Note.— The reference ground speed, V_{Gr}, *can be derived from true airspeed data since, by definition, the true airspeed and ground speed are identical for the zero wind reference condition.*

801(c)(5) Multi-segmented flight path conditions at constant airspeed [ETM GM No. 5 ATT H 2.3]

This guidance applies to multi-segmented approach profiles at a single constant reference airspeed, with each segment having a different reference descent angle or level flight condition.

Note.—An alternative procedure for supplying LUP data for multi-segmented flight profiles at constant airspeed is possible by combining segments from constant profile data sets. The applicant should be aware, however, that directivity effects can be important in propagating acoustic data to the flight paths for each segment, necessitating the use of additional microphones to provide greater geometric resolution of the recorded noise data.

801(c)(6) Guidance for multi-segmented flight paths with climb segments [ETM GM No. 6 ATT H 2.3]

(Reserved)

801(c)(7) Non-constant airspeeds and/or flight path conditions [ETM GM No. 7 ATT H 2.3]

(Reserved)

801(c)(8) Approaches with constant deceleration and flight path conditions [ETM GM No. 8 ATT H 2.3]

The deceleration phase of the reference flight profile should span the entire 10 dB-down period for each of the noise certification measurement points as illustrated in Figure 52 and Figure 53. If not, the reference approach procedure should not be treated as a single flight segment. It is also advisable that the deceleration phase be initiated as close as possible to the start of the 10 dB-down period in order to ensure that the airspeed is as close as possible to the reference airspeed at the first 10 dB-down point. This will be useful in minimizing the potential effects of wind on meeting both airspeed tolerance requirements.

Note.— Practice flights may be advisable to establish and/or confirm a reference flight profile that meets these criteria.

If a reference deceleration or airspeed schedule is not predefined, its value needs to be derived or otherwise determined from the measured data. One method to define reference deceleration or airspeed schedule is to determine the mean of the test runs by averaging the deceleration or airspeed profile of each test run that meets the test window criteria.

801(c)(9) Other non-constant airspeeds and/or flight path conditions [ETM GM No. 9 ATT H 2.3]

(Reserved)

802 EQUIVALENT PROCEDURES INFORMATION [ETM 8.2]

(Reserved)

803 TECHNICAL PROCEDURES INFORMATION [ETM 8.3]

803(a) Adjustments to Reference Conditions [ETM 8.3.1]

803(a)(1) Constant airspeed and flight path conditions [ETM GM No. 10 ATT H 2.3]

Helicopter noise data acquired for constant airspeed and flight path conditions are typically adjusted to reference conditions using standardized procedures such as provided in Appendices H and J of part 36.

803(a)(2) [Measurements processed using the procedures of Appendix J of part 36 [ETM GM No. 11 ATT H 2.3]

The following adjustments to noise data assume corrected as-measured one-third octave and aircraft position time history data and are available in Appendix J of part 36.

Note.— Corrected as-measured noise data are data corrected as per the requirements of A36.3.9 and A36.3.10 of part 36.

If a reference flight condition with a fixed flight path and/or fixed airspeed different from those defined for noise certification testing under Appendix H of part 36 is measured, the same data adjustment procedures defined in Appendix H of part 36 can be used with the new reference conditions substituted in the adjustment procedures as appropriate and the adjustment procedures modified as necessary to give results in terms of sound exposure level (L_{AE}) and any other metrics selected by the applicant.

The adjustments to be applied to time-integrated noise metrics (e.g., L_{AE} or EPNdB) should include:

a) band-sharing correction for tone corrected metrics such as EPNL;

b) Δ_1 adjustment for sound attenuation;

c) Δ_2 duration adjustment for time-integrated metrics; and

d) Δ_3 source noise adjustment for Flyovers.

Note.— The band-sharing correction, the Δ_1 *adjustment and the* Δ_3 *adjustment should also be applied, as appropriate, to the maximum noise level (e.g.,* PNLTM, L_{Amax}*) if the value is to be published.*

Δ_1 can be calculated for L_{AE} and L_{Amax} as follows:

a) determine the aircraft position at the time that the noise at L_{Amax} was emitted and the slant range to the microphone diaphragm;

b) determine the reference aircraft position based on the reference flight path and the reference slant range to the microphone diaphragm;

c) calculate a new reference L_{Amax} from the one-third octave spectrum as adjusted using the equation in H36.205(f) of part 36;

d) calculate Δ_1 by subtracting the test L_{Amax} from the reference L_{Amax} as in H36.205(f) of part 36.

Note 1.— Use of the Δ_1 *adjustment derived for* EPNL *and* PNLTM *is acceptable for application to* L_{AE} *and* L_{Amax} *noise data.*

Note 2.— If the temperature and humidity meteorological conditions are within the zero attenuation adjustment window, the reference and test slant ranges may be replaced by the reference and test distances to the helicopter when the helicopter is over the center noise measuring point (see 402(c)(2)(A) of this AC). This assumes that the measurement points are the same or close to the locations used for noise certification testing, and the aircraft slant ranges are similar to those seen during noise certification testing. If additional measurement points are used that are significantly further from the flight path, consideration should be given to the increased error that is inherently added by the increased distances.

The Δ_2 adjustment is applied only to time-integrated noise metrics. The measured and reference distance values used in determining Δ_1 adjustments to the test data may be used to determine the distance term of the Δ_2 adjustment.

An example of calculating Δ_2 for L_{AE} is:

a) determine a mean ground speed, V_G, for each test run;

b) if a reference ground speed, V_{Gr}, has not been predefined, determine a reference ground speed from the test results to be used as V_{Gr} in the Δ_2 adjustment; and

c) calculate Δ_2 as in H36.205(g) of part 36 from the slant ranges determined from the Δ_1 adjustment procedure, mean ground speed, V_G, of the test run, and the reference ground speed, V_{Gr}.

During noise certification testing, an accepted source noise adjustment procedure for flyovers is the method described in H36.205(e) of part 36. This adjustment is normally made using a sensitivity curve of the maximum PNLTM versus main rotor advancing blade tip Mach number. For time-integrated metrics other than EPNL, the corresponding maximum noise metric should be used in place of PNLTM.

An alternative method, the equivalent Mach number test procedure, is to calculate an adjusted reference true airspeed based on the pre-selected reference airspeed and/or test airspeed and the test-day outside air temperature (see 401(h)(7), section 10 of 401(h)(8), 402(c)(2)(B) and AMC J36.105(c) of this AC). Either method is acceptable for adjusting flyover data for LUP purposes at other speeds when the reference airspeed is known beforehand.

Note.— Use of the source noise adjustment derived for EPNL *and* PNLTM *is acceptable for application to* L_{AE} *and* L_{Amax} *noise data.*

For some flyover tests without a predefined reference airspeed, V_r, for which the equivalent Mach number method is intended to be used, test runs may be flown at selected airspeeds without first adjusting the airspeed for test-day outside air temperature. In this case, the reference airspeed, V_r, may be derived from the test data so that it includes the adjustment for source noise. This can be achieved by the following process:

a) calculate a main rotor advancing tip Mach number, M_T, for each test run from the test true airspeed, V_T, the main rotor blade tip rotational speed, V_{TIP}, and the speed of sound, c_T, calculated from the on-board measurement of outside air temperature:

$$M_T = \frac{V_T + V_{TIP}}{c_T}$$

b) calculate the mean of the test Mach numbers;

c) set the reference Mach number, M_R, equal to the mean of the test Mach numbers;

d) calculate V_r from the reference Mach number, M_R, the main rotor blade tip rotational speed, V_{TIP}, and the speed of sound, c, at 25°C (77°F):

$$V_r = c(M_R) - V_{TIP}; \text{ and}$$

e) calculate the adjusted reference airspeed V_{ar} and Δ_2 for each test run as in the normal manner (see 401(h), section 10 of 401(h)(8) of this AC of and H36.205(g) and J36.205(c) of part 36).

Note.— A value of V_r *can be selected that is different from that calculated above, with* V_{ar} *adjusted accordingly, as long as each test run used to determine the mean noise level for the chosen* V_r *is within the test window for airspeed.*

803(a)(3) Measurements processed using the procedures of Appendix J of part 36 [ETM GM No. 12 ATT H 2.3]

Note 1.— Appendix J applicants are encouraged to record the sound pressure signals and/or one-third octave data and, if possible, aircraft position time-history data in addition to the requirements of Appendix 4 of the Annex. This will enable additional analysis and provision of data, including additional sound metrics.

Note 2.— In addition to the center microphone required by Appendix J, applicants should give consideration to acquiring data using two additional measurement points symmetrically disposed at 492 ft (150 m). The adjustments *in this section can be applied to the noise levels measured at those locations. This requires the calculation of the slant range distance from the aircraft position at the overhead point to the sideline location.*

The following adjustments assume corrected as-measured data obtained from an integrating sound level meter and aircraft position at the overhead point and are available in Appendix J of part 36. When as-measured one-third octave data are used to calculate L_{AE}, the method described in 803(a)(2) can be used if aircraft time-history position data are also available.

Note.— Corrected as-measured noise data are data corrected as per the requirements of J36.109(d)(ii) of Appendix J of part 36.

The adjustments to be applied to time-integrated noise metrics (e.g., L_{AE}) should include:

a) Δ_1 adjustment separated into spherical spreading and duration terms (see example below); and

b) Δ_2 adjustment.

Note 1.— The separation of the Δ_1 adjustment into spherical spreading and duration terms is based on the terms specified in Appendix 2 of the Annex.

Note 2.— The spherical spreading term of the Δ_1 adjustment should be applied to the maximum noise value (e.g., L_{Amax}) if the value is also to be provided.

An example of calculating Δ_1 is:

a) determine the slant range distance, SR*,* from the aircraft to the microphone using the measured aircraft height, H*,* when the helicopter is over the center noise measuring point; for the flight track microphone, SR will equal H;

b) determine the reference slant range, SR_{REF}, to the microphone using the reference flight path; and

c) calculate spherical spreading term of Δ_{1SS} as follows:

$$\Delta_{1SS} = 20 \log (SR/SR_{REF})$$

The duration term of the Δ_1 adjustment need be applied only to the time-integrated metric and is calculated as follows:

$$\Delta_{1D} = -7.5 \log (SR/SR_{REF})$$

The Δ_2 adjustment need be applied only to the time-integrated noise metric. For flyovers, the equation described in J36.205(c) of part 36 for ΔJ_3 and reproduced here should be used to calculate Δ_2.

$$\Delta_2 = 10 \log (V_{ar}/V_r)$$

where V_{ar} is the adjusted reference true airspeed.

To calculate the Δ_2 adjustment for takeoff and approach flight conditions, the ground speed of each test run is required. However, Appendix J of part 36 requires measurement of the ground speed, V_G. If each test run is performed with a headwind component, then it is considered acceptable that a Δ_2 adjustment need not be calculated. Note, however, that the resulting noise level will be higher than if adjusted. If ground speed is measured, then Δ_2 should be calculated using the following equation:

$$\Delta_2 = 10 \log (V_G/V_r)$$

where V_r is predefined or calculated as in 801(c)(7).

803(a)(4) Multi-segmented flight path conditions at constant airspeed [ETM GM No. 13 ATT H 2.3]

Because of the multiple flight segments, determination of Q_r to define a Q_rK_r distance may not be feasible. Alternatively, if Q_rK_r cannot be located on the reference flight profile, the minimum distances to the test and reference flight profiles can be used to approximate the ratio of Q_rK_r to QK in determining the Δ_1 and Δ_2 adjustments. The determination of minimum distances should be made to ensure that the adjustments to data are based on distances from the corresponding flight segment on both the test and reference profiles.

803(a)(5) Non-constant airspeed and flight path conditions [ETM GM No. 14 ATT H 2.3]

(Reserved)

803(a)(6) Approaches with constant deceleration and flight path conditions [ETM GM No. 15 ATT H 2.3]

If a predefined constant reference flight path equivalent to or similar to that defined for noise certification testing under Appendix H is used, the Δ_1 adjustment and the first (distance) component of Δ_2 adjustment defined in Appendix H of part 36, can be used with:

a) the new reference conditions substituted as appropriate; and

b) the adjustment procedures modified as necessary to give results in terms of adjusted sound exposure level, L_{AE}, and any additional metrics selected by the applicant.

For the constant reference airspeed conditions of noise certification under Appendix H of part 36 the second term of the Δ_2 adjustment uses a ground speed ratio to effect a duration adjustment to the measured noise levels. Because the reference airspeed is constant, this ground speed ratio is a time ratio. With a non-constant reference airspeed due to deceleration, however, a single reference ground speed is not available and the second term of the Δ_2 duration adjustment is better determined directly from reference and test-time deltas defined for each test run. In this case, the Δ_2 adjustment is modified to:

$$\Delta_2 = -7.5 \log (QK/Q_rK_r) + 10 \log (\Delta t_{r,j} / \Delta t_{T,j})$$

where $\Delta t_{r,j}$ is the reference flight path time interval between the test run 10 dB-down time points and $\Delta t_{T,j}$ is the test time interval of the 10 dB-down period for test run *j*.

Times for the first and last 10 dB-down points on the reference profile can be determined by the following procedure:

a) distance along the reference flight profile can be represented by:

$$X_r = \frac{1}{2} at^2 + V_0t + X_0,$$

where a is the reference deceleration, V_0 is the reference airspeed at X_0, and X_0 is the selected reference flight track coordinate, typically at the initiation of the deceleration, overhead of the flight track microphone, or at the termination of the deceleration;

b) for each measurement point for each test run, *j*, time *t* can be incremented until the calculated X_r coordinate agrees with the X_T coordinates of the first and last 10 dB-down points to determine the corresponding times on the reference flight profile; alternatively, the solution to the quadratic equation can be used to directly calculate t_{first} and t_{last} as a function of x, i.e.:

$$t = \frac{-V_0 + \sqrt{V_0^2 - 4(\frac{1}{2a})(X_0 - x)}}{2(\frac{1}{2a})}$$

c) $\Delta t_{r,j}$ is then given by the difference between these two time values.

803(a)(7) Other non-constant airspeed and flight path conditions [ETM GM No. 16 ATT H 2.3]

(Reserved)

Chapter 9

GUIDELINES FOR AIRCRAFT RECERTIFICATION TO STAGE 4 and 5

CHAPTER TABLE OF CONTENTS

901 INTRODUCTION [ETM 9.1]

Although the procedures described in this Chapter were developed for recertification to Stage 4 from its original certification, they are equally acceptable for recertification to Stage 5 from its original certification. In other words recertification to Stage 4 also means recertification to Stage 5 if its noise limits and supplementary requirements are met. Recertification using the procedures in this Chapter is acceptable because there were no substantial procedural modifications to Part 36 between Stage 4 (Amendment 24) to Stage 5 (Amendement 31) that will influence the certification noise level.

Recertification is defined as the “Certification of an aircraft, with or without revision to noise levels, to a Standard different to that which it had been originally certificated”. The recertification of helicopters and light propeller-driven airplanes to a different Standard from that to which they were originally certificated is not considered.

In the case of an airplane being recertificated to part 36, amendment 36-24 and later, noise recertification should be granted on the basis that the evidence used to determine compliance is as satisfactory as the evidence expected of a new type design. In this respect the date used by the FAA to determine the recertification basis should be the date of acceptance of the first application for recertification.

Section 902 of this chapter addresses the assessment of existing approved noise levels associated with applications for the recertification of an airplane to Stage 4 or Stage 5. Section 903 includes guidelines for the recertification to Stage 4 of airplanes specially “modified” in order to achieve compliance with Stage 4 or Stage 5. The appropriate process for determining the compliance of a recertificated aircraft with a new standard should be determined by the aircraft’s certification noise levels and the associated substantiation documents. A flow chart describing the process for the recertification of subsonic jet airplanes from Stage 3 to Stage 4 or Stage 5 is presented in Figure 54. In the application of these recertification guidelines, existing arrangements between certificating authorities should be respected. It is expected that bilateral arrangements will facilitate the mutual recognition between authorities of approvals granted in accordance with the guidelines recommended in this AC.

902 ASSESSMENT CRITERIA [ETM 9.2]

902(a) General

Sections 902(b) and (d) are concerned with the assessment of existing approved noise levels associated with applications for the recertification of an airplane from Stage 3 to Stage 4 or 5 under part 36. Section 902(c) is concerned with the recertification of an airplane from Stage 2 to Stage 4 or 5 under part 36.

In applying the assessment criteria of each section, if the applicant is able to answer in the affirmative, to the satisfaction of FAA, all the questions that may be relevant then reassessment is not required. The existing approved Stage 3 noise levels of the airplane should be used to determine compliance with the new standard. Otherwise, in order to satisfy the requirements of FAA, the applicant may propose additional analysis or data. Such analysis may lead to an adjustment being applied to the existing approved Stage 3 noise levels. Applicants, at their discretion, may elect to provide new test data in place of, or in addition to, the analysis.

Note.— The FAA's assessment of the suitability of the existing approved noise levels for compliance with the requirements of Stage 4 or Stage 5 will include a review of any equivalencies proposed by the applicant to meet the assessment criteria.

902(b) Recertification from Stage 3 to Stage 4 or Stage 5 [ETM 9.2.2]

Noise levels already approved for compliance with Stage 3 and submitted in support of applications for recertification of existing aircraft should be assessed against the criteria presented in this section. These criteria have been developed to ensure satisfactory compliance with the new standard. The criteria consist of a list of simple questions concerning the manner in which the original Stage 3 data were obtained and subsequently processed. The questions are the result of a comparison of the various amendments and revisions to part 36, and to this AC to which an aircraft's existing Stage 3 noise levels may have been approved.

For airplanes that were approved with Amendment 36-24 or later, a reassessment is not required. The airplane's existing approved Stage 3 noise levels should be used to determine compliance with Stage 4 or Stage 5.

For airplanes that were approved in accordance with Amendment 36-23 or earlier, the applicant is required to show that the existing approved Stage 3 noise levels are equivalent to those approved to Amendment 36-24 by answering the following questions. Unless otherwise noted, section references refer to Amendment 36-24 to part 36.

For all airplanes:

a) Was full takeoff power used throughout the reference flight path in the determination of the lateral noise level? (See B36.3(a) of part 36, Amendment 36-24.)

b) Was the "average engine" rather than the "minimum engine" thrust or power used in the calculation of the takeoff reference flight path? (See B36.7(b)(1) of part 36, Amendment 36-24.)

Note.— The applicant may demonstrate compliance with Stage 4 or Stage 5 requirements by determining the lateral and flyover noise levels by adding a delta dB corresponding to the difference between the average and the minimum engine, as derived from approved NPD data based on the airplane performance changes due to this difference.

c) Was the "simplified" method of adjustment defined in A36.9.3 of part 36, used, and if so, was –7.5 used as the factor in the calculation of the noise propagation path duration correction term? (See A36.9.3.3.2 of part 36, Amendment 36-24.)

d) Was the takeoff reference speed between V_2 + 10 kt and V_2 + 20 kt? (See B36.7(b)(4) of part 36, Amendment 36-24.)

Note.— The takeoff reference speed used to demonstrate compliance with Stage 4 requirements must meet the requirements of B36.7(b)(4) of part 36, Amendment 36-24.

e) Was the four half-second linear average approximation to exponential averaging used and, if so, were the 100 percent weighting factors used? (See A36.3.7.5 of part 36, Amendment 36-24.)

Note.— The applicant is required to demonstrate compliance with the requirements of A36.3.7.5 of part 36, through Amendment 36-24, which equates to an exponential averaging process for the determination of SLOW weighted sound pressure levels. Simulated SLOW weighted sound pressure levels may be obtained by using one of the two equations described in A36.3.7.5 of part 36 through Amendment 36-24, as appropriate, or by other methods as approved by the FAA.

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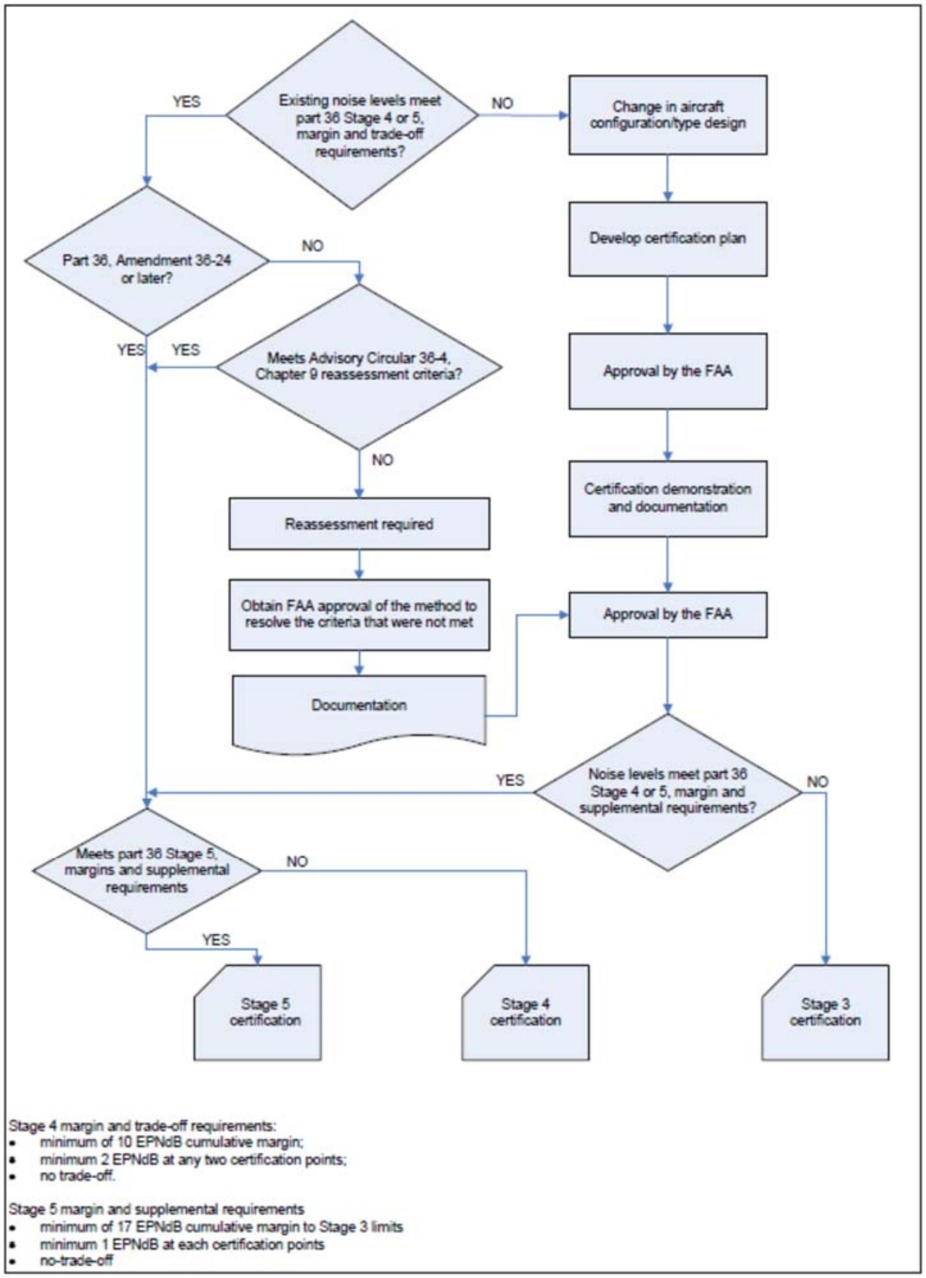

Figure 54. "Road map" for recertification of subsonic jet airplanes

For jet airplanes only:

f) Were the noise measurements conducted at a test site below 1200 ft (366 m), and if not, was a jet source noise correction applied? (See 403(b)(3) of this AC.)

g) Do the engines have bypass ratios of more than 2, and if not, was the peak lateral noise established by undertaking a number of flights over a range of heights? (See 402(a)(1)(C) of this AC.)

h) In the event that "family" certification methods were used, were the 90 percent confidence intervals for the pooling together of flight and static engine test data established according to the guidance in this AC? (See 305(c) of this AC.)

i) Do the engines have bypass ratios of 2 or less, and if not, in the event that "family" certification methods were used, did all associated static engine tests involve the use of a turbulence control screen (TCS) or ICD? (See 402(a)(3)(C)(ii) of this AC.)

For propeller-driven airplanes only:

j) Were symmetrical microphones used at every position along the lateral array for the determination of the peak lateral noise level? (See B36.3(a)(1) of part 36, Amendment 36-24.)

k) Was the approach noise level demonstrated at the noisiest configuration? (See B36.7(c)(5) of part 36, Amendment 36-24.)

l) Was the target airspeed flown during the flight tests appropriate to the actual test weight of the airplane? (See 402(a)(1)(B)(i) of this AC.)

902(c) Recertification from Stage 2 to Stage 4 or Stage 5 [ETM 9.2.3]

Many aircraft originally certificated to the standards of Stage 2 of part 36, may have already been recertificated to the standards of Stage 3. In such a case the approved Stage 3 noise levels may be assessed for compliance with Stage 4 or Stage 5 according to the criteria of 902 of this Chapter. For a Stage 2 aircraft not already recertificated to Stage 3, noise data originally developed to demonstrate compliance with the requirements of Stage 2 should first be corrected in an approved manner to the requirements of Stage 3 part 36, through Amendment 36-24, before the aircraft is assessed against the requirements of Stage 4 or Stage 5.

In the assessment of data submitted in support of an application for the recertification of an airplane from Stage 2 to Stage 3, the recommendations of 903(b)(1) should be followed.

902(d) Recertification from Part 36, Stage 3 to Stage 4 or Stage 5 [ETM 9.2.4]

Noise levels already approved to part 36, Stage 3, and submitted in support of applications for recertification of existing aircraft to Stage 4 should be assessed against the criteria presented as follows.

For Stage 3 airplanes that were approved in accordance with part 36, Amendment 24 (effective date 7 August 2002) or later, the only assessment criterion of 902(b) of this AC that may not have been satisfied is criterion g). Aside from consideration of criterion g), the existing approved part 36, Stage 3, noise levels of the airplane should be used to determine compliance with Stage 4 or Stage 5.

For Stage 3 airplanes that were approved in accordance with Amendments 36-7 through 36-23 of part 36, in addition to the reassessment criteria of 902(b) of this Chapter, the following criteria should also be considered:

a) Was the speed component of the EPNL duration adjustment determined by using 10 log V/V_r? (See A36.9.3.3.1 of part 36, Amendment 36-24.)

b) For derivative engine certifications using static engine test procedures, is the summation of the magnitudes, neglecting signs, of the noise changes for the three reference certification conditions between the “flight datum” airplane and derived version not greater than 5 EPNdB, with a maximum 3 EPNdB at any one of the reference conditions? (See 402(a)(3)(C) of this AC.)

Note.— These limitations may be exceeded under the circumstances described in 402(a)(3)(B) of this AC.

903 RECERTIFICATION GUIDELINES FOR “MODIFIED”AIRPLANES [ETM 9.3]

An existing airplane may have been approved with Stage 3 certification noise levels that are higher than the maximum levels required by Stage 4. For such an airplane to be considered for recertification to Stage 4 or Stage 5, it will be necessary to “modify” the airplane in order to lower its noise levels below the limits required by Stage 4 or Stage 5. In order for the FAA to evaluate applications for recertification of “modified” airplanes in a consistent manner, the guidelines described in this section should be followed. These guidelines will be developed to cover other “modification” possibilities.

903(a) Operational Limitations [ETM 9.3.1]

Operational limitations may be imposed on a recertificated aircraft as a condition of compliance with the new noise certification requirements. In this context, an “operational limitation” is defined as a restriction on either the configuration or manner in which an aircraft may be flown .

903(a)(1) Flap deflection [ETM 9.3.1.1]

For the noise certification demonstration on approach:

a) Only the most critical flap deflection (i.e., that which gives the highest noise level) must be certificated. Noise levels for other flap deflections may be approved only as supplementary information and should be determined in conformity with B36.7(c) of part 36, through Amendment 36-24 by using the same demonstrations as for the most critical flap deflection.

b) Typically for a jet airplane, the most critical flap configuration is associated with the maximum flap deflection. If the aircraft in its original state cannot comply with the requirements at the maximum flap deflection or, if an applicant wishes to have an aircraft certificated at less than maximum deflection, the flap deflection must be limited by means of a physical limit which, for the sake of prudence, may be frangible. A simple flight manual limitation is not acceptable. It is permitted to exceed the frangible limit only in the case of an emergency situation, defined here as an unforeseen situation which endangers the safety of the airplane or persons, necessitating the violation of the operational limitation. In such cases the frangible device must be replaced according to established maintenance practices and the replacement recorded in the aircraft log before the next flight. Reference to emergency exceedance of the frangible limit must be incorporated into only the emergency procedures section of the AFM.

c) It is necessary to actually fly the approach profile defined in B36.3(c) of part 36.

d) It should be noted that in the case of a recertificated propeller-driven airplane, the most critical flap configuration may not be associated with the maximum flap deflection, and all normally permitted flap deflections must be flown in order to determine the noisiest configuration.

903(a)(2) Propeller speed
[ETM 9.3.1.2]

The demonstration of the certification noise level on approach must be made with the aircraft in its most critical configuration (i.e., that which produces the highest noise level). For propeller-driven airplanes, the configuration includes the propeller rotational speed. For a recertificated propeller-driven airplane, only the noisiest propeller speed defined for normal operation on approach may be approved. It should not be acceptable to define an alternative normal procedure using a different "quieter", typically slower, propeller speed. A noise level for such a procedure may be approved as supplementary information only.

903(a)(3) Maximum authorized takeoff and landing weight
[ETM 9.3.1.3]

It may be possible to lower the certification noise levels of an airplane by lowering its maximum authorized takeoff and/or landing weight. An individual aircraft must be certificated at only one pair of maximum takeoff/landing weight at any one time. Noise levels for other takeoff/landing weight may be approved only as supplementary information.

903(a)(4) Takeoff thrust de-rate
[ETM 9.3.1.4]

If a de-rating in takeoff thrust is used, a method for control of this thrust is required. The methods that may be available, at the discretion of the FAA, could include a physical or electronic control, engine re-designation, and a flight manual limitation. De-rated takeoff thrust defined for noise purposes must be equal to the takeoff operating thrust limit for normal operation and may be exceeded in an emergency situation. In all cases the flight manual limitations and performance sections must be consistent.

903(b) Demonstration Methods
[ETM 9.3.2]

903(b)(1) Demonstration of lateral noise measured at 650 m
[ETM 9.3.2.1]

The location of the noise measurement points for measuring lateral noise is defined in B36.3(a)(2) of part 36 as being along a line parallel to, and 2133 ft (650 m) from, the extended runway centerline. In the case of an airplane recertificated to Stage 4 or Stage 5, but initially certificated as Stage 2, lateral noise data taken at a lateral offset of 2133 ft (650 m) are acceptable only if they are corrected to an offset of 1476 ft (450 m) by means of the "integrated" method of adjustment. In such cases, at any particular time, the "measured" and "reference" acoustic emission angles must be the same.

903(b)(2) Center of gravity position during takeoff
[ETM 9.3.2.2]

The demonstration of approach noise level must be made with the aircraft in its most critical configuration (i.e., noisiest). Configuration includes the location of the center of gravity position which, for approach, is most critically fully forward. No such restriction exists for the demonstration of takeoff noise levels, and the applicant is therefore free to select any configuration provided it is within the normal limits defined in the flight manual. In the case of a recertificated airplane, the center of gravity position used in the definition of the reference takeoff profile must be within the normal certificated range.

Appendix 1. GENERAL REFERENCES

G1. FAA Order 1050.1E, *Policies and Procedures For Considering Environmental Impacts*, (Change 1, March 20, 2006), or current version

G2. Public Law 103-272, *Codification of Certain U.S. Transportation Laws as Title 49*, United States Code, Section 44715, July 5, 1994

G3. Advisory Circular (AC) 25-7A, *Flight Test Guide*, (Change 1, June 3, 1999), or current version

G4. FAA Order 8110.4C, *Type Certification Process*, (Change 3, March 24, 2011), or current version

G5. ICAO Committee on Aviation Environmental Protection (CAEP), *Environmental Technical Manual*, (Doc 9501), Volume l, *Procedures for Noise Certification of Aircraft*, First Edition, 2010

G6. FAA Order 8110.37E, March 30, 2011, *Designated Engineering Representative (DER) Guidance Handbook*, or current version

G7. International Civil Aviation Organization (ICAO), *Environmental Protection*, Annex 16, Volume 1, *Aircraft Noise*, Sixth Edition -2011. (Amendment 10, Applicable November 17, 2011)

G8. *Required Aproval level for Part 36 Subpart B and C Equivalent Procedures*, FAA AEE Memorandum, August 19, 1998

Appendix 2. TECHNICAL REFERENCES

T1. Bureau Central de la Electrotechnique Internationale, *Electroacoustics — Instruments for Measurement of Aircraft Noise — Performance Requirements for Systems to Measure One-third-octave-band Sound Pressure Levels in Noise Certification of Transport-Category Aeroplanes,* IEC 61265, April 1995.

T2. Bureau Central de la Electrotechnique Internationale, *Electroacoustics — Octave-band and Fractional-octave-band Filters,* IEC 61260, July 1995.

T3. Bureau Central de la Electrotechnique Internationale, *Electroacoustics — Sound Level Meters*, IEC 61672-1, 2002.

T4. ESDU International plc., *The Correction of Measured Noise Spectra for the Effects of Ground Reflection,* Data Item No. 94035 (Amendment A), December 1995.

T5. Fink, M.R., *Airframe Noise Prediction Method,* USA DOT Report FAA-RD-77-29, Washington, D.C., 29 March 1977.

T6. Laufer, J., R.E. Kaplan and W.T. Chu, "Noise Produced by Subsonic Jets," *Proceedings of the Second Inter-Agency Symposium on University Research in Transportation Noise*, 1974, Volume 1, pp. 50-58.

T7. National Marine Electronics Association, *Standards for Interfacing Marine Electronics Devices,* NMEA 0183, Version 1.5, December 1987.

T8. National Marine Electronics Association, *Standards for Interfacing Marine Electronics Devices,* NMEA 0183, Version 2.0, 1 January 1992.

T9. Radio Technical Commission for Aeronautics, *Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment,* DO-229C, 28 November 2001.

T10. Radio Technical Commission for Maritime Services, *Recommended Standards for Differential Navstar GPS Service,* Paper 194-93/SC104-STD, Version 2.1, January 1994.

T11. SAE International, *Gas Turbine Coaxial Exhaust Flow Noise Prediction,* Aerospace Information Report AIR 1905, December 1985.

T12. SAE International, *Gas Turbine Jet Exhaust Noise Prediction,* Aerospace Recommended Practice ARP 876E, February 2006.

T13. SAE International, *Measurement of Far Field Noise from Gas Turbine Engines During Static Operation,* Aerospace Recommended Practice ARP 1846A, March 2008.

T14. SAE International, *Method for Predicting Lateral Attenuation of Airplane Noise,* Aerospace Information Report AIR 5662, April 2006.

T15. SAE International, *Practical Methods to Obtain Free-Field Sound Pressure Levels from Acoustical Measurements Over Ground Surfaces,* Aerospace Information Report AIR 1672B, June 1983.

T16. SAE International, *Standard Values of Atmospheric Absorption as a Function of Temperature and Humidity,* Aerospace Recommended Practice ARP 866A, March 1975.

T17. Tester, B.J. and V.M. Szewczyk, *Mixing Noise: Comparison of Measurement and Theory*. American Institute of Aeronautics and Astronautics Paper 79-0570, March 1979.

T18. Ueno, Mami, Kazuaki Hoshinoo et al., *Assessment of Atmospheric Delay Correction Models for the Japanese MSAS*, Proceedings of ION GPS, http://gauss.gge.unb.ca/papers.pdf/iongps2001.ueno.pdf, 2001.

T19. United States Coast Guard, *Broadcast Standard for the USCG DGPS Navigation Service,* COMDTINST M16577, 1 April 1993.

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4. Rose, D.M. and F.W. Scholz. *Statistical Analysis of Cumulative Shipper-Receiver Data.* U.S. Nuclear Regulatory Commission, Division of Facility Operations, Office of Nuclear Regulatory Research, Washington, D.C., 1983. NUREG/CR-2819. NRC FIN B1076.

5. Snedecor, G.W. and W.G. Cochran. *Statistical Methods.* 6th ed. Arnes, Iowa: The Iowa State University Press, 1968.

6. Walpole, R.E. and R.H. Myers. *Probability and Statistics for Engineers and Scientists.* New York: MacMillan, 1972.

7. Wonnacott, T.H. and R.J. Wonnacott. *Introductory Statistics,* 5th ed. N.p.: John Wiley & Sons, 1990.

Appendix 4. DOT/FAA ADDRESSES

DOT/FAA Offices, Washington, D.C.:

1. FAA Office of Environment and Energy (AEE-1) Federal Aviation Administration
   Headquarters Building, Room 900W,
   800 Independence Avenue, SW.
   Washington D.C. 20591

2. FAA Office of the Chief Council (AGC-1)
   Federal Aviation Administration Headquarters Building, Room 900E
   800 Independence Avenue, SW.
   Washington D.C. 20591

FAA Noise Certification Specialists:

1. Rotorcraft Noise Certification Specialist (ASW-110)
   Federal Aviation Administration
   Rotorcraft Directorate
   2601 Meacham Boulevard
   Fort Worth, Texas 76137

2. Small Airplane Noise Certification Specialist (ACE-111)
   Federal Aviation Administration
   Small Airplane Directorate
   901 Locust, Room 301
   Kansas City, Missouri 64106

3. Transport Airplane Noise Certification Specialist (ANM-112)
   Federal Aviation Administration
   Transport Airplane Directorate (ANM-100)
   1601 Lind Avenue Southwest
   Renton, Washington 98057-3356

Note.— An applicant must coordinate airworthiness and noise certification activities with the appropriate ACO Office. Assistance in selecting the appropriate ACO Office may be obtained from FAA Directorate, Regional or Noise Certification Specialist Offices.