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 conventional turbofan-powered 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. The requirements for approval of acoustical changes are contained in FAR section 21.93(b), not in Part 36. As a result, once a flight test data base is approved for the baseline airplane, it is seldom necessary to employ full Part 36 noise tests to demonstrate compliance for an acoustical change. In many instances, approval has been based on compliance demonstration methods not requiring flight tests. 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 AC. The use of these methods for demonstrating noise compliance is discretionary and does not preclude an applicant from conducting a noise demonstration flight test to show compliance.

c. When it has been determined in advance that more than one aircraft configuration may be certificated from common flight test data bases, it is often useful to the applicant to develop and seek FAA approval of an overall certification plan for that family of aircraft. This is referred to as a "family plan." These plans characteristically involve one or more approved NPD data bases and supplementary demonstrations, such as engine static tests.

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 3. 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 that has demonstrated, by flight test, compliance with FAR Part 36, 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 paragraph 18 of this AC.

(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 an NPD, which has been extended using approved analytical techniques.

(3) For type changes 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.

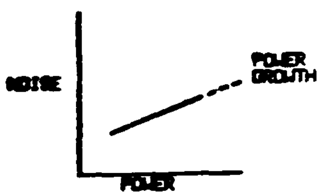
c. Noise Increment Derivation Using Common Demonstration Method. To ensure derivation of the correct noise increment between two different airplane configurations, the supplemental test and analysis methods used for both the previously approved and changed version must be of the same type.

FIGURE 3

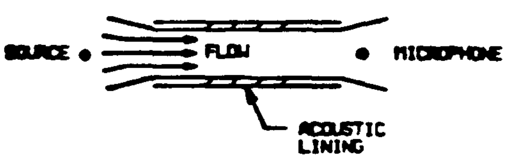
POSSIBLE APPLICATIONS OF SUPPLEMENTAL NOISE DEMONSTRATION METHODS

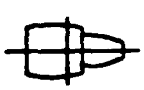
DEMONSTRATION BASIS	EXAMPLE OF CHANGES IN TYPE DESIGN
ANALYSIS	AIRPLANE AERO-PERFORMANCE CHANGES (e.g., Gross Weight, Flap, Fuselage, etc.) MINOR ENGINE THRUST AND/OR RATING CHANGES MINOR MODIFICATIONS TO ENGINE MINOR MODIFICATIONS TO ENGINE NACELLE
COMPONENT TESTING	ENGINE COMPONENTS (e.g., Jet, Fan, etc.) ACOUSTIC TREATMENT CHANGES
STATIC TESTING	NEW ENGINE OF COMPARABLE TECHNOLOGY AND SOURCE NOISE CHARACTERISTICS ACOUSTIC TREATMENT CHANGES NEW ENGINE NACELLE ENGINE COMPONENT CHANGES
SUPPLEMENTAL FLIGHT TESTING	NOISE SUPPRESSION DEVICE (e.g., Exhaust Gas Mixer) ENGINE COMPONENTS (e.g., Jet, Fan, etc.)

ANALYSIS

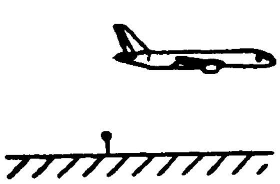


COMPONENT TESTING





STATIC TESTING



SUPPLEMENTAL FLIGHT TESTING

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

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). Furthermore, the spectral characteristics of the basic and modified configurations need to be similar.

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 16 and the general guidelines for test site, measurement and analysis instrumentation and test procedures provided in Society of Automotive Engineers (SAE) Aerospace Recommended Practice (ARP) No. 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 conducting the test. 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.; and (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 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 ARP 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 17(g) of this AC 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. Test Hardware. A flight inlet adjusted for static testing by the addition of a bellmouth forward of the inlet may be used with each turbofan or turbojet static noise test. Production inlet acoustic lining and spinners are also to be installed during noise testing.

d. Inflow Control Devices. The use of static engine test noise data for Part 36 noise certification under an approved "family plan" requires the use of an approved Inflow Control Device (ICD) for high bypass engines (BPR 2.0). For static tests conducted after May 1, 1986, the following requirements have been imposed on the ICD:

(1) The specific ICD hardware must be inspected for conformance with an approved ICD design by an approved method.

(2) The ICD must be acoustically calibrated for sound transmission loss by an approved method.

(3) The ICD acoustic calibration must be used as a correction in the certification data analysis. In applying the calibration, an approved method must be used to determine that portion of the noise received at the forward quadrant microphones that is radiated through the ICD. The calibration is applied to that portion of the noise that is radiated through the ICD.

(4) The ICD position relative to the engine inlet must be determined and found to be one of the calibrated positions.

(5) The ICD calibration consists of an SPL correction for each one-third octave band at each forward quadrant microphone that will be used during static engine testing.

(6) No more than one calibration is required for an ICD hardware design, provided that there is no deviation from the design for any one ICD serial number hardware set.

The above calibration requirements are not required if the same ICD hardware (identical serial number) is used as was previously used in the static noise test of the flight engine configuration, and the fan tones for both engines remain in the same one-third octave bands.

e. ICD Calibration. An acceptable ICD calibration method is as follows:

(1) Assume the correction is zero for the one-third octave bands from 30 Hz through 800 Hz, unless the engine design would dictate that forward radiated tones or major inlet broadband noise occurs below 1000 Hz. In that case, an approved correction procedure is required.

(2) Place an acoustic driver(s) on a simulated engine centerline in the plane of the engine inlet lip. Locate the calibration outer microphones on the forward quadrant azimuth at a radius between 50 and 150 feet that provides a good signal-to-ambient noise ratio and at each microphone angle to be used to analyze static engine noise data. Locate a near-field microphone on the centerline of and within 2 feet of the acoustic center of the acoustic driver(s).

(3) Conduct a test without the ICD in place. The test must be for a minimum of 60 seconds duration following system stabilization. The test must be conducted at a constant input voltage to the acoustic driver(s).

(4) Repeat item (3), alternately with and without the ICD in place. A minimum of three tests of each configuration is required. To be acceptable, the total variation of the 55° microphone on-line OASPL signal (averaged for a 1 minute duration) for all three test conditions of each configuration shall not exceed 0.5 dB. NOTE: Physically moving the ICD alternately in and out of place for this calibration may be eliminated if it is demonstrated that the ICD positioning does not affect the calibration results.

(5) All measured data are to be corrected for sound pressure level variations as measured with the near-field microphone and for atmospheric absorption to 77°F and 70 percent RH conditions using the slant distance between the outer microphones and the acoustic driver(s).

(6) The calibration for each one-third octave band at each microphone is the difference between the average of the corrected SPLs without the ICD in place and the average of the corrected SPLs with the ICD in place.

(7) The tests must be conducted under wind and thermal conditions that preclude acoustic shadowing at the outer microphones and weather induced variations in the measured SPL data.

f. Acoustic Shadowing.

(1) 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. When there is a wind in the opposite direction to the sound wave propagating from the engine, or when there is a substantial thermal gradient in the test area, refraction can influence near-ground plane microphone measurements to a larger degree than measurements at greater heights. 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 (TMIC)

(2) Ground plane microphones should be mounted within one-half microphone diameter or one-quarter wavelength of the highest frequency to be recorded, whichever is least. Generally, this spacing is 7 mm (0.25 inch).

(3) The instruments for these measurements should be co-located at a distance from the engine similar to that of the microphones and placed close to the 90 degree noise measurement position without impeding the acoustic measurement. The limits that follow are in addition to any wind and temperature limits established by other criteria, such as the maximum crosswind 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) $\geq$ -7°F (-3.9°C),

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

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

- Engine centerline height at 21 ft.

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

  (TCL - TMIC) $\geq$ -7°F (-3.9°C),

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

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

g. 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 ARP 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 18(b) of this AC). 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.

h. 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 percent confidence intervals in flight projected EPNL can be established over the desired range. (See Appendix 5 of this AC.)

i. 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 verified by analyzing the same tape on both systems. The systems are 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.

j. 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. Instrumentation and test procedures described in SAE ARP 1846 are acceptable. 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 corrected 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 Part 36 reference ambient conditions of temperature and relative humidity.

(4) Spectral distortions resulting from ground reflections (methods to account for spectral distortions are presented in SAE Aerospace Information Report (AIR) No. 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 adjusted to account for the effects identified in paragraph 17(h) of this AC. 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 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 4 and 5. It is not intended that the procedure illustrated in Figures 4 and 5 should be exclusive. There are several options, depending upon the nature of the powerplant noise sources and the relevance of individual noise sources to the EPNL of the airplane. The method presented does, however, specify the main features that should be considered in the computational procedure. It is also not necessary that the computations 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 procedures for 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 sources, such as jet/flap or jet/wing interaction effects, may be introduced on a derivative version of the airplane which are not present on the flight datum airplane. The aircraft's 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 derivative version of the airplane, the geometry of the airframe 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.

FIGURE 4

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

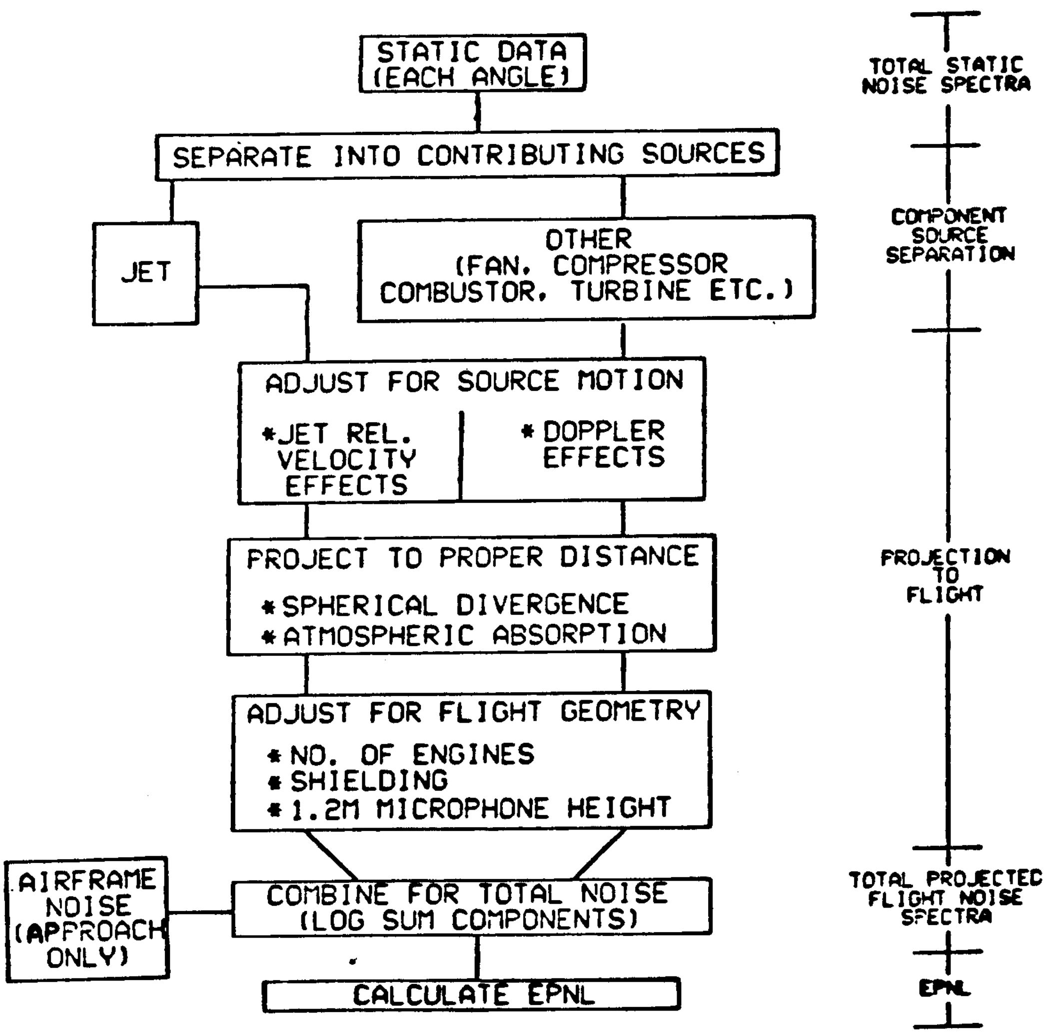
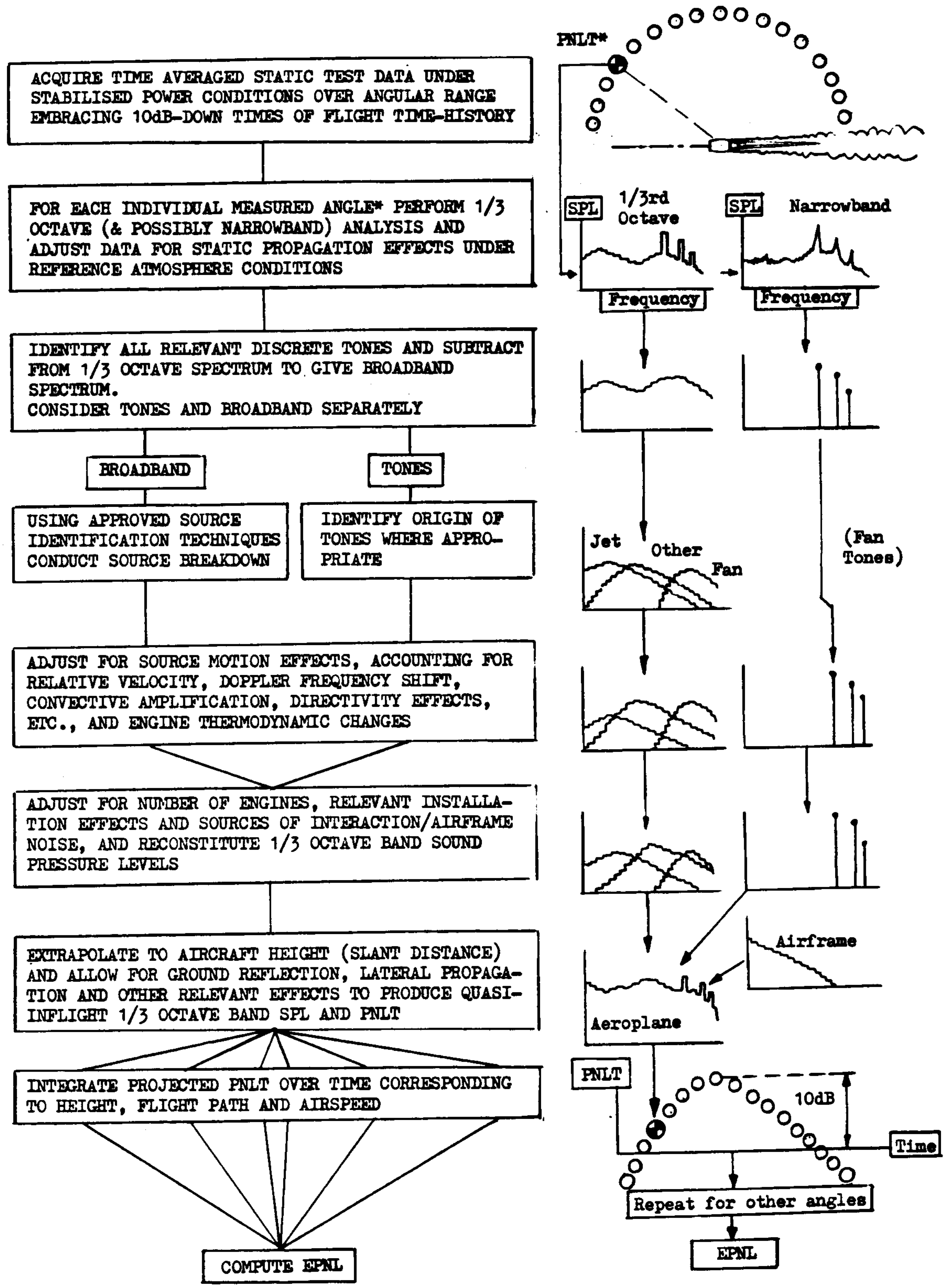


FIGURE 5

PROJECTION OF STATIC ENGINE DATA TO AEROPLANE FLIGHT CONDITIONS



b. Normalization to Reference Conditions. The analyzed static test data should be normalized to standard 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 March 15, 1975). The atmospheric absorption should be computed over the actual distance from the effective center of each noise source to each microphone, as described below. 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 correcting measured sound pressure levels to standard conditions 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 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 measured static engine SPL data 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 that 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.

(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 or 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 EPNL are not particularly sensitive to the assumption made regarding the spatial distribution of noise sources. However, in some circumstances (for example, where changes are made to exhaust 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 and discrete tones 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. As 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 variation 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 EPNL, 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:

$$\Delta SPL_{flight} = SPL_{static} - K \log (1 - M \cos \theta)$$

where SPL_{flight} = flight sound pressure level
SPL_{static} = static sound level and M and θ 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 SPLs 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 March 15, 1975. In the event that minor differences in absorption values exist in SAE ARP 866A among 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:

$$\Delta SPL_{airframe} = 50 \, Log \left(\frac{V_{NPD}}{V_{TEST}} \right)$$

where: V_{TEST} 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 airplane 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 of this AC 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. This residual has been limited to 3 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 of this AC. 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 procedures similar to those outlined in paragraph 17 of this AC for static tests.

20. SUPPLEMENTAL ANALYSES. Approved 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, 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 14(e)(2) of this AC.

(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 percent confidence interval at the extended power;

(b) airplane/engine noise source characteristics and behavior;

(c) engine cycle changes; and

(d) quality of data to be extrapolated.

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 manner similar to the static test procedures described in paragraph 18 of this AC.

(1) Airplane Noise Components. A model of detailed spectral and directivity characteristics 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 18, 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 18(k). 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 AC.

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, and the use of noise units other than EPNL, where appropriate, to determine relative differences. 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 AC.

CHAPTER 4. DOCUMENTATION REQUIREMENTS

23. GENERAL. Documentation is a vital part of the noise certification process. A clear and concise record is necessary detailing where, how, and what tests were conducted, the data analyzed, and the results obtained. Good communication between the applicant and the certificating authorities before, during, and after the testing is desirable.

24. 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 AC, a particular plan should address only those items of interest to an applicant. The plan should list equivalencies anticipated to be needed along with supporting documentation. NOTE: All plans must be FAA approved and all equivalencies must be identified and any new equivalency not addressed in this AC must be submitted for approval.

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 Part 36 and this AC 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 Part 36 and this AC 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.

25. 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 measurement 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 range.

(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).

26. DER WITNESS INFORMAL REPORT. In those cases where the acoustic test is witnessed by a Designated Engineering Representative (DER) appointed and acting under the DER Handbook, Order 8110.37, the following information may be required by the FAA (as appropriate) to establish validity or invalidity of the testing in accordance with the test plan. This report should be submitted as soon as practical following the completion of the acoustic flight test or ground test program:

a. Copy of the FAA approved planned test sequence or test plan itemizing conditions that were tested.

b. DER recorded manual notes for each condition and daily test summary.

c. Weather information for each condition.

d. DER observed equipment description, by type, model, and serial number, as appropriate.

e. Recorded miscellaneous DER comments: (1) observed peak and/or average dB, (2) reasons for acceptability or unacceptability of test conditions, (3) observed narrow band analysis results, (4) etc.

f. Reported equipment calibration results.

g. Reported equipment failures, malfunctions, anomalous operation, spurious signals, etc., and corrective action taken.

h. Overall after-the-test summary by DER.

i. Summary of all meetings or negotiations between the applicant, the testing organization, and the DER.

j. Any additional information witnessed by the DER that should be reported in order to establish validity or invalidity of the testing, data reduction/analysis, and certification approval.

k. Plotted examples of measured and corrected spectral values for each of the three measuring locations, together with appropriate time-related (computer) listings, may be necessary for complete data review.

27. NOISE CONTROL ACT FINDINGS. The Noise Control Act of 1972 provides that the FAA, before issuing any original type certificate for any aircraft of any category (except experimental) and regardless of whether Part 36 applies to the aircraft, must determine whether (1) substantial noise abatement cannot be

achieved for that aircraft by prescribing standards and regulations consistent with the limitations of section 611(d), or (2) substantial noise abatement may be so achieved in which case the regulatory process must be used to determine the extent of noise reduction to be required before an original type certificate may be issued. This finding must be made by FAA notwithstanding any delegation to companies or other private persons or procedures for type certificating foreign-manufactured aircraft. It is legally important that these findings be based on actual examination of each type design. This examination must be initiated as soon as possible after the application for type certificate in each original type certification process and reflect noise reduction potentials that become evident during the certification process. The noise finding documentation is not limited to, but should include:

a. The sources of audible noise, aerodynamic or otherwise, in the particular type design, including any noise measurements made, who made them, whether witnessed by FAA or not, and an estimate as to their reliability.

b. The technical alternatives and means that may be available for reducing such noise, including appropriate recommendations regarding choices of practical technical alternatives which have a potential for reducing noise.

c. An estimate of the expected degree of potential noise reduction associated with each alternative identified in b. above.

d. Investigation and review of the manufacturer's design information, data, and tests.

e. For each noise reduction technical alternative identified in b. above, that is not incorporated in the type design, the economic and technical justification for not requiring that it be so incorporated.

28. AIRPLANE FLIGHT MANUALS. The Airplane Flight Manual (AFM) aboard each airplane must contain (in addition to airworthiness required information) the certificated noise levels and the procedures used to demonstrate those levels. Further, the AFM must describe clearly the type certificate limits, if any, that are established as a result of Part 36 compliance when combined with the airworthiness limitations.

a. General Requirements for Limitation.

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

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

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

b. AFM Maximum Certificated Weight Limits. The takeoff and landing weight limits may be categorized (structural, customer option, noise-limited, etc.) provided that instructions in the Limitations Section clearly state that the most restrictive takeoff weight limit and landing weight limit of these categories are the maximum certificated weight limits. The Limitations Section may include more than one maximum landing weight limit if those landing weight limits are flap configuration dependent, based on structural, customer option, or noise certification considerations.

c. Multiple Noise Certifications.

(1) Multiple noise-limited gross weight pairs (takeoff and landing) for one configuration are not allowed. Only one set of gross weight limits that pertain to a particular configuration (hardware build) may be established under Part 36 for a particular airplane.

(2) An airplane configuration (hardware build) must be certificated to only a single "Stage" as appropriate under Part 36 (Stage 1, Stage 2, or Stage 3). The Limitations Section of the AFM for that airplane configuration shall not contain operating limits that do not meet the noise certification criteria for Part 36 for the "Stage." However, the Part 36 certification status of an airplane configuration may be amended to reflect another "Stage," if appropriate, provided the AFM is revised for that configuration to reflect this new "Stage" compliance status, and the previous "Stage" approval is deleted.

d. Landing Flap Restriction.

(1) An operating limitation preventing the use of an approved landing flap setting cannot be imposed under Part 36 and must be established under airworthiness requirements or a voluntary design change. If such a restriction is desired in order to comply with Part 36 certification requirements, that flap position is not approved for normal operation. Reference to emergency use of the restricted flap may be incorporated in the Limitations Section and operational information may be included in the Emergency Procedures Section of the AFM.

(2) For airworthiness purposes, some airplane models have a "softguard," which makes it obvious that the maximum flap setting is not to be used for normal operation and would indicate any use of the unapproved setting by its deformation. This policy is also required by the Transport Category Directorate on all Stage 3 airplanes that fail to comply with the provisions of Part 36 in the "noisiest" landing flap configuration. This is particularly important for STC projects where the basic AFM may not be modified, only supplemented, allowing the unapproved maximum flap performance information to remain intact and available.

(3) In order to approve a design that involves the restriction of the original landing flap settings, it is recommended that the following steps be taken in addition to any other requirements:

(a) Where permitted, remove the performance information that is relevant to the unapproved flap setting from the Performance Section of the AFM. (Note that supplemental type certificate (STC) applicants are not authorized to modify the basic AFM.)

(b) If the "unapproved" flap setting remains selectable:

(i) State in the Limitations Section of the AFM that the unapproved flap setting cannot be used except for emergencies.

(ii) Place appropriate placards in the cockpit to prevent use of the restricted flap setting.

(iii) For Stage 3 airplanes, provide a "softguard," such as a crushable cover plate, over the slot in which the flap selector handle travels, to restrain normal use of the unapproved flap setting.

e. Optional Engine Thrust Ratings (Derated and Reduced Thrust). Compliance with Part 36 is only required at full rated takeoff thrust. It is acceptable to establish through the type certification process a derated/reduced thrust that is less than the full rated takeoff thrust. The derated/reduced thrust is not an acoustical change under section 21.93(b) provided that the full rated takeoff thrust remains approved for that airplane. (Nothing herein precludes the use of the Part 36 thrust cutback procedure.)

f. Noise Level Information. The noise levels achieved during the type certification must be included in the AFM and consist of only one takeoff, one sideline, and one approach noise level per configuration (hardware build) for each airplane. The Part 36 "Stage" number should accompany the noise level information to indicate the compliance status. Supplementary information (labeled as such) may be added to the AFM concerning noise levels for other configurations and/or conditions not included in the certification summary.

29. ICAO CERTIFICATIONS. The FAA certificates for noise to the requirements of Part 36. However, some applicants require certification to the Annex 16 requirements published by the International Civil Aviation Organization (ICAO). Unless there is an in-force bilateral agreement which specifically includes noise and emissions certification, FAA participation is dependent upon management determination of the availability of resources. In any event, the FAA does not grant final approval of Annex 16 noise levels. This is the responsibility of the foreign airworthiness authority involved. FAA participation is limited to witnessing the tests and reviewing the data for accuracy. In those cases where Stage 3 has been demonstrated, it is permissible to insert the following statement in the AFM:

"CERTIFICATION NOISE LEVELS

The following noise levels comply with FAR Part 36, Appendix C, Stage 3 noise level requirements and were obtained by analysis of approved data from noise tests conducted under the provisions of FAR Part 36, Amendment 36-12. The test and analysis procedures used to obtain these noise levels are essentially equivalent to those required by the International Civil Aviation Organization (ICAO) in Annex 16, Volume I, Chapter 3.

ICAO Annex 16, Volume I, Chapter 3 approval is applicable only after endorsement by the Civil Aviation Authority of the country of airplane registration."