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AEROSPACE RECOMMENDED PRACTICE

ARP 1307

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Revised

MEASUREMENT OF EXTERIOR NOISE PRODUCED BY AIRCRAFT AUXILIARY POWER UNITS (APUs) AND ASSOCIATED EQUIPMENT DURING GROUND OPERATION

1. INTRODUCTION

Many commercial and military transport aircraft are equipped with one or more on-board auxiliary power units (APUs) to provide self-contained power for operating essential aircraft systems during typical servicing of aircraft and during passenger boarding operations. Increased awareness of noise produced during these operations of APUs and associated ground operated equipment such as environmental control systems, electrical generators, blowers and cooling fans has created a need for a common basis whereby noise information can be communicated among airport authorities, airline operators, aircraft and equipment manufacturers. Standard procedures for noise measurement, analysis and reporting will help fulfill this need.

2. PURPOSE

This Aerospace Recommended Practice (ARP) describes standard conditions and procedures for measuring, analyzing and reporting noise, resulting from operation of on-board APUs and associated equipment of aircraft undergoing servicing.

3. SCOPE

Test procedures are described for measuring noise at specific locations (passenger and cargo doors, and servicing positions) and for conducting general noise surveys around aircraft.

Requirements are identified with respect to instrumentation; acoustic and atmospheric environment; data acquisition, reduction and presentation, and such other information as is needed for reporting the results.

Recommended procedures involve recording data on magnetic tape for subsequent processing. The use of tape-recorder/time-integrating analyzer systems avoids the need to average by eye the variations associated with manual readings from sound level meters and octave band analyzers and therefore yields more accurate results.

This document makes no provision for predicting APU noise from basic engine characteristics, nor for measuring noise of more than one aircraft operating at the same time.

No attempt is made to suggest acceptable levels of noise or suitable subjective criteria for judging acceptability.

4. GENERAL TEST CONDITIONS

4.1 Meteorological Conditions:

Wind	Not more than 10 knots (5 m/s).
Temperature	Not less than 35° F (2° C) nor more than 95° F (35° C).
Humidity	Relative humidity not less than 30% nor more than 90%.
Precipitation	None.
Barometric Pressure	Not less than 800 mbar (80 kPa) nor more than 1100 mbar (110 kPa).

4.2 Test Site: The ground between microphones and aircraft should be a smooth, hard surface. No obstructions should be present between aircraft and measurement positions and no reflecting surfaces (except the ground and aircraft) should be near enough to sound paths to significantly influence results. Surface of the ground surrounding the aircraft should be sensibly flat and level at least over an area formed by boundaries parallel to and 200 ft (60 m) beyond the outermost microphone array identified in item 4 of 6.2.

4.3 Ambient Noise: Ambient noise of the measurement system and test area (that is, composite of the noise due to environmental background and the electrical noise of the acoustic intrumentation) should be determined.

4.4 APU Installation: Pertinent APU and associated aircraft systems should be tested for each aircraft model for which acoustic data are required.

4.5 Aircraft Ground Configuration: Aircraft flight control surfaces should be in the "neutral" or "clean" configuration, with gust locks on, or as stated in the aircraft's approved operating manual for aircraft undergoing servicing.

5. INSTRUMENTATION

5.1 Aircraft: Operation data identified in 7.4 should be determined from normal aircraft instruments and controls.

5.2 Acoustical:

5.2.1 General: Instrumentation and measurement procedures should be consistent with requirements of latest applicable issues of appropriate standards listed in the references (Section 8.). All data samples should be at least 2.5 times the data reduction integration period which in no case should be less than 8 seconds. All sound pressure levels should be in decibels to a reference pressure of 20 μpa.

5.2.2 Data Acquisition Systems: Instrumentation systems for recording and analysis of noise, shown in the block diagram of Fig. 1, should meet the following specifications:

5.2.2.1 Microphone System: Over a frequency range of at least 45 Hz to 11,200 Hz the system should meet the requirements as outlined under microphone system specifications in the latest issue of reference 9.

Microphones should be omnidirectional, vented for pressure equalization if of condenser type, and should have known ambient pressure and temperature coefficients. Microphone amplifier specifications should be compatible with those of the microphone and tape recorder.

Microphone wind screens should be employed when wind speed is in excess of 6 knots (3 m/s). Corrections as a function of frequency should be applied to measured data to account for the presence of microphone wind screens.

5.2.2.2 Tape Recorder: The tape recorder may be direct record or FM and should have the following characteristics:

Dynamic range 50 dB minimum in 1/1 octave or 1/3 octave bands.
Tape speed accuracy within ± 0.2% of rated speed.
Wow and flutter (peak to peak) less than 0.5% of tape speed.
Maximum third harmonic distortion less than 2%.

5.2.3 Calibration:

5.2.3.1 Microphone: Frequency response calibration should be performed prior to the test series and a subsequent post calibration should be performed within one month of the pre-calibration, with additional calibrations made when shock or damage is suspected. Response calibration should cover the range of at least 45 Hz to 11,200 Hz. Pressure response characteristics of the microphone should be corrected to obtain random incidence calibration.

5.2.3.2 Recording System: A calibration tape, a recording of broadband noise or a sweep of sinusoidal signals over a minimum frequency range of 45 Hz to 11,200 Hz should be recorded in the field or in the laboratory at the beginning and end of each test. The tape should also include signals at the frequencies employed during sound pressure sensitivity checks as defined in the following paragraph:

This calibration signal, an insert voltage, should be applied to the input and should include all signal conditioning preamplifiers, networks and recorder electronicsused to record acoustic data. In addition, a "shorted input" (i.e, microphone pressure sensitive element replaced with equivalent electrical impedance) recording of at least 20 sec. should be made as a check on system dynamic range and noise floor.

Sound pressure sensitivity calibrations with the arrangement shown in Fig. 1 should be made in the field for each microphone prior to beginning and after completion of measurements each day. These calibrations should be made using a calibrator producing a known and constant-amplitude sound pressure level at one or more 1/3 octave band center frequencies, specified in reference 3 or 10 in the frequency range from 45 Hz to 11,200 Hz. A barometric correction should be applied as required. Calibrators employed should be precise at least to within $\pm$0.5 dB and should have a calibration obtained according to reference 5 that is traceable to the United States National Bureau of Standards, or to a recognized international equivalent.

Each reel of tape should have comparable response and background noise as the calibration tape. A constant amplitude sine wave should be recorded at the start of each reel of tape, for reel-to-reel sound pressure sensitivity comparisons. The frequency of this sine wave should be within the same frequency range as used for sound pressure sensitivity checks. A separate voltage insert device or an acoustic calibrator may be used for this purpose. If an acoustic calibrator is used, it should be carefully "seated" and corrections for ambient pressure should be made so that effects of pressure on calibrator and microphone response are eliminated.

Battery-driven tape recorders should be checked at frequent intervals during a test to ensure good battery condition. Tape recorders should not be moved while recording is in progress unless it has been established that such movements will not change tape recorder characteristics.

5.2.3.3 Data Reduction Equipment: Data reduction equipment should be calibrated with electrical signals of known amplitude either at a series of discreet frequencies or with broadband signals covering the frequency range of 45 Hz to 11,200 Hz.

5.2.4 Data Reduction: The data reduction system of Fig. 1 should provide 1/3 or 1/1 octave band sound pressure levels. Analyzer filters should comply with requirements of references 8 or 11 (Class II for octave-band filters and Class III for one-third octave-band filters). Analyzer amplitude resolution should be no worse than 0.5 dB; dynamic range should be a minimum of 50 dB between full scale and the root-mean-square (rms) value of the analyzer noise floor in the octave band with the highest noise floor; and amplitude response over the upper 40 dB range should be linear to within $\pm$0.5 dB.

Mean square sound pressures should be time averaged by integration of the squared output of frequency band filters over an integration interval that should be no less than 8 seconds. All data should be processed within the frequency range from 45 Hz to 11,200 Hz. Data should be corrected for all known or predictable errors, such as deviations of system frequency response from a flat response.

5.2.5 Total System: In addition to specifications for component systems, frequency response of the combined data acquisition and reduction system should be flat within ±3 dB over the frequency range from 45 Hz to 11,200 Hz. Frequency response gradient anywhere within this range should not exceed 5 dB per octave.

Amplitude resolution should be at least 1.0 dB. Dynamic range should be a minimum of 45 dB between full scale and the rms value of the system noise floor in the frequency band with the highest noise floor. Amplitude response should be linear within ±0.5 dB over the upper 35 dB in each frequency band.

5.3 Meterological: The wind speed should be measured with a device having a range of at least 0 to 15 knots (0 to 8 m/s) with an accuracy of at least ±0.5 knots (±0.3 m/s). Temperature measurements should be made with a device having a range of at least 30° - 110° F (0° - 40° C) with an accuracy at least ±0.5° F (±0.2° C). Relative humidity should be measured with a device having a range of 0 to 100 percent with an accuracy of at least ±3 percentage points. Atmospheric pressure should be measured with a device having a range of at least 800 to 1100 mbar (80 to 110 kPa) with an accuracy of at least ±2.5 mbar (±0.25 kPa).

6. TEST PROCEDURE

6.1 Test Conditions: Ambient noise measurements should be made in sufficient number to be representative for all acoustic measurement stations, providing correction data to apply to measured APU noise where necessary (see 6.4).

Acoustic test measurements should be made with the installed APU and associated equipment operating under load conditions appropriate to the normal modes of operations required for aircraft ground handling.

6.2 Acoustical Measurement Locations: Except where specified otherwise, noise measurements should be made with microphones at 5.25 ft ± 1.0 in. (1.6 m ± 0.025 m) above the ground or surface where passengers or servicing personnel may stand, with the microphone diaphragm parallel to the ground and facing upwards.

Locations for measuring noise should be as follows:

6.2.1 Cargo Door Locations: Measurements should be made at each cargo door location, with the door open, while the aircraft is in a typical ground handling configuration. These measurements should be taken at the center of the opening, in the plane of the fuselage skin.

6.2.2 Passenger Door Locations: Measurements should be made at each passenger entry door, with the door open, on the vertical centerline of the opening, in the plane of the fuselage skin.

6.2.3 Servicing Locations: Measurements should be made at all servicing positions where persons are normally working during aircraft ground handling operations. These positions to be determined by reference to the approved aircraft operating and service manuals.

6.2.4 Survey Locations: Appropriate measurement positions should be chosen from a rectilinear grid pattern centered on the test airplane as illustrated in Fig. 2. The grid pattern should originate 20 m aft of the aircraft and extend at least 20 m forward of the aircraft as well as perpendicular to the aircraft centerline. The length of sides of squares in the grid should be 10 metres. Further subdivision of the grid pattern to accommodate small airplanes or to fulfill special requirements may be accomplished by progressively halving dimensions of grid squares as appropriate.

6.3 Meterorological Measurement Locations: Meteorological data should be measured at a location at the test site within the microphone array of Fig. 2, but upwind of the aircraft, and at a height of 5.25 ft (1.6 m) above ground level.

6.4 Data Presentation: A-weighted sound levels should be calculated by applying frequency weighting corrections derived from the standards for precision sound level meters (reference 6 or 9) to 1/3 or 1/1 octave-band sound pressure levels. The 1/1 octave-band sound pressure levels may be determined from a summation of mean-square sound pressures in appropriate 1/3 octave bands. Overall sound pressure levels should be determined from a summation of mean-square sound pressures in the twenty-four 1/3 octave, or eight 1/1 octave, frequency bands included in the frequency range from 45 Hz to 11,200 Hz.

Overall sound pressure levels, A-weighted sound levels and 1/3 octave band or 1/1 octave band data should be presented to the nearest decibel (dB) in tabular form, with supplementary graphical presentations as appropriate. Sound pressure levels should be corrected, if necessary, for the presence of high ambient noise. No corrections are needed if a sound pressure level is 10 dB or more above ambient noise. For sound pressure levels between 3 and 10 dB above ambient noise, appropriate corrections should be applied, see Table 4 of reference 4. If sound pressure levels are 3 dB or less above the ambient noise, no corrections should be attempted and these data should not be reported.

Acoustical data need not be normalized for atmospheric absorption losses. Test results should be reported under the actual test-day meteorological conditions.

7. DATA REPORTING

7.1 Identification Information:

7.1.1 Test location, date and time of test.

7.1.2 Manufacturer and model of the APU and pertinent associated equipment.

7.1.3 Aircraft type, manufacturer, model and air registry number

7.1.4 Plan and elevation views, as appropriate, of the aircraft outline showing location of the APU (including inlet & exhaust ports), all associated equipment, and all acoustical measurement stations.

7.2 Test Site Description:

7.2.1 Type and location of ground surfaces.

7.2.2 Location and extent of any above-ground-level reflective surfaces, such as buildings or other aircraft, that might have been present in spite of the precautions noted in 4.2.

7.3 Meteorological Data: For each test condition:

7.3.1 Wind speed, knots or (m/s) and direction, degrees, relative to aircraft centerline (forward - 0°)

7.3.2 Ambient temperature, °F (°C).

7.3.3 Relative humidity, percent.

7.3.4 Barometric pressure, mbar (kPa)

7.4 Operational Data: For each test condition:

7.4.1 Number of air conditioning packs operated and their locations.

7.4.2 APU shaft speed(s), rpm or percent of normal rated.

7.4.3 APU normal rated shaft speed, rpm.

7.4.4 APU shaft load, horsepower, (W), and/or electrical power output, kVA.

7.4.5 Pneumatic load, lb/min (kg/min) delivered by APU to all pneumatically operated aircraft systems during the test (calculated as required).

7.4.6 Temperature of APU exhaust gas at location specified in aircraft's approved operations manual, °F, (°C).

7.4.7 Operating mode of environmental control system, cooling or heating.

7.4.8 Air conditioning distribution system supply duct temperature, °F, (°C).

7.4.9 Events occuring during the test which may have influenced the measurements.

7.5 Instrumentation:

7.5.1 A complete description (including manufacturer and type or model numbers) of the acoustical and meteorological measuring instruments.

7.5.2 A complete description (including manufacturer and type or model numbers) of the data acquisition and data processing systems.

7.6 Acoustical Data:

7.6.1 Ambient noise.

7.6.2 Acoustical data per 6.4 with a description of corresponding microphone locations.

7.6.3 List of standards used and description and reason for any deviations.

PREPARED BY

SAE COMMITTEE A-21, AIRCRAFT NOISE MEASUREMENT

8. REFERENCES

RELATED STANDARDS FOR INSTRUMENTS AND MEASUREMENT PROCEDURES

1. American National Standard Acoustical Terminology, American National Standards Institute, ANSI S1.1-1960.

2. American National Standard Preferred Reference Quantities for Acoustical Levels, American National Standards Institute, ANSI S1.8-1969.

3. American National Standard Preferred Frequencies and Band Numbers for Acoustical Measurements, American National Standards Institute, ANSI S1.6-1967.

4. American National Standard Methods for Measurement of Sound Pressure Levels, American National Standards Institute, ANSI S1.13-1971.

5. American National Standard Specifications for Laboratory Standard Microphones, American National Standards Institute, ANSI S1.12-1967.

6. American National Standard Specification for Sound Level Meters, American National Standards Institute, ANSI S1.4-1971.

7. American National Standard Method for the Calibration of Microphones, American National Standards Institute, ANSI S1.10-1966.

8. American National Standard Specification for Octave, Half-Octave and Third-Octave-Band Filter Sets, American National Standards Institute, ANSI S1.11-1966.

9. IEC Recommendations for Precision Sound Level Meters, International Electrotechnical Commission, IEC 179 (1965).

10. ISO Recommendations for Preferred Frequencies for Acoustical Measurements, International Organization for Standardization, ISO/R266-1962(E).

11. IEC Recommendations for Octave, Half-Octave and Third Octave-Band Filters Intended for the Analysis of Sounds and Vibrations, International Electrotechnical Commission, IEC 225 (1966).