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Advisory Circular

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NOISE CERTIFICATION TEST AND ANALYSIS PROCEDURES

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FOREWORD

This advisory circular presents test and analysis procedures that have been determined to be technically acceptable means for demonstrating compliance with the FAR Part 36 noise certification requirements for subsonic turbojet aircraft and large transport category aircraft.

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Director of Environment and Energy

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CHAPTER 1. GENERAL

1. PURPOSE. This advisory circular presents test and analysis procedures for subsonic turbojet airplanes that have been determined by the FAA to be a technically acceptable means for demonstrating compliance under Part 36 of the Federal Aviation Regulations.

2. CANCELLATION. Advisory Circular 36.4, Noise Certification Test and Analysis Procedures, dated October 27, 1983, is cancelled.

3. BACKGROUND. Part 36 contains standard noise certification procedures for turbojets, for large transport category airplanes, and for propeller-driven small airplanes. Those regulations require that the standard procedures must be used unless an equivalent procedure is approved by the FAA. However, airplane noise measurement and analysis technology has developed considerably since Part 36 was adopted in 1969. Further, Part 36 specifically allows the use of "approved equivalent procedures." With the impetus of noise certification, a body of technically sophisticated measurement and analysis methods has been developed by certificate applicants. As a result of this experience, alternative compliance methods have evolved and have been approved by the FAA. This advisory circular presents those procedures which are believed to have general applicability. Prior approval should always be obtained from the responsible FAA certificating official before initiating any noise certification action. It should also be noted that the methods presented in this advisory circular are not the only ways to demonstrate compliance with Part 36 nor the only ones that may be approved in the future.

4. OBJECTIVE. The objective of a compliance program is the demonstration of compliance with Part 36 for a specific airplane version. The demonstration method used to determine noise levels will depend upon a number of factors. For example, Part 36 requires an applicant for a new type design to conduct a noise demonstration flight test. However, for a change to an existing type design, depending upon the extent of the data already in existence for the type design, the applicant may submit for FAA approval a proposal either to conduct a flight test or to conduct supplementary tests and/or analyses. When supplementary data are used they serve as the basis to adjust flight noise levels already approved for an earlier version. Dialogue between the applicant and the certificating authority at the beginning of an airplane program is necessary to identify anticipated changes in airplane type design that can impact noise certification. A noise compliance demonstration plan outlining the planned tests and/or analyses should be submitted ahead of time to the FAA by the applicant. This plan contains the method by which the applicant proposes to show compliance with the noise certification requirements. Because of the unique nature of each noise demonstration, the test plan is reviewed with the certificating authority before each test and, if necessary, modified to incorporate future developments as they evolve. A single test plan, submitted to encompass more than the immediate test, is often advantageous. Guidance on preparation of noise compliance demonstration plans and certification compliance data reports is provided in Appendix 1.

5. NOISE DEMONSTRATION FLIGHT TESTS. As a supplement to the standard procedures detailed in FAR Part 36, this AC presents guidelines on methods to acquire noise data from a sufficient number of flights of a particular airplane to derive the three certificated EPNL levels. Guidelines are also provided on acquisition and normalization methods such that a generalized noise data base (defined by noise-power-distance relationships) may be developed for an airplane type. Procedures for determining the certificated Part 36 noise levels derived from this generalized noise data base are also provided. This generalized data base is directly applicable to changes in type design which retain the same basic noise source characteristics.

6. SUPPLEMENTAL NOISE DEMONSTRATION METHODS. For those applicants seeking approval for changes in type design, guidance is also provided on procedures for determining noise level changes relative to a previously approved version of the type. These procedures rely on supplementary testing and/or analysis techniques in conjunction with approved noise data already available for the type. The use of such methods for demonstrating noise compliance is optional, subject to FAA approval, and does not preclude an applicant from using a flight test for each noise certification demonstration.

7. CHANGES TO NOISE CERTIFICATION LEVELS FOR DERIVED VERSIONS. Many of the equivalent procedures given in this AC relate to derived versions, where the procedure used yields the information needed to obtain the noise certification levels of the derived version by adjustment of the noise levels of the "flight datum" aircraft (i.e., the most appropriate aircraft for which the noise levels were measured during an approved Part 36 flight test demonstration).

The physical differences between the "flight datum" aircraft and the derived version can take many forms, for example, an increased takeoff weight, an increased engine thrust, changed powerplant or propeller types, etc. Some of these changes will alter the distance between the aircraft and the noise certification reference points, others the noise source characteristics. Procedures used in the determination of the noise certification levels of the derived versions will, therefore, depend upon the change to the aircraft being considered. However, where several similar changes are being made, for example, introduction of engines from different manufacturers, the procedures used to obtain the noise certification levels of each derivative aircraft should be followed in identical fashion.

CHAPTER 2. NOISE DEMONSTRATION FLIGHT TEST UNDER PART 36 APPENDICES A AND B

8. <u>TEST CONDITIONS</u>. The airplane is operated such that noise values corresponding to the takeoff, sideline, and approach reference conditions defined in FAR Part 36 can be derived. To meet the test environmental requirements prescribed in Part 36, the following test site and atmospheric conditions have been approved as providing an acceptable test environment.

a. <u>Test Site Characteristics</u>. The noise measurement stations are placed such that the reference locations specified in Part 36 can be adequately simulated. FAR Part 36 prescribes reference noise measurement stations relative to runway brake release or threshold point (e.g., 6500 meters from brake release for takeoff measurements); however, actual test measurement station locations may differ for the following reasons:

(1) To minimize the impact of ambient sound on the measurement of the airplane sound pressure levels. Prior to testing, a comparison of expected airplane sound pressure levels with the expected test-site ambient sound will aid in choosing test microphone locations. It is generally preferable to relocate measurement stations rather than contaminate airplane noise measurements with ambient sound from sources such as nearby road or air traffic.

(2) On takeoff, if necessary to increase the airplane signal-to-noise ratio to ensure adequate measurement of the airplane's acoustic signature. In such cases, the takeoff measurement station and/or the airplane flight trajectory may be relocated so that the test day sound propagation path length is less than the reference path length to ensure acquisition of acceptable data. In the selection of an adequate signal-to-noise ratio, consideration should be given to limitations on corrections for the influence of ambient sound.

(3) When obstructions near the noise measurement station(s) will influence sound measurements. Takeoff and approach measurement stations may be relocated as necessary to avoid undesirable obstructions. Sideline measurement stations (distances) 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 path that occur during flight testing.

NOTE: Flight path intercepts adopted as alternatives to full takeoffs and full stop landings may be adjusted to attain the same performance as would be observed at the reference distances.

b. <u>Atmospheric Conditions.</u>

(1) <u>Temperature and Relative Humidity Limits</u>. When atmospheric conditions of ambient temperature and relative humidity result in atmospheric absorption in the 8 kHz one-third-octave band at any point

along the sound propagation path exceeding 12 dB/100 m, then instrumentation used to determine relative humidity should consist of an ambient air temperature and dew point temperature measurement system accurate to within $\pm$ 0.5°C. When such instrumentation is used, the 8 kHz atmospheric absorption may be extended to 14 dB/100 meters and, for approaches only, to 16 decibels per 100 meters. Relative humidity is required to be between 10 and 95 percent.

(2) Wind Limits. Testing may be conducted when: the wind speed does not exceed an average value, over the sound measurement period, of 12 kts and a maximum value of 15 kts; the crosswind component does not exceed an average value over the sound measurement period, of 7 kts and a maximum value of 10 kts. An averaging period of 30 seconds is used to define average wind speed. Part 36 requires the wind measurements to be made 10 meters above the ground.

9. FLIGHT PROCEDURES.

a. Selection of a Flight Test Noise Demonstration Method. An accurate, reliable definition of the airplane noise characteristics is the primary objective of the demonstration test. To achieve this goal, at least six sound measurements are required by paragraph A36.5(e) to ensure that a mean noise level for each of the three certification reference conditions can be defined with a 90% confidence interval not exceeding $\pm$ 1.5 EPNdB. This requirement can be achieved by conducting a series of test flights at or near reference power. After adjusting each measured noise level to Part 36 reference conditions, a certification noise value should be computed by averaging the adjusted levels (see paragraph 13). An alternate method is to acquire sufficient measurements (at least six) to allow the generalized noise characteristics of the airplane to be developed (a noise-power-distance data base (NPD)). (See paragraph 13(e)(2)). The three certification levels for any specific configuration are then determined by entering the developed data base at the certification reference distance and power and applying appropriate airplane speed corrections.

(1) For a range of powers covering full and cut-back powers, the airplane is flown past sideline and under-flight-path microphones in accordance with Section C36.3 of Part 36. Sufficient noise measurements are made to enable noise-power curves at a given distance for both sideline and takeoff cases to be established. These curves are extended either by calculation or by the use of additional flight test data to cover a range of takeoff distances to form the generalized noise NPD data base for use in the noise certification of the "flight datum" and derived versions of the type. The 90% confidence intervals about the mean lines are constructed through the data. This sequence should be repeated for an under-flight-path microphone for a range of approach powers using the appropriate speed and airplane configuration.

(2) When approved data are available to define the engine spool down characteristics, it may be appropriate to substantiate noise levels for cutback power without the implementation of a cutback takeoff procedure by making noise measurement during reduced power operations. Engine spool down time should be representative of average conditions and should reflect a 1.0 second minimum altitude-recognition lag time to account for pilot response. For determination of the reference cutback noise levels, the cutback initiation should be selected to ensure stabilized cutback power conditions before the initial 10 PNdB down point.

(3) The airplane's source noise characteristics should be measured over the operating range in sufficient detail to define the difference between test and reference day source noise. To aid in obtaining adequate data for these adjustments it may be necessary to identify those airplane/engine parameters, e.g., $N_1/\sqrt{\theta_{t2}}$ for jets, that are the major controllers of the airplane's noise level and appropriately vary these parameters during the test. For propeller-driven airplanes, the engine parameters are propeller helical tip Mach number and shaft horsepower.

b. Nominal Conditions for Development of a Reference Noise-Power-Distance Data Base (NPD). For the development of a generalized NPD, SPL data are normalized to the ambient environmental conditions specified in Part 36 and to nominal takeoff and approach aerodynamic configurations and performance. For example, the selected airplane speed should be representative of the range of speeds for the configurations and weights which are anticipated to be certified. In addition, takeoff and approach configurations may be different; requiring normalizing SPL data to different airplane speeds. Note that the adjustment procedure requires FAA approval when developing an NPD. (See paragraph 12(c) of this advisory circular.) An example of a generalized NPD is shown in Figure 1.

c. Measurements at Non-reference Points. In some instances test measurement points may differ from the reference measurement points in Part 36, Appendix C. Under these circumstances an applicant may request approval of data that have been adjusted from the actual measurements to represent data that would have been measured at the reference points in reference conditions.

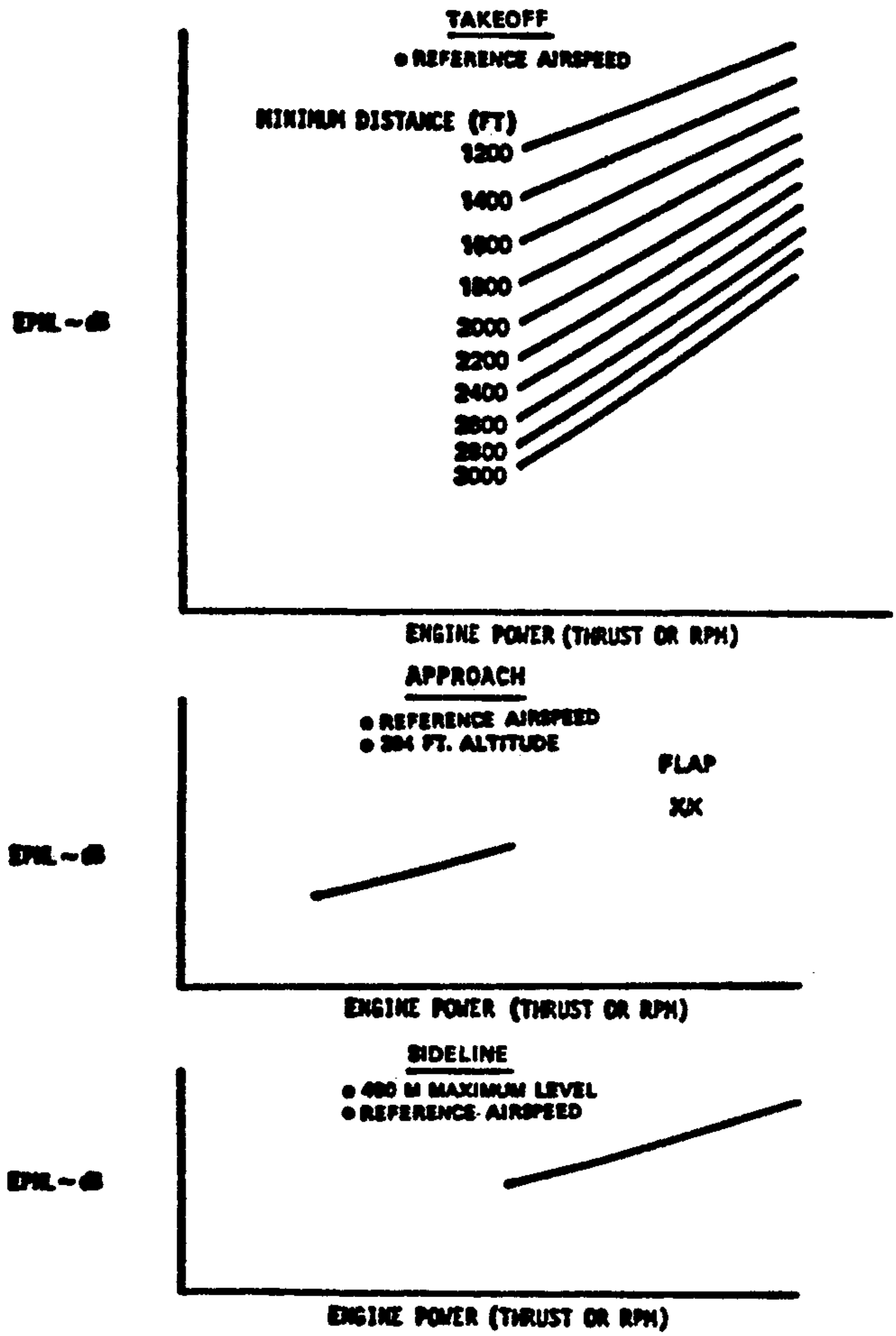
Reasons for such a request may be:

(1) 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;

(2) to enable the use of an existing, approved certification data base 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;

FIGURE 1

EXAMPLE OF GENERALIZED NOISE POWER DISTANCE DATA BASE



(3) to avoid obstructions near the noise measurement stations(s) which could influence sound measurements. By using a flight path intercept technique, takeoff and approach noise measurement stations may be located as necessary to avoid undesirable obstructions. Sideline measurement stations 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 and limitations of Part 36, Appendices A and B.

d. Test Day Flight Procedures. Airplane weight and flight trajectory can be properly simulated by controlling those parameters most directly related to the airplane/engine noise source strength and directivity. Test day flight procedures should be chosen to provide an adequate definition of the airplane noise source characteristics. The selection of test day flight procedures will depend upon the methodology chosen to derive certification noise levels, i.e., either by repeating the reference conditions or from an NPD.

(1) Test Day Procedures. Selection of test day flight procedures should be compatible with the methodology chosen to derive certification noise levels. If an applicant chooses to derive certification noise levels by averaging at least six conditions flown at or near reference power and distance, then corrections should account for differences in airplane source noise between test and reference airplane power settings. To qualify these corrections, testing at other operating conditions may be required to define in sufficient detail the airplane source noise levels. This testing may be in addition to the number of measurements at or near reference power necessary to achieve a 90% confidence interval not exceeding $\pm$ 1.5 EPNdB. The applicant may, however, choose to derive the certification noise level directly from a generalized NPD. The NPD is developed by conducting a sufficient number of sound measurements over a range of airplane operating conditions so that the 90% confidence interval about a mean line does not exceed $\pm$1.5 EPNdB. To describe a power line an applicant should conduct a minimum of six flights, each at a different power setting, at a common target altitude. To attain the required confidence interval, more than six flights may be necessary. Typically, the power-related parameter which governs noise generation is corrected low pressure rotor speed, $N_1/\sqrt{\theta_{t2}}$, corrected net thrust, Fn/δ_{amb}, or EPR, where:

N_1 is the actual low pressure rotor speed,

θ_{t2} is the ratio of absolute static temperature of the air at the height of the airplane to the absolute temperature of the air for an international standard atmosphere (ISA) at mean sea level (i.e., 288.15°K)

EPR is engine pressure ratio.

F_n is the actual engine net thrust per engine, and

δ_{amb} is the ratio of absolute static pressure of the ambient air at the height of the aeroplane to ISA air pressure at mean sea level (i.e., 101.325 kPa).

(2) Simulated Takeoffs and Approaches. Where shown by the applicant to be equivalent to the procedures specified in Part 36, simulated takeoffs and approaches, consisting of flight path intercepts may be used in lieu of starting and ending each flight from a full stop. For takeoff, flight path intercepts consist of intercepting and following the desired climb profile beginning at a target distance above ground level. Approach intercepts maintain the approach path over the measurement location without actually landing. In either case, the airplane is stabilized and following the target trajectory throughout the sound measurement period. (The sound measurement period includes levels within 10 PNdB below the maximum.) Test airplane weights, speeds and aerodynamic configurations should be selected to allow achieving target test conditions for those performance parameters having the major effect on noise generation.

e. Target Test Conditions. Target test conditions can be established for each sound measurement. These target test conditions will define the selected aerodynamic configuration, airplane weight, flight procedure (such as takeoff flight path intercept), altitude, power and airspeed at the closest point of approach to the measurement location. For example, a takeoff aerodynamic configuration may be defined by the climb gradient and flap setting. Note: The airplane angle of attack will remain approximately constant for all weights if the tests are conducted at a constant flap setting and the airplane speeds correspond to the reference speed, V_2 + 10 kts for each weight. The aerodynamic configuration, e.g., flap setting, should remain constant during the sound measurement period. Speed corrections, however, are generally permitted up to 15 kts. Alternatively, for many airplanes the airplane attitude remains approximately constant for all weights if the tests are conducted at the V_2 + 10 kts for the maximum takeoff weight. In the execution of the flight for purposes of obtaining sound meaurements, the pilot should "set up" the airplane with the selected configuration in order to pass by the measurement location at the target altitude, power and airspeed.

10. MEASUREMENTS. This section provides guidelines on how to obtain sound measurements, relevant airplane position and performance data necessary for normalizing the measured sound data to conditions differing from the actual test day conditions. All of these are synchronized.

a. Sound Measurements.

(1) All sound measurements are made with equipment meeting the specification in Part 36. The measurements are made such that, when processed, they will provide one-third-octave band sound pressure levels as a function of time for the calculation of Effective Perceived Noise Level (EPNL).

(2) Microphones should be located at the certification reference height of 1.2m(4 ft) above the ground surface. In some cases, such as for pseudotone identification, it may be desirable to obtain additional data exhibiting free-field spectral shapes by selecting a microphone location to minimize the interference effects of ground reflections on the measured sound spectra (see Appendix 3 of this advisory circular). Free field spectral shapes can be obtained by:

(a) mounting the microphone high above the ground so that the first interference frequency falls below the range of interest. A height of 10 m (33 ft) is generally adequate.

(b) mounting the microphone diaphragm in the plane of, or very close to, a large, acoustically hard (reflective) ground-plane surface so that the direct and reflected waves arrive in phase causing a doubling of the sound pressure.

(3) Orientation of the microphone will depend on the microphone type. Most commonly used are grazing incidence microphones which are designed so that nearly a flat frequency response is maintained at grazing incidence to the microphone; the microphone is oriented to maintain near grazing incidence throughout the airplane flyover. Perpendicular incidence microphones are designed so that maximum sensitivity occurs when they are oriented so that the sound impinges upon the diaphragm in a perpendicular direction when the airplane is at the closest point of approach. Data obtained using perpendicular incidence microphone are acceptable provided that the data are corrected for directivity and frequency response effects and the maximum noy value for the corrected data is located in the one-third-octave band centered at 5000 Hz or less.

(4) If the airplane sound pressure levels within the sound measurement period do not exceed the background sound pressure levels by at least 10 dB in each one-third-octave band, they may be adjusted to eliminate the additive influence of the background sound. When the airplane sound is less than 10dB, but more than 5 dB above the background, the corrected airplane sound levels are obtained by logarithmically subtracting the background sound levels. For those situations where the airplane levels are less than 5 dB above the background, this influence may be avoided by obtaining measurements at distances closer to the airplane and then adjusting the measurement to the desired distance or by adjusting the measured sound pressure levels using technically supported analytical shaping methods (see Appendix 2 of this advisory). NOTE: If the measurements are not adjusted to delete background noise, the resultant EPNL values will be higher than if measured in the absence of background noise.

(5) Maximum sideline noise may be determined by positioning several measurement stations parallel to the airplane flight track as prescribed in Part 36. An alternative to this method may be to use two measurement stations, symmetically positioned about the nominal flight

track, and fly the airplane at several altitudes and thus simulate the data that would have been acquired during a "climb-out" using a series of measurement stations. Experience suggests that the maximum noise level will occur at an elevation angle near 34 degrees (approximately 1000 ft altitude) and the levels will be rather insensitive within several degrees of this value. When the two-station method is used, the sideline noise for each run is the arithmetic average of the corrected EPNL from each of the two lateral measurement points. The confidence level should be calculated using the method in Appendix 5 (paragraph 2.b).

b. Airplane Position and Performance.

(1) The airplane height and lateral position relative to a fixed location (the nominal flight track along the extended centerline of the runway) should be determined by a method independent of normal flight deck instrumentation. Methods found to be acceptable include radar tracking, theodolite triangulation, laser trajectography, microwave positioning and photographic scaling techniques. Care must be taken when the photographic scaling technique is used to ensure that the airplane position can be reliably related to the sound measurement positions. In the past, inaccuracies in space positioning have been introduced by using hand-held cameras to take single photographs of aircraft supposedly overhead. The aircraft are often off-center from the reference flight path. Firm mounting on a fixed tripod can eliminate some of the sources of possible error and should improve the acceptability of the results.

(2) The airplane position along the flight path can be related to the sound pressure levels recorded at the measurement locations by using synchronized signals. Airplane position should be recorded during the sound measurement period.

(3) Measurements of airplane/engine performance parameters for calculation of test day performance should be recorded throughout the sound measurement period. These measurements should be time-related to the airplane position along the flight path. Examples of parameters for measurement are airplane attitude, engine power setting, climb angle, and airplane speed. Flap position and gear position should be fixed and noted for each test condition.

11. SOUND MEASUREMENT SYSTEM SPECIFICATIONS. The noise certification test should use a quality sound measurement system. Output should be measured in the form of one-third-octave band sound pressure levels covering the frequency range from 45 Hz to 11,200 Hz for each one-half second over the sound measurement period. Included in the measurement system should be components that perform the following functions: transform sound pressure waves to electrical signals (microphones), condition the signals, store signals for later analysis, and retrieve and analyze the signals in terms of one-third-octave band levels as a function of time.

a. Corrections to compensate for instrumentation non-uniform frequency response characteristics should be determined and applied to the sound pressure level data. These should include response characteristics of (a) microphone free field and directivity, (b) windscreen insertion loss and directivity, (c) preemphasis, (d) signal conditioning equipment, (e) data storage and retrieval system, and (f) analysis system. All corrections should be identified, documented, and FAA approved.

b. When selecting sound measurement system components, compliance with requirements may be determined from manufacturers' specifications, user calibrations, or a combination of both. When multiple systems of the same type are used, demonstration of compliance of at least one system is satisfactory. However, this does not preclude the need to perform the system calibrations and checks described in Part 36 and paragraph 11 of this advisory circular. Analysis systems that meet the specifications defined in the following paragraphs have been approved.

12. <u>ANALYSIS SYSTEM</u>. The analysis system may be either analog or digital and provide a root mean square (RMS) sound pressure level in one-half second increments in each of the 24 one-third octave bands having geometric mean frequencies from 50 Hz to 10 kHz. The averaging properties of the integrator may correspond to one of the following:

a. For instruments with exponential averaging characteristics, the requirements for Type 1 sound level meter with "slow" response as defined in IEC 651.

b. For true integrating instruments compliance with the "slow" response as defined in IEC 651 may be demonstrated by combining successive readouts from the data processor. This combination of readouts is required since the effective "slow" response averaging time is greater than the sampling interval. When a true integration system is used, an acceptable alternative to combining "successive" readouts is to set the integration time equal to the sampling interval. The use of this type of data reduction system has required the use of the integrated EPNL method.

13. <u>SOUND MEASUREMENT EQUIPMENT CALIBRATIONS AND SYSTEM CHECKS</u>. Part 36 requires calibration of the sound measurement system. This section describes approved procedures to calibrate and check the complete measurement system. These procedures provide guidance which ensures proper equipment peformance over the frequency range from 45 Hz to 11.2 kHz.

a. <u>Frequency Response</u>.

(1) The free-field frequency response characteristics of each microphone are determined by a pressure response calibration (which may be obtained from an electrostatic calibrator) in combination with manufacturer provided corrections or by a free-field calibration in an anechoic facility. The directivity response characteristics of the microphone need to be defined and cover a sufficient angular range to encompass the sound measurement period.

(2) Within 5 days of test the electrical response characteristics of each measurement system, excluding the microphone and windscreen, should be determined at a level within 10 dB of the full-scale reading used during the test, using one of the following input signals: sine waves at the center frequency of each one-third-octave band, or pink noise. Sufficient determinations are made to ensure that the overall calibration of the system is known for each test. The calibration signal generator should have been checked within six months of the test series with instruments which meet standards set by the National Bureau of Standards.

b. Amplitude

(1) An acoustic calibration of the system, including the microphone, should be performed in the field at least once every 5 days. The acoustic calibration should contain a reference signal of known amplitude and frequency in order to provide correlation with the calibrated sound pressure level. A pistonphone operating at a nominal 124 dB (re: 20 pa) and 250 Hz is generally used. In addition, immediately before and after each days testing, a recorded calibration of the system can be made in the field by injecting a 250 Hz sine wave signal into each microphone preamplifier.

(2) Each magnetic tape reel should contain a reference signal of known amplitude and frequency in order to provide correlation with the calibrated sound pressure level. The reference signal (which represents a known sound pressure level) is generated when the acoustic calibrator is in the proper position over the microphone or an electrical signal of known amplitude is inserted into the tape recorder.

14. COMPUTATION OF EFFECTIVE PERCEIVED NOISE LEVEL (EPNL). SPL data used in compliance demonstrations should be corrected to the airplane and environmental reference conditions prescribed in Part 36. Methods to determine a corrected EPNL at each measurement location for evaluating compliance with Part 36 noise level requirements are provided in this section.

a. Data Processing. Before computing an EPNL, the measured SPL, meteorological, and airplane position and performance data acquired as described in paragraph 9 should be reviewed to ensure there are no anomalous data. However, it should be noted that Part 36 requires that no data may be omitted without specific FAA approval. Measured data should be processed in accordance with the guidelines provided below.

(1) Sound Pressure Level Data. Sound pressure levels for each of the one-third-octave bands covering the frequency range from 45 Hz to 11200 Hz can be provided for each one-half second over the sound measurement period by analyzing measured signals with equipment that is consistent with the performance specifications defined in paragraph 10. Corrections for instrument responses, as described in paragraph 12 (such as frequency response), should be taken into account during the data

processing. Measured SPL data may be adjusted to account for the presence of the following undesirable data contamination. (NOTE: If the measurements are not adjusted to delete the presence of contamination the resultant levels will be higher than if measured in the absence of such contamination.)

(a) Extraneous Sound Sources. Contamination of the measured airplane-generated signal may occur occasionally due to the presence of extraneous sound sources. Examples of such sound sources include birds chirping in the vicinity of the microphone or tape anomalies (tape anomalies can be caused by an infrequent, temporary loss of the FM carrier signal). The measured SPL's may be adjusted to reflect the SPL which would have been measured in the absence of the extraneous source. Where appropriate, spurious one-third-octave band spectrum levels may be replaced by linear interpolation of adjacent, uncontaminated spectral levels.

(b) Background Noise Corrections. The resultant airplane sound pressure level values, after adjustment, should correspond to the sound pressure levels which would have been measured under test conditions in the absence of any background noise. As discussed in paragraph 10(a)(4), sound pressure levels recorded during the airplane flyover and which do not exceed the mean background noise sound pressure levels by at least 5 dB, or the analyzer floor by 1 dB, may be adjusted using a technically supported analytical shaping method. Acceptable methods are provided in Appendix 2.

(c) Pseudotone/Fictitious Tone Identification. Spectral irregularities resulting from ground plan reflections, known as pseudotones, or any spectral irregularities other than those resulting from airplane sound, known as fictitious tones, may be excluded from the tone correction evaluation in the EPNL calculation. Acceptable methods for identifying pseudotones/fictitious tones are provided in Appendix 3 of this advisory circular.

(2) Airplane Position and Performance Data. Representative airplane position and performance data for the sound measurement period should be computed for each measurement location.

(3) Meteorological Data. The ambient air temperature and relative humidity values which are used for the computation of the atmospheric absorption of sound, are those which are representative of the atmospheric conditions over the sound propagation path at the time of each sound measurement. An absorption value determined from the meteorological data acquired at 10 m (33 feet) provides an adequate representation of the atmospheric conditions, if the absorption coefficient in the 3150 Hz one-third octave band does not vary more than ± 0.5 dB/100 m over the sound propagation path corresponding to the maximum PNLT. When the

atmospheric absorption coefficient in the 3150 Hz one-third-octave band, over the sound propagation path relative to the PNLTM varies more than $\pm$ 0.5 dB/100 m, then "layered" sections of the atmosphere should be used to compute equivalent weighted sound attenuations in each one-third-octave band. The arithmetic average of values of the atmospheric absorption coefficients at the top and bottom of each layer should be used to represent the sound path atmospheric absorption rate for each layer.

b. Test Day EPNL. Using the SPL data, corrected for instrumentation and background noise and processed in a manner described in 13(a), an EPNL corresponding to test day conditions should be calculated per the method provided in Part 36, Appendix B. To reduce the influence of random spectral irregularities, one or more of the correction methods provided in Appendix 3 of this advisory circular may be used to meet the requirements of Part 36, Appendix B.

c. Normalized EPNL. Measured SPL data are normalized to the reference ambient conditions specified in Part 36 and to nominal airplane position and engine performance conditions. Nominal airplane position and engine performance data should be derived by using approved aerodynamic performance data at the reference ambient conditions. The measured SPL data should be corrected for the effects caused by differences between test day and nominal conditions. The corrections account for the effects of atmospheric absorption, sound propagation distance airplane speed, and airplane source noise. A normalized EPNL should be calculated using either the "simplified" or "integrated" adjustment methods as described in Part 36, Appendix A (A36.11(f)) for takeoff. The integrated method has been extended to sideline and approach noise measurements for some applications. However, the "simplified" method should generally be used for adjusting sideline noise measurements. Some NPD procedures have required the use of the integrated adjustment method. When an array of sideline microphones located on one side of the airplane flight path is used, the maximum sideline noise level and the associated airplane altitude should be determined from a least squares polynomial regression of sideline noise as a function of airplane altitude. The regression curve, and thus the maximum sideline noise, is adjusted by an amount equal to half the difference between noise levels observed at the symmetric sideline locations. When the airplane is flown past two symmetrical microphones at several altitudes, the average of the two microphone levels is used as the datum for each flight.

d. Duration Correction for Simplified Adjustment Method. When calculating a normalized EPNL using the "simplified" method of adjustment, a duration correction may be applied as follows:

$$\Delta 2 = -7.5 \log (DM/DR)$$

where: DM is the minimum distance to the measured flight path for takeoff and approach. For sideline, DM is the measure sound propagation distance associated with maximum PNLT.

DR is the minimum distance to the reference flight path for takeoff and approach. For sideline, DR is the reference sound propagation distance for maximum PNLT.

e. <u>Reference EPNL Evaluation</u>. Reference EPNL values for each of the three certification reference measurement locations and their 90% confidence intervals can be produced from the test results and reported. Guidance on confidence interval computations is provided in Appendix 5. No test result should be omitted in the evaluation of the reference EPNL unless otherwise specified by the certificating authorities. Applicants should meet the 90% confidence interval as required by A36.5(e)(2) not to exceed $\pm$ 1.5 EPNdB.

(1) <u>Average of Clustered Flight Conditions</u>. For each measurement location, one method for demonstrating compliance with the 90% confidence interval requirements is to conduct a series of sound measurements at prescribed flight conditions. A minimum of six flight conditions may be conducted at or near reference power or at judiciously spaced intervals surrounding the reference power. Measured SPL data for each flight condition should be normalized to reference ambient conditions and to reference airplane position and performance accounting for the effects of atmospheric absorption and sound propagation distance. These normalized values of SPL should be used to compute EPNL. Values of EPNL should be further corrected to account for differences between test and reference airplane speed and source noise. Source noise level corrections may be derived from approved supplemental data acquired in addition to the test flights clustered around the reference power. The resulting EPNL's for all flight conditions at a measurement location are arithmetically averaged to drive a single reference EPNL value. The corrections may be derived solely from the test fights provided the test flight conditions were conducted at intervals surrounding the reference power such that the source noise level versus power setting is defined. In this case, the resulting EPNL's at a measurement location are obtained using the NPD methods in the following paragraph.

(2) <u>Noise-Power-Distance Data Base</u>.

(a) An alternate method of demonstrating compliance with the 90% confidence interval requirements is achieved by developing an NPD. The NPD should be developed by conducting a series of flights, each at a different airplane operating condition, while maintaining the same aerodynamic configuration. The measured sound pressure level data for each power condition should be normalized to the reference ambient conditions and specified airplane position and performance. The normalized sound pressure level data are used to compute values of EPNL. For each measurement location, the nominal airplane position and performance will be obtained for each selected aerodynamic configuration.

The EPNL at each power condition is then normalized to an array of minimum distances. All correction techniques in paragraph 13(c) should be applied except the source noise correction which is not applicable in the development of the NPD data base.

(b) For each array of EPNL and power values, corresponding to a common airplane to ground minimum distance, a mean line and the 90% confidence intervals about the line should be computed. This mean line as shown in Figure 1, is obtained from a first or second order least-squares polynomial regression analysis. The reference EPNL value should be derived by entering the NPD at the reference location, aerodynamic performance conditions of power and minimum distance and applying a duration correction to account for the difference between the nominal airplane speed used in development of the NPD and the reference airplane speed. To minimize errors introduced in the speed correction process, it is generally best to hold the variations in test speed around the reference values to less than 15 knots.

(3) Procedures for the Determination of Changes in Noise Levels. 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 comparison to the noise levels of the flight datum airplane. These noise changes should be added to or subtracted from the noise levels obtained from individual flights of the "flight datum" airplane.

CHAPTER 3. SUPPLEMENTAL NOISE DEMONSTRATION METHODS UNDER PART 36 APPENDICES A AND B

15. ALTERNATIVE METHODS. This chapter provides guidance on alternative methods for deriving noise levels in support of Part 36 compliance demonstration for airplanes that result from a change in type design. The methods addressed are ground static engine testing, supplemental flight testing, analytical adjustment and component testing. Although emphasis is placed on deriving noise increments suitable for adjustment of a Noise-Power-Distance (NPD) data base derived according to the methods outlined in Chapter 2, the guidance provided is also applicable to adjustment of singular noise levels at any of the three Part 36 reference locations. Approval of equivalent procedures for the use of static test information depends critically upon the availability of an adequate approved data base acquired from the flight testing of the flight datum airplane. For each application the FAA will review the technical validity of the existing certification noise levels/NPD to ensure the data base is sufficient for derivation of certification noise levels for airplanes resulting from a change in type design.

a. To satisfy the acoustical change requirements of FAR Part 21.93(b), noise compliance for an airplane resulting from a change in type design, in many instances, has been approved based on compliance demonstration by methods that did not require conducting a noise demonstration flight test. In these instances noise level increments between two airplane versions were derived using supplemental test and/or analysis techniques. The results of these analyses were used to demonstrate either no acoustical change, or to establish certification noise levels for the changed airplane version. Certification noise levels for a derived version are determined by applying the appropriate noise increments to noise levels already approved for the airplane prior to the design change provided that the data are within the required confidence interval. This adjustment of previously approved noise levels may be made either at the specific Part 36 reference points or, more generally, to an approved NPD for the type design from which Part 36 noise levels may be derived.

b. Noise increments for certain changes in type design can be established by a specific supplementary demonstration method; for example, noise increments due to airplane performance changes may be assessed using an approved NPD analysis. The available supplementary demonstration methods should be reviewed for the most appropriate method based on the guidelines in this advisory circular. The use of these methods for demonstrating noise compliance is discretionary and does not preclude an applicant from conducting a noise demonstration flight test for a noise certification demonstration.

16. TECHNICAL CONSIDERATIONS. Selection of a supplementary noise demonstration method for a specific change of type design depends upon a number of general technical considerations. The technical items common to

each demonstration method are discussed in this section; technical items associated with a particular type of supplemental demonstration method are provided in the respective sections.

a. Examples of Demonstration Applications. The nature of the change in type design may limit the selection of appropriate supplementary noise demonstration method(s). Examples of the application of supplementary methods are provided in Figure 2. The list is not comprehensive, and, for a specific type change, more than one method may be technically valid.

b. Noise Source Characteristics.

(1) For type changes which retain the same basic noise source characteristics as the approved version, certification noise levels may be derived directly from the approved NPD; for example, noise increments resulting from airplane aerodynamic performance differences can be obtained directly from the NPD by using analytical methods described in Section 19(a).

(2) The nature of some type changes may or may not constitute a change in the basic airplane noise source characteristics. In such cases, the approved NPD may be acceptable for deriving noise increments if supporting data or analyses are provided which demonstrate that the noise source characteristics remain unchanged. For a power rating extension, a certification noise level may be directly derived from a NPD, which has been extended using approved analytical techniques.

(3) For type change which may result in changes to the basic noise source characteristics, modifications to the approved NPD may be incorporated through use of one of the supplementary methods described in this AC. Noise level increments representative of the differences between the reference and changed version should be algebraically added to the approved NPD values. A new engine type or nacelle are examples of changes in type design which may change the basic noise source characteristics.

(4) For some type changes which may result in altering the basic noise source characteristics, adjustments may be made directly to the approved flight levels. These adjustments reflect the noise difference between two nacelle and/or engine configurations and may be applied to the approved flight levels as one-third-octave band adjustments or as EPNL adjustments. Application of this method follows the same procedures as defined for adjusting an NPD data base, except it is applicable only to a discrete airplane flight condition.

c. Noise Increment Derivation Using Common Demonstration Method. To ensure derivation of the correct noise increment between two different airplane configurations, the supplemental test and analysis methods used for both the previously approved and changed version should be of the same type. This avoids discrepancies that can occur from merging differing methods. The demonstration method is designed to provide noise levels representative of those occurring with production hardware (e.g., engine and nacelle).

FIGURE 2

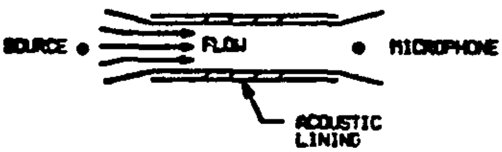
POSSIBLE APPLICATIONS OF SUPPLEMENTAL NOISE DEMONSTRATION METHODS

DEMONSTRATION BASIS | **EXAMPLE OF CHANGES IN TYPE DESIGN**

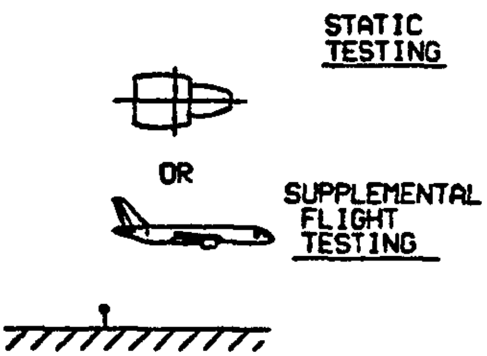
ANALYSIS

- AIRPLANE AERO-PERFORMANCE CHANGES (e.g., Gross Weight, Flap, Fuselage, etc.)
- ENGINE THRUST AND/OR RATING CHANGES
- MINOR MODIFICATIONS TO ENGINE
- MINOR MODIFICATIONS TO ENGINE NACELLE

COMPONENT TESTING



- ENGINE COMPONENTS (e.g., Jet, Fan, etc.)
- ACOUSTIC TREATMENT CHANGES



- ENGINE REDESIGN (e.g., New Fan Design)
- NEW ENGINE OF COMPARABLE TECHNOLOGY
- NEW ENGINE NACELLE
- NOISE SUPPRESSION DEVICE (e.g., Exhaust Gas Mixer)
- ACOUSTIC TREATMENT CHANGES

NOTE: THIS LIST IS NOT COMPREHENSIVE AND FOR A SPECIFIC TYPE CHANGE, MORE THAN ONE DEMONSTRATION METHOD MAY BE TECHNICALLY VALID.

d. Supplemental Test Data Compatibility. The application of a noise demonstration method depends upon the compatibility with data previously acquired. Items which should be considered include test hardware, test and analysis procedures, test site and configuration.

e. Component Noise Sources. The airplane noise source components affected by the change should be considered in determination of the best method for the evaluation of changes to the total airplane source noise characteristics. Parameters controlling the component noise source generation mechanisms and directional characteristics should be identified in order to assess the noise sensitivity of each component source. For example, when the total airplane noise characteristics are dominated by one source, such as the low speed rotor, the use of component test results, in combination with a component noise source analysis, may be an appropriate method to demonstrate noise increments.

f. Noise Increments Caused by Nacelle Acoustic Treatment Changes. Noise increments caused by nacelle acoustic treatment changes made to noise certified aircraft can be empirically derived by coupling data from static engine noise tests with data from certification flyover noise tests. The noise increments, in EPNdB, can be determined by applying the difference in measured spectra between the two nacelle treatments to measured one-third-octave band sound pressure levels in flight at the same directivity angle. If the modified nacelle treatment produces levels lower than the existing nacelle treatment, noise generated by the airframe should be considered in determining the dominant noise source.

17. STATIC ENGINE TESTS. Data acquired from static tests of engines incorporating similar designs to those that were flight tested may be projected, where appropriate, to flight conditions and, after FAA approval, used to supplement an approved NPD for the purpose of demonstrating compliance with Part 36 in support of a change in type design. This section provides guidelines on static engine test data acquisition, analysis and normalization techniques. The information provided is used in conjunction with the technical considerations in paragraph 15 and the general guidelines for test site, measurement and analysis instrumentation and test procedures provided in SAE AIR 1846, "Measurement of Noise from Gas Turbine Engines During Static Operation." The engine designs and the test and analysis techniques to be used should be presented in the test plan and submitted to the FAA for concurrence prior to test conduct. It should be noted that test restrictions defined for flight testing in conformity with Part 36 are not necessarily appropriate for static testing. For example, the distances associated with atmospheric absorption for static tests are substantially less than those encountered in flight testing and thus may require different criteria.

a. Limits on the Projection of Static to Flight Data. The amount by which the measured noise levels of a derivative engine will differ from the reference engine is a function of several factors, including:

(1) thermodynamic changes to the engine cycle, including increases in thrust;

(2) design changes to major components, e.g., the fan, compressor, turbine, exhaust system, etc;

(3) changes to the nacelle.

Additionally, day-to-day and test site-to-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.

While the FAA does not impose a fixed numerical limit on the amount of extrapolation from reference to derivative engines, it is important for the approving authority to consider whether there are practical limitations to proposed extrapolation techniques and at what point new flight test data may be required.

b. Test Site Requirements. The test site should meet at least the criteria specified in SAE AIR 1846. Different test sites may be selected for testing the subject configurations provided the test sites approved by the FAA are acoustically similar. See paragraph 16(d) for criteria concerning data acquisition and analysis systems. Depending upon test objectives and unique test stand and test site characteristics, wind speed and direction limits should be considered.

c. Acoustic Shadowing. If ground-plane microphones are used, the applicant should demonstrate that acoustic "shadowing" resulting from either thermal gradients or wind does not significantly influence the measured sound pressure levels. Previous evidence, or data from supplemental tests, may be used to demonstrate that testing within the approved weather restrictions at a particular test site results in no significant evidence of shadowing. In lieu of this evidence, the supplemental noise demonstration tests should include an approved method to indicate the absence of shadowing effects. One such method that has been approved involves the use of three measurements located as follows:

- average windspeed at engine centerline height (WCL)

- air temperature at engine centerline height (TCL)

- air temperature at the ground-plane microphone height, usually 13 mm (0.5 inch) (TMIC).

The instruments for these measurements should be co-located at a distance from the engine similar to that of the microphones and approximately 90 degrees from the engine axis on the microphone side of the engine. The limits that follow are in addition to any wind and temperature limits established by other criteria, such as the maximum cross-wind at the engine and the maximum windspeed at the microphones if microphone windscreens are not used. For an acceptable data test point, the average windspeed and temperature should be within the following limits:

- Engine centerline height at 16 ft.

  (assuming a 150 ft radius microphone array and smooth concrete pad):

  (TCL - TMIC) $\geqq$ -7°F (-3.9°C),

  WCL $\leqq$ 11 km/h (6 kts) average during test time for each data point (typically 30 seconds),

  WCL $\leqq$ 15 km/h (8 kts) maximum during test time for each data point.

- Engine centerline height at 24 ft.

  (assuming a 150 ft radius microphone array and smooth concrete pad):

  (TCL - TMIC) $\geqq$ -7°F (-3.9°C),

  WCL $\leqq$ 19 km/h (10 kts) average during test time for each data point,

  WCL $\leqq$ 23 km/h (12 kts) maximum during test time for each data point.

d. Microphone Locations. Microphones should be located at sufficient angular locations and at a height to provide adequate definition of the engine noise source characteristics. More specific guidance is given in SAE AIR 1846. The objective is to obtain measurements which can be corrected to a common reference condition. One method is to obtain or correct data to free field conditions (see paragraph 15(e)). Certification experience has been primarily limited to microphone installations near the ground or at centerline height. Because of the difficulties associated with extrapolating to flight conditions, the FAA suggests using near-ground plane microphone installations. However, the choice of microphone installations is dependent upon the specific test objectives and FAA approval of methods to be used for data normalization. It is currently required to use consistent microphone locations, heights, etc., for noise measurements of both the prior approved and changed aircraft version.

e. Engine Power Test Conditions. A range of static engine operating conditions should be selected to correspond to the expected maximum range of in-flight engine operating conditions. A sufficient number of engine power settings should be tested to ensure that the 90% confidence intervals in flight projected EPNL can be established over the desired range. (See Appendix 5 of this AC.)

f. Data Analysis System Compatibility. If more than one data analysis system is used for the acquisition of static data, compatibility of the two analysis systems is necessary. This can be accomplished by analyzing the same tape on both systems. The systems should be compatible if the resulting differences in the projected in-flight EPNL values are no greater than 0.5 EPNdB. Evaluation should be conducted at flight conditions representative of those for certification.

g. Data Acquisition, Analysis and Normalization. For each power setting designated in the test plan, the engine performance, meteorological and sound pressure level data should be acquired and analyzed using the instrumentation and test procedures described in SAE AIR 1846. Sound measurements should be normalized to consistent conditions (generally free field) and consist of 24 one-third-octave band RMS sound pressure levels between 45 and 11,200 Hz for each measurement (microphone) station. Before projecting the static engine data to flight conditions, the sound pressure level data should be normalized for the following effects:

(1) Frequency response characteristics of the data acquisition and analysis system.

(2) Spherical divergence over the sound propagation path.

(3) Atmospheric absorption over the sound propagation path due to the difference in test and FAR 36 reference ambient conditions of temperature and relative humidity.

(4) Spectral distortions resulting from ground reflections (methods to account for spectral distortions are referred to in SAE AIR 1672B).

(5) Contamination by background ambient or electrical system noise.

18. PROJECTION OF STATIC ENGINE DATA TO AIRPLANE FLIGHT CONDITIONS. The static engine sound pressure level data acquired at each angular location should be analyzed and normalized to account for the effects identified in paragraph 16(g). They should be then projected to the same airplane flight conditions used in the development of the approved NPD. As appropriate, the projection procedure includes the effects of source motion, number of engines and shielding, flight geometry and atmospheric propagation. To account for these effects, the measured total static noise data should be analyzed to determine contributions from individual noise sources. After projecting the one-third-octave band spectral data to flight conditions, EPNL values should be calculated for the revised NPD plot. Guidelines on the elements of an acceptable projection procedure are provided in this section. This process is also illustrated in Figures 3 and 4. It is not intended that the procedure illustrated in Figures 3 and 4 should be exclusive. There are several options, depending upon the nature of the powerplant noise sources and the relevance of individual

FIGURE 3

EXAMPLE OF A METHOD FOR PROJECTING STATIC ENGINE DATA TO FLIGHT CONDITIONS

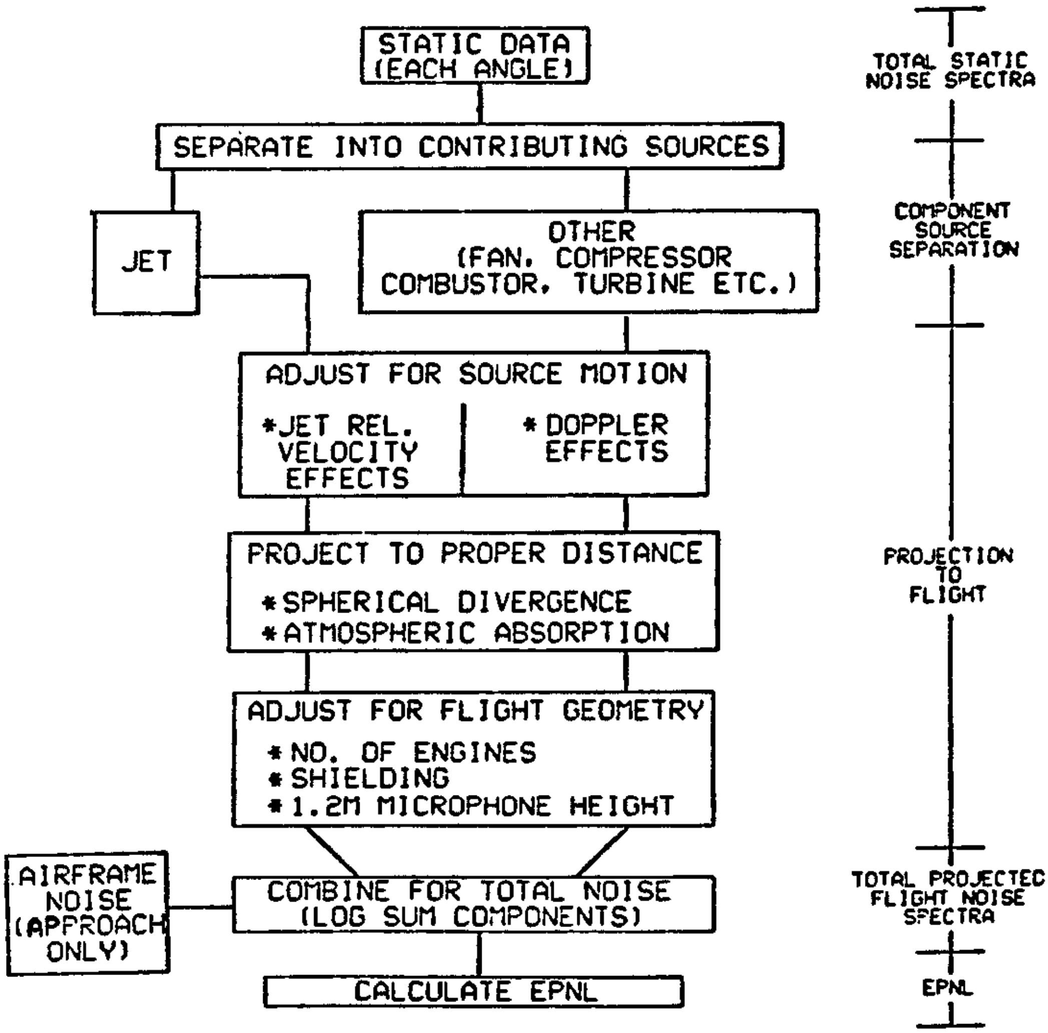
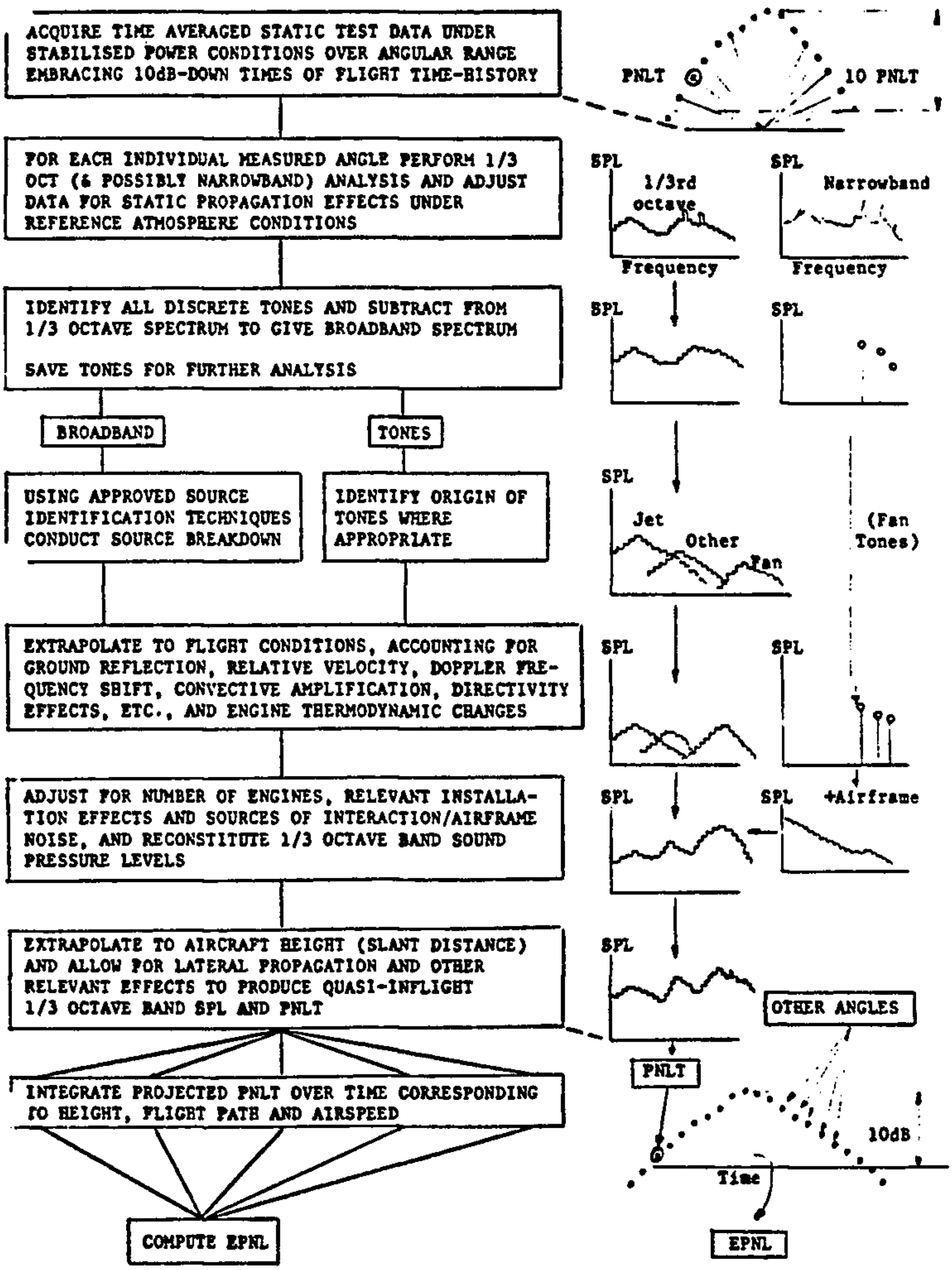


FIGURE 4

PROJECTION OF STATIC ENGINE DATA TO AEROPLANE FLIGHT CONDITIONS

(EXAMPLE PROCEDURE)



noise sources to the Effective Perceived Noise Level 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 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.

NOTE: Static-to-flight projection procedure approvals of installations or engine types that are not similar to those that have been previously approved may require flight validation.

a. Engine Installation Effects. There are several engine installation effects which can modify the generated noise levels but which are not derivable from static tests. Additional noise souces such as jet/flap or jet/wing interaction effects may be introducted on a derived version of the airplane which are not present on the flight datum airplane. Farfield noise directivity patterns (field shapes) may be modified by wing/nacelle or jet-by-jet shielding, tailplane 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 can be shown to be essentially identical to that of the flight datum airplane so that the radiated noise is unaffected.

b. Normalization to Reference Conditions. The analysed static test data should be normalized to freefield conditions in the Part 36 reference atmosphere. The latter correction can only be applied with a knowledge of the spectra of the sources and hence the computations in paragraphs (c), (d), and (e) below should be considered together with the following:

(1) Atmospheric absorption - adjustments to account for the acoustical reference day atmospheric absorption are defined in SAE ARP 866A (revised 15th March 1975). The atmospheric absorption should be computed over the actual distance from the effective center of each noise source to each microphone, as determined in paragraph (e). In the event that minor differences in absorption values are found in SAE ARP 866A between equations, tables or graphs, the equations should be used.

(2) Ground reflection - examples of methods for obtaining freefield sound pressure levels are described in SAE AIR 1672B-(1983). Spatial distribution of noise sources does 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 identify the large spectral irregularities caused by interference effects at frequencies less than 1 KHz.

(c) Engine Component Noise Source Separation. Unless dominated by just one noise source (e.g., fan noise from a turbofan engine), the total static engine SPL data measured at each angular location should be separated into each of the noise sources that may provide significant contributions to the total. This separation should be performed in terms of one-third octave band level and the total noise should be separated into broadband and turbomachinery noise components. To meet the minimum requirement, separation of sources of broadband noise into those due to external jet mixing and those generated internally can be carried out by estimating the jet noise by one or more of the methods identified below, and 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. A further separation of components may be necessary in some instances.

(1) Normally, jet noise dominates the low frequency range of the total noise spectrum and the peak jet noise one-third octave band can readily be discerned. In the mid-frequency range the contribution of jet noise relative to turbomachinery noise sources may not be as apparent. Predictions of jet noise spectral characteristics may be obtained from procedures in SAE ARP 876C "Gas Turbine Jet Exhaust Noise Prediction" or from other approved methods such as component tests of comparable configurations. These spectral shapes are generally defined as a function of angle and operating condition. The predicted jet noise spectral shape derived for the relevant position and operating condition should be adjusted to match the measured jet noise level in the low frequency range. The logarithmic sum of the jet and "other" noise sources should be reviewed to ensure the summation for the mid-frequency range is consistent with the total measured noise. Two other techniques may be useful in obtaining additional information on changes in jet noise levels and spectral shapes:

(a) Analytical procedures based on correlating full scale engine data with model nozzle characteristics may be useful. Such data have been used to supplement full scale engine data, particularly at low power settings, where noise from other engine sources may make a significant contribution to the broadband noise. Example procedures for coaxial flow jet engines are provided in SAE AIR 1905-1985.

(b) Special noise source locations techniques such as directional microphones, are available which, when used during full-scale engine tests, can identify the positions and levels of separate engine noise sources.

(2) Turbomachinery noise sources produce both tones and broadband noise. Methods for identifying one-third octave bands containing tones include use of either narrowband analysis of analytical procedures that consider the slopes between adjacent one-third octave bands (analogous to the tone identification procedure in the computation of EPNL).

(3) After separating the total noise into the contributions from each source, the summation, on an energy basis, of the source contributions in each one-third-octave band should equal the total noise.

d. Noise Source Position Effects. 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 Effective Perceived Noise Levels 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 nozzles and 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 to be 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:

(1) Spherical divergence - the distance of the source from the microphone differs from the nominal distance; an inverse square law adjustment should be applied.

(2) Directivity - the angle of the microphone to the source differs from the nominal microphone angle; a linear interpolation should be made to obtain data for the proper angle.

(3) Atmospheric attenuation - the difference between the true and the nominal distance between the source and the microphone alters the allowance made for atmospheric attenuation.

e. Engine Flight Conditions. Some thermodynamic conditions within an engine tested statically differ from those that exist in flight; account should be taken of the difference. Noise source strengths may be changed accordingly. Therefore, values for key correlating parameters for component noise source generation should be based on the flight condition and the static data base should be entered at the appropriate correlating parameter value. Turbo-machinery noise levels should be based on the inflight corrected rotor speeds $N_1/\sqrt{\theta_{t2}}$ and jet noise levels should be based on the relative jet velocities that exist at the flight condition. The varation of source noise levels with key correlating parameters can be determined from the static data base which includes a number of different thermodynamic operating conditions.

f. Noise Source Motion Effects. The effects of motion on jet noise differ from speed effects on other noise sources, and hence should be considered separately during static-to-flight projection.

(1) External Jet Noise. Account should be taken of the frequency-dependent jet relative velocity effects and convective amplification effects. Broadly, two sources of information may be used to develop an approved method for defining the effect of flight on external jet noise.

(a) For single-stream engines having circular exhaust geometries, SAE ARP 876C-1985 provides guidance. However, additional supporting evidence may be needed to show when jet noise is the major contributor to the noise from an engine with a more complex nozzle assembly.

(b) 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 Effective Perceived Noise Level, with changes of jet noise spectra at high frequencies.

(2) Doppler Effect. Frequency shifting that results from motion of the source (airplane) relative to a microphone can be accounted for by using the following equation:

$$f_{FLIGHT} = \frac{f_{STATIC}}{(1-M \cos \theta)}$$

where f_{FLIGHT} = flight frequency
f_{STATIC} = static frequency
M = airplane Mach number
θ = angle between the flight path and the sound path connecting the airplane and the microphone

It should be noted that for those one-third-octave bands dominated by a turbomachinery tone, the Doppler shift may move the tone (and its harmonics) into an adjacent band.

(3) Source Amplitude Modification. Some available test data support the concept that airplane speed changes affect the apparent strength of noise sources internal to the engine, such as fan or combustor noise. In many instances it will not be essential to apply static-to-flight adjustments for these factors when establishing noise changes between two engine types or models. However, if an adjustment is used, the same technique should be applied to both the flight datum and derivative configuration when establishing noise changes. In such instances, the adjustment for sound pressure level changes that result from the motion of the airplane relative to the microphone may be accounted for using the equation:

$$SPL_{flight} = SPL_{static} - K \log (91-M \cos \theta)$$

where SPL_{flight} = flight sound pressure level
SPL_{static} = static sound level and M and 0 are defined in (2) 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.

(4) Number of engines and engine shielding - noise sources of having more than one engine are accounted for by adding the factor 10 log N, where N is the number of engines, to the static data. If it is appropriate (e.g., for the sideline case) it may be necessary to account for shielding effects. NASA CR-114649, "Aircraft Noise Source and Contour Estimation", July 1973, provides guidance on engine shielding effects.

(5) Spherical divergence - this effect results in a lowering of SPL's when moving farther away from the noise source. The amount that should be subtracted from the static data is 20 log (D FLIGHT/D STATIC) where D represents the distance from the source to the microphone.

(6) Atmospheric absorption - adjustments that should be used to account for reference day atmospheric absorption are defined in SAE ARP 866A revised 3-15-75. In the event that minor differences in absorption values exist in SAE ARP 866A between equations, tables, or graphs, the equations should be used.

(7) Ground reflection - In those instances where the noise tests for both the reference and changed versions have been conducted over the same type of surface, it may not be necessary to adjust the measured data for test surface effects. Any adjustment for ground reflection should correspond to the difference between the static measurements and flight measurements made 1.2 m (4 ft) above the ground surface. Examples of methods for obtaining free-field sound pressure levels are described in SAE AIR 1672B. Alternatively, free field sound pressure levels may be derived from other approved analytical or empirically derived models or a combination of both.

g. Airframe Noise Component. To account for the possible contribution of airframe noise, measured airframe noise or an approved airframe noise analytical model should be used to develop an airframe noise data base. The airframe generated noise should be normalized to the same conditions as those of the adjusted static engine conditions: i.e., sound propagation distances, and the approved NPD airspeed. In normalizing to these conditions, the following effects should be accounted for:

- spherical divergence
- atmospheric absorption, and
- airspeed. Airframe noise for a given configuration varies with velocity as follows:

$$SPL_{airframe} = 50 \text{ Log } \frac{V_{NPD}}{V_{TEST}}$$

where: VTEST is model or measured airspeed
V_{NPD} is approved NPD airspeed

This equation is also valid for adjustments to EPNL where an empirically derived coefficient replaces the coefficient 50 since this value may be somewhat configuration dependent. However, FAA approval should be obtained for values other than 50.

h. Extrapolation to Airplane Flight Path. When computing noise levels corresponding to the slant distance of the aeroplane in flight from the noise measuring point, the principal effects are spherical divergence (inverse square law adjustments from the nominal static distance) and atmospheric attenuation, as described in sections A36.9 and A36.11 of Part 36. Further, 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.

i. Total Noise Spectra. Both the engine tonal and broadband noise source components in flight, as discussed earlier, together with the airframe noise and any installation effects, are summed on a mean-square pressure basis to construct the spectra of total airplane noise levels.

(1) During the merging of broadband and tonal components consideration should be given to appropriate bandsharing of discrete frequency tones.

(2) The effects of ground reflections should be included in the estimate of freefield sound pressure levels to simulate the sound pressure levels that would be measured by a microphone at a height of 1.2 m above a natural terrain. Information in SAE AIR 1672B-1983 may be used to apply adjustments to the freefield spectra to allow for flight measurements being made 1.2 m (4 ft). Alternatively, the ground reflection correction can be derived from other approved analytical or empirically derived models. Note that the Doppler correction for a static source at frequency f_{static} applies to a moving (airplane) source at a frequency f_{flight} where $f_{flight} = f_{static}/(1 - M \cos \theta)$.

(3) With regard to lateral attenuation, information in SAE AIR 1751-1981 applicable to the computation of lateral noise may be applied.

The process in this section is repeated for each measurement angle and for each engine power setting.

j. EPNL Computations. For EPNL calculation, a time should be associated with each extrapolated spectrum along the flight path by adjusting the measured data to the approved NPD reference conditions and the distance to the flight path. (NOTE: A time should be derived from each measurement location with respect to engine centerline and the airplane's true airspeed along the reference flight path assuming zero wind.) For each power setting and array of minimum distances, an EPNL should be computed from the projected time history using the methods described in Part 36, Appendix B. To reduce the influence of random spectral irregularities the tone corrections provided in Appendix 4 may be used to meet the requirements of Part 36, Appendix B.

k. Noise Increment Computations. An NPD plot can be constructed from the projected static data for both the original and changed versions of the engine or nacelle tested. Comparisons of the noise vs power relationships for the two configurations at equivalent minimum distances, should determine whether the changed configuration resulted in an acoustic change. If there is an acoustic change or if a new NPD is requested, the data applicable to the changed configuration should be developed from the static data projected to flight conditions plus the approved residual. This residual can be developed from the difference between flight data and static data for the flight configuration projected to flight. Generally, this residual has been limited to three decibels.

19. SUPPLEMENTAL FLIGHT TESTS. Supplemental flight testing has been found adequate for some type changes. An acceptable compliance plan may be developed by considering the technical items of paragraph 15 in conjunction with the flight test procedures outlined in Chapter 2. Additionally, consideration should be given to the effects the change in type design will have on the noise level at each of the Part 36 reference locations. Data should be acquired, analyzed, and normalized using the procedures described in Chapter 2, Noise Demonstration Flight Tests. The computation of noise increments, the development of the changed version NPD, computation of confidence intervals, and evaluation of the changed version noise levels can be made using procedure similar to those outlined in paragraph 17(k) of this AC for static tests.

20. SUPPLEMENTAL ANALYSES. Analytical procedures may be acceptable for demonstrating compliance with Part 36 for airplanes resulting from a change in type design. Depending upon the effect the change in type design will have on the basic airplane noise source characteristics, certification noise levels may be derived directly from the existing NPD, or from an analytical extension of the existing NPD, or by supplementing the existing NPD with noise data derived by analytical modeling of the noise components.

a. Noise Increments Derived from an Approved NPD. For type changes which retain the same basic noise source characteristics, certification noise levels may be derived directly from the approved NPD using the methods in paragraph 13(e)(2).

(1) Example Applications

a. Weight increase or decrease from the originally certificated airplane weight, for both takeoff and approach.

(b) Engine power increase or decrease.

(c) Airplane changes that could indirectly affect noise levels because of an impact on airplane performance (increased drag for example).

(2) Extension of the Approved NPD. For the type change examples above, certification noise levels may be derived from the approved NPD provided the reference aerodynamic performance is within the limits of the approved NPD. For cases where the reference aerodynamic performance (e.g., engine power) is beyond the limits of the approved NPD, the NPD may be extended within approved limitations. Among the items which should be considered in extension of the NPD are:

(a) the 90% confidence interval at the extended power;

(b) airplane noise source characteristics and behavior; and

(c) engine cycle changes.

b. Analytical Modeling of Noise Components. Analytical procedures may be considered when validated by test data to demonstrate limited changes to the basic airplane noise source characteristics or to demonstrate no acoustical change. For type design changes, such as engine or nacelle redesign and acoustic lining changes, a validated analytical noise model may be used to derive predictions of noise increments within approved limitations. The analysis may consist of modeling each airplane component noise source and projecting these to flight conditions in a matter similar to the static test procedures described in paragraph 17.

(1) Airplane Noise Components. A model of detailed spectral and directivity charactertistics for each airplane noise component may be developed by theoretical and/or empirical analysis. Each noise component should be correlated to the parameter(s) which relates to the physical behavior of the 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.

(2) Projection of Airplane Component Noise Sources to Flight Conditions. As described in paragraph 17, an EPNL representative of flight conditions should be computed by adjusting the airplane component noise source for motion, number of engines and shielding, reconstructing the total noise spectra and projecting the total noise spectra to flight conditions by accounting for propagation effects. In some cases adjustments for additional effects on the component noise sources may be required. For example, the effect of changes in acoustic treatment, such as nacelle lining, may be modeled and applied to the appropriate component noise sources.

(3) Noise Increment Computations. The computation of noise increments, the development of the changed version NPD, and evaluation of the changed version certification noise levels should be made using the procedures in paragraph 17(f). The validity of the resulting data base should be determined using an approved methodology. Guidance on confidence interval computations is provided in Appendix 5 of this advisory circular.

21. SUPPLEMENTAL COMPONENT TESTS. Full scale or scale models of components of production hardware can be acoustically tested in a controlled laboratory environment such as a flow duct transmission loss facility, an anechoic chamber or a wind tunnel. Results from scale model component tests should be adjusted to full scale conditions using approved procedures. An example use of approved laboratory facilities is the determination of noise increments, resulting from changes in nacelle acoustic lining, in flow duct transmission loss facilities. These noise increments should be determined by applying the laboratory measured attenuation spectral differences to the measured one-third octave band flight levels.

22. METHODS FOR DEMONSTRATING NO ACOUSTICAL CHANGE. Several noise demonstration methods have previously been limited to use in demonstration of no acoustical change (defined in FAR 21.93(b)). These methods include analytical noise component models and component tests. Approval of these methods has previously been confined to no acoustical change demonstrations. For demonstration of no acoustical change, the applicant is not precluded from use of either a noise demonstration flight test or other supplemental noise demonstration methods described in this advisory circular.

APPENDIX 1. OUTLINES FOR NOISE COMPLIANCE DEMONSTRATION PLAN AND REPORT

1. NOISE COMPLIANCE DEMONSTRATION PLAN. At a minimum, a typical noise certification compliance demonstration plan should contain the information shown in the outline below. While the outline covers all types of noise demonstration methods described in the advisory circular, a particular plan should address only those item of interest to an applicant. The plan should list equivalencies anticipated to be needed along with supporting documentation.

a. Introduction. Address planned certification action.

b. Test Item. Airplane, complete with engine and nacelle description, weights, flaps, etc.

c. Type of Noise Demonstration Method.

(1) Noise Demonstration Flight Test.

(2) Supplemental Methods.

(a) Static Test

(b) Flight Test

(c) Analysis

(d) Component Test

d. Test Description. Highlights of the planned test should be noted and any deviations from the procedures described in Part 36 should be identified.

e. Data Acquisition Systems. Type and model of hardware and any deviations from the hardware and procedures described in FAR Part 36 and this advisory circular should be noted.

f. Data Analyses and Normalization Procedures. Highlights of the hardware and methods to be used should be noted. Also any deviations from the procedures described in FAR Part 36 and this advisory circular should be identified. The applicant's reference conditions also should be identified.

g. Equivalencies. All "equivalent procedures" to be considered in this certification should be identified. Any new equivalencies submitted for FAA approval should be supported with adequate engineering analyses and/or test data. Requests for approvals of equivalencies should be submitted in a timely manner to provide for review by both regional and AEE personnel. Generally, this takes 30 to 60 days, depending upon the engineering complexity of the proposal.

2. NOISE CERTIFICATION COMPLIANCE REPORT. At a minimum, typical noise certification reports should contain the information shown in the outline below (as applicable to the configuration being certified). It is likely that there will be more than one report for a basic airplane with several derivative configurations.

a. Introduction. Define applicable requirements of Part 36 under which noise certification is requested.

b. Airplane, Engine, and Nacelle Descriptions. Provide the gross dimensions of the airplane (including the engine locations), descriptions of the engine and nacelle acoustic treatments, landing and takeoff weights, thrusts, and flap settings.

c. Airplane Performance at Reference Conditions. For the reference aerodynamic configuration (e.g., airplane weight, flap setting, etc.) provide the aerodynamic performance necessary to derive the certification noise levels. At a minimum, this includes power, height, and airspeed.

d. Certification Noise Levels. For the reference aerodynamic configuration, provide the certification noise levels and the applicable noise limits for each of the three Part 36 measurement locations.

e. Noise Certification Test Results. Provide details on the results of tests and analyses which demonstrate compliance with the applicable requirements of Part 36. The following information should be reported.

(1) Noise Demonstration Method - A description of the type of noise certification demonstration method used.

(2) Test Airplane, Engine and Nacelle Descriptions - The type, model and serial numbers of the airplane and engine used in the test.

(3) Test Description and Resultant Measurements - A summary of the conduct of test, the type of equipment used for meaurement and analysis of the noise, airplane position and performance, and meteorological data, and representative examples of the acquired data.

(a) Test Site Description - The test site location, terrain and ground cover description, microphone locations, and any events interfering with sound measurements.

(b) Meteorological Data - Wind speed and profiles of ambient air temperature and relative humidity.

(c) Airplane Position and Performance - Airplane configuration, gross weight, airspeed, power, and the position over the test engine.

(d) Engine Performance - Engine power settings and thrust, rotor speeds, and engine spool down characteristics (if appropriate).

(4) Analysis Procedure - A summary of the procedures used in the normalization of the measured data to reference conditions for each of the three measurement locations.

(5) Airplane Flight Manual page (example).

APPENDIX 2. GUIDANCE MATERIAL ON METHODS TO ACCOUNT FOR THE EFFECTS OF BACKGROUND NOISE ON AIRPLANE RECORDED NOISE DATA

1. INTRODUCTION.

a. The following information on methods for removing the effect of background noise on measured recorded airplane sound pressure level data is provided as guidance material for the certificate applicant.

b. Sound measurement and analysis system dynamic range performance limitations can result in measured sound pressure levels that are influenced by the presence of background noise. This problem occurs primarily at high frequencies where airplane noise source characteristics and atmospheric absorption result in low one-third-octave band sound pressure levels relative to those of the lower frequency portion of the spectrum.

c. The influence of background noise on recorded sound pressure level data may be unavoidable and, in some instances, correction of recorded sound pressure level data may be required.

d. The application of the data correction methods presented in this guidance material will provide an acceptable estimate of sound pressure level data that would have been measured in the absence of background noise. Approval for the use of other correction procedures may be requested by certificate applicants, and approval for the use of any procedure remains with the certificating authority.

2. BACKGROUND NOISE.

a. The lowest level of true airplane sound pressure levels measured during a flyover test may be limited by background noise. Background noise is established by the test site ambient sound and electrical noise of the measurement system (predetection noise). The predetection ambient sound will add, on an energy basis, to the true aircraft noise. In addition, the dynamic range of the analysis equipment may establish the lowest possible read-out value for any one-third-octave band level (post detection background noise).

b. The background noise level is defined as the mean predetection level or the post detection level, whichever is the greater. For the purposes of the corrections described in this appendix the background noise level is defined as the means predetection level plus 5 dB, or the post detection level plus 1 dB, whichever is greater.

c. The ambient sound and electrical noise of the measurement system should be determined in accordance with requirements of Part 36 and this advisory circular.

3. CORRECTION PROCEDURES.

a. Where the airplane sound pressure level is greater than the background noise level the true airplane sound pressure level may be estimated by subtracting, on an energy basis, the predetection level from the total measured sound pressure level. No correction for post detection noise is required if measured sound pressure levels exceed the post detection noise level.

b. Where measured sound pressure levels are equal to or less than the background noise level the airplane sound pressure levels are defined as being masked.

c. If no more than the four highest frequency one-third octave bands are masked, the Noy value for these bands may be set equal to zero.

d. If more than the four highest frequency one-third octave bands are masked, then the sound pressure levels for the masked bands may be determined by applying one or more of the correction procedures described below.

e. Time Extrapolation.

(1) This procedure can be applied to measured data where one-third octave bands are masked during only a portion of the sound measurement period.

(2) Corrections in the time domain are made by taking into account propagation distance (spherical divergence and atmospheric absorption) relative to the first (approaching) or last (receding) unmasked sound pressure level measurement in the one-third octave band requiring correction. Source directional characteristics in each masked frequency band may be assumed to be:

(a) Directional, as supported by test data, or

(b) Omnidirectional.

Note: Preference should be given to test data.

f. Frequency Extrapolation.

(1) Sound pressure levels in each of the masked high frequency one-third octave bands should be estimated by extrapolating the highest unmasked frequency band by an amount equal to the sum of source spectrum slope and the atmospheric absorption in each frequency band along the sound propagation path from source to measurement location. The source high frequency spectrum slope is defined by:

(a) a slope supported by test data, acquired from closer-in microphones or static engine noise measurements; or

(b) in the absence of test data, a slope of -9 dB/octave may be assumed.

Note: Preference should be given to test data.

(2) No more than four one-third-octave bands in any spectrum should be corrected using frequency extrapolation if an assumed source spectrum slope is used.

g. In those cases where masked band(s) occur between unmasked bands, the measured sound pressure levels in the masked band(s) should be used, or other values as supported by applicants data. In the case where one masked band is located between two unmasked bands, the mean value of the adjacent unmasked bands may be ascribed to the masked band if this mean value is lower than the measured level in the masked band.

h. No penalty for spectral irregularities resulting from the correction procedure is ascribed to those masked frequency bands that have been corrected for the effects of ambient noise.

APPENDIX 3. GUIDANCE MATERIAL ON METHODS TO IDENTIFY PSEUDOTONES/ FICTITIOUS TONES IN AIRPLANE RECORDED NOISE DATA

1. INTRODUCTION.

a. The following information on methods for identifying pseudotones/fictitious tones in airplane sound measurements is provided as guidance material for the certificate applicant.

b. Airplane sound measured at 1.2 m (4 ft) above the ground should be composed of broadband noise superimposed with spectral irregularities. The spectral irregularities may be caused by actual airplane/engine tones, ground plane reflections or atmospheric propagation effects. In addition, spectral irregularities may be artifically created by data processing techniques which account for ambient sound and atmospheric absorption corrections.

c. The application of a tone correction factor in the computation of EPNL accounts for the subjective response due to the presence of pronounced spectral irregularities. Tones generated by airplane noise sources constitute the spectral irregularities requiring application of tone correction factors.

d. The application of pseudotone/ficititious tone identification methods presented in this guidance material should provide an acceptable means of identifying spectral irregularities not requiring application of tone correction factors. Approval for the use of other correction procedures may be requested by certificate applicants and approval for the use of any procedure remains with the certificating authority.

2. SPECTRAL IRREGULARITIES.

a. Discrete frequency tones generated by airplane noise sources set the measured spectral irregularities requiring application of tone correction factors.

b. Spectral irregularities occur in data measured at 1.2 m (4 ft) due to interference effects caused by the reflection of sound from the ground surface. These ground reflection effects, known as pseudotones, are most pronounced at low frequencies. Any other spectral irregularity not related to aircraft noise sources, such as those caused by atmospheric propagation effects, are termed fictitious tones. Spectral irregularities producing fictitious tone correction factors may result from corrections applied to the measured sound pressure level data due to:

(1) masking of sound pressure levels, or

(2) differences between test and reference sound attenuation in the 4.0 kHz and 5 kHz one-third-octave bands (as prescribed in ARP 866A). Neither fictitious tones or pseudotones are related to aircraft noise sources and, therefore, need to be identified so that tone correction factors are not applied.

c. Pseudotones in the 800 Hz and lower one-third-octave bands may be excluded from the calculation of corrections for spectral irregularities. To qualify for this exclusion, the pseudotones should be clearly identified using one of the methods outlined below. Pseudotones at frequencies above 800 Hz generally should not yield significant tone corrections. However, for consistency, each tone correction value should be included in the computation for spectral irregularities.

d. If fictitious tones are identified (using one of the methods outlined in paragraph 3), a revised value for the background sound pressure level should be determined and used to compute a revised tone correction factor for that particular one-third octave band.

3. METHODS FOR IDENTIFICATION OF PSEUDOTONES/FICTITIOUS TONES.

a. Narrowband Analysis. By analyzing the measured data using a filter with a bandwidth narrower than one-third of an octave, the presence or absence of airplane or engine generated discrete frequency tones may be determined.

b. Frequency Tracking of Spectral Irregularities During the Flyover. The observed frequencies of airplane noise sources progressively increases prior to the point of airplane acoustic overhead and then progressively decreases after overhead due to the Doppler shift.

$$f_{\text{Doppler shifted}} = \frac{f_{\text{source}}}{1 - M \cos \theta}$$

where

f = frequency
M = Mach number
θ = angle between the flight path and a line connecting the source and observer at the time of noise emission.

In contrast to the Doppler shift effect, ground reflection effects in the spectra decrease in frequency prior to, and increase in frequency after, the point of airplane acoustic overhead. These differing characteristics can be used to separate source and reflection effects.

c. Microphone Arrangement. Pseudotones may be identified by comparing measurements from 1.2 meter (4 ft) microphone with corresponding data from an adjacent microphone which is:

(1) mounted near (within one-half microphone diameter) a hard reflecting ground surface, or

(2) raised to a height above the ground surface so that the first interference dip falls below the range of interest (50 Hz). Microphones at 10 meters (33 ft) have been used.

Using either microphone arrangement eliminates the interference irregularities from the low frequency range of the measured spectra and when a comparison is made between the two data sets, airplane source tones can be separated from any pseudotones that may be present.

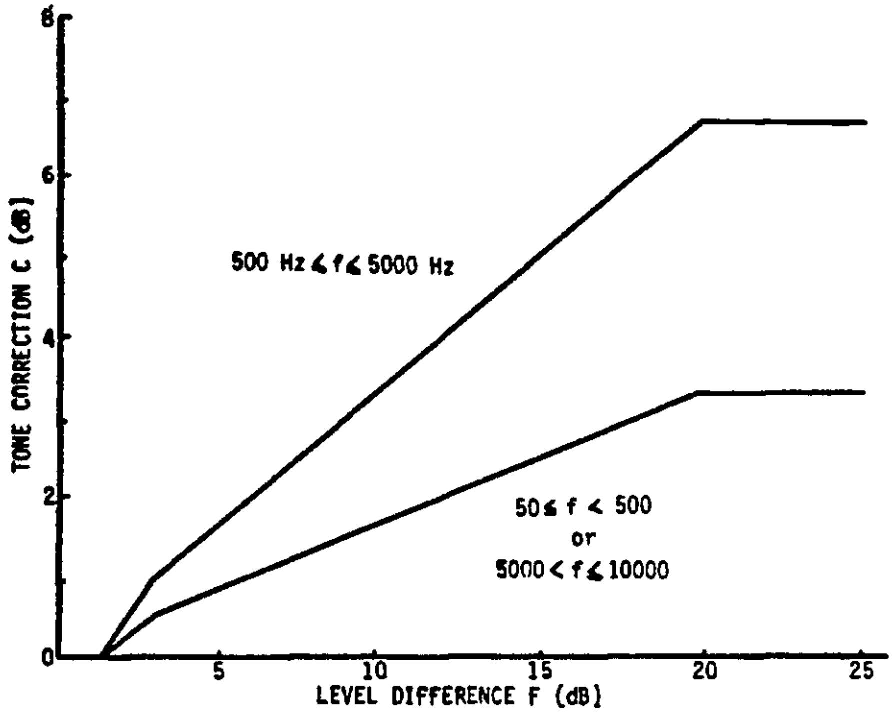
d. Inspection of Noise Time Histories. Spectral irregularities which produce fictitious tone correction factors will usually occur in the 1 kHz to 10 kHz frequency range. Depending upon the variation with frequency of the tone correction calculation procedure, the magnitude of these tone corrections typically ranges from 0.2 to 0.6 dB. PNL and PNLT time histories with constant level differences indicates invalid fictitious tone corrections. This analysis may be supplemented by narrowband analysis to demonstrate that these characteristics do not result from the Doppler shift effect.

APPENDIX 4. COMPUTATION OF EFFECTIVE PERCEIVED NOISE LEVEL (EPNL)

1. EPNL should be computed by the methods prescribed in Part 36, Appendix B. In the computation, noise having pronounced spectral irregularities should be adjusted by a tone correction factor (see B36.5). An approved tone correction factor may be determined from the sound pressure level differences (f(i,k)) and Table 1. All other procedures in the computation of EPNL are the same as Part 36, Appendix B.

APPENDIX 4

TABLE 1 - TONE CORRECTION FACTORS



FREQUENCY f (Hz)	LEVEL DIFFERENCE F (dB)	TONE CORRECTION C (dB)
50 ≤ f < 500 or 5000 < f ≤ 10000	0 < F < 1.5	0
	1.5 ≤ F ≤ 3.0	(F -1.5)/3
	3.0 < F < 20.0	F/6
	20.0 ≤ F	3 1/3
500 ≤ f ≤ 5000	0 < F < 1.5	0
	1.5 ≤ F ≤ 3.0	(2F - 3)/3
	3.0 < F < 20.0	F/3
	20.0 ≤ F	6 2/3

APPENDIX 5. GUIDANCE MATERIAL ON METHODS TO CALCULATE CONFIDENCE INTERVALS

1. INTRODUCTION. The use of NPD maps requires confidence intervals to be determined using a more general formulation than used for a cluster of data points. For this more general case, confidence intervals should be calculated about a regression line for:

a. flight test data;

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

c. analytic data results.

The latter two are of particular significance for family certifications.

2. CONFIDENCE INTERVAL ABOUT FLIGHT TEST DATA.

a. Ninety percent confidence interval for clustered flight conditions is defined as:

$$\text{Confidence Interval} = \pm\, t_{\frac{x}{2}} \frac{S}{n}$$

S = standard deviation of the mean EPNL
n = number of data points
$t_{\frac{x}{2}}$ = student t distribution

b. Ninety percent confidence interval for a least squares fit polynominal regression of flight test data is defined as:

$$\text{Confidence Interval} = \pm\, t_{\frac{x}{2}}\, S \quad \text{POWER}' \; A^{-1} \; \text{POWER}$$

and is calculated as follows:

For the point (power, $EPNL_o$) on the following regression

$$EPNL = A_o + A_1\, \text{POWER} + A_2\, \text{POWER}^2$$

The confidence limits are obtained as follows:

$$CI = \pm\, t_{\frac{x}{2}}\, S \quad \underline{\text{POWER}'_o} \; \underline{A}^{-1} \; \underline{\text{POWER}_o}$$

$$EPNL = A_o + A_1\, \text{POWER} + A_2\, \text{POWER}^2 + \ldots A_k\, \text{POWER}^k$$

POWER is the transpose of the POWER vector

$$\underline{\text{POWER}'} = [\; 1 \;\; \text{POWER}_o \;\; \text{POWER}_o \ldots \; \text{POWER} \;]$$

$$\underline{POWER_o} = \begin{bmatrix} 1 \\ POWER_o \\ POWER_o^2 \end{bmatrix}$$

$$S = \sqrt{\frac{\sum_{i=1}^{N} (EPNL_i - \overline{EPNL})^2}{N-3}} \qquad N = \text{Number of data points}$$

S^2A^{-1} is the variance-covariance matrix for the A_k values estimated with S^2. A^{-1} results from the solution of the normal equations used for obtaining the least squares solution.

3. CONFIDENCE INTERVAL FOR STATIC TEST DERIVED NPD MAPS.

a. When static test data is used in family certification, NPD maps are formed by the linear combination of baseline flight regressions, baseline projected static regressions, and derivative projected static regressions in the form

$$EPNL(\text{Derivative Flight}) = EPNL_{(\text{Baseline Flight})} -$$

$$EPNL(\text{Baseline Static}) + EPNL_{(\text{Derivative Static})}.$$

Confidence intervals for the derivative flight NPD curves are obtained by pooling the three data sets.

$$\text{Confidence Interval} = \pm T' \sqrt{X_{BF} + X_{BS} + X_{DS}}$$

$$X_{BF} = S_{BF}\sqrt{\underline{POWER'}_{BFO} \; A^{-1} \; \underline{POWER}_{BFO}}$$

$$X_{BS} = S_{BS}\sqrt{\underline{POWER'}_{BSO} \; A^{-1} \; \underline{POWER}_{BSO}}$$

$$X_{DS} = S_{DS}\sqrt{\underline{POWER'}_{DSO} \; A^{-1} \; \underline{POWER}_{DSO}}$$

$$T' = \frac{X_{BF}\, t_{BF} + X_{BS}\, t_{BS} + X_{DS}\, t_{DS}}{X_{BF} + X_{BS} + X_{DS}}$$

$$t_{BF} = t\,\alpha/2 \;,\; (N_{BF} - 3)$$

$$t_{BS} = t\,\alpha/2 \;,\; (N_{BS} - 3)$$

$$t_{DS} = t\,\alpha/2 \;,\; (N_{DS} - 3)$$

where N = number of data points in the corresponding sets

K = order of corresponding curve fit

4. CONFIDENCE INTERVAL FOR ANALYTICALLY DERIVED NPD MAPS.

a. Analysis may be used to determine the effect of changes in noise source components on certificated levels. This can be accomplished by analytically determined the effect of a hardware change on the noise component it generates. The resultant delta should be 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 should be computed using the appropriate method from above. The term

$$S\sqrt{\underline{POWER}'\ \ A^{-1}\ \ \underline{POWER}}$$

for the altered configuration should be adjusted to account for the uncertainty in the analysis. The adjustment necessary will be unique to each situation. The new term then should be substituted into the equation and the confidence interval for the new configuration should be calculated.

b. Reference: "Probability and Statistics for Engineers and Scientists" by R.E. Walpole and R.H. Meyer (1972).

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