Meteorological measurement by using light aircraft (for acoustic certification)

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Abstract: In the acoustic aircraft certification framework, some atmospheric soundings are required in order to characterize the whole sound propagation path between aircraft and microphones.

This characterization consists in humidity and temperature measurements as an altitude function.
Usual means lead to limitation in the test conditions linked to the local weather and extend the acoustic tests duration.

The proposed test mean involves a light aircraft which allows sensors, with required accuracy, to be taken on board, in order to make the adapted measurements.
This test mean is fully compliant with up to date international requirements. It allows to extend the usable meteorological windows and so to reduce the certification cycle.

Keywords: Acoustic, Certification, Meteorology.

1. Introduction

Airbus supports ICAO in defining the international legal framework for air transport and is totally committed in ensuring that air transportation becomes less and less noise polluting.

To achieve certification any Airbus aircraft must demonstrate that its noise level does not exceed the limits defined by ICAO Annex 16.

This is why each Airbus aircraft type noise is measured during certification cycle.

In order to reduce this certification cycles and to increase tests quality, Airbus has chosen to upgrade its meteorological environmental measurement.

This article describes the new test facility which permits the increase of the meteorological window.

2. Background

To achieve certification of an aircraft, it must be demonstrated that the noise levels measured at three certification points do not exceed the limits defined by ICAO Annex 16.

These three points are, shown in the figure 1 :

- Flyover : at 6.5km from brake release point, under the takeoff flight path ;
- Highest measurement recorded at the sideline, 450m from the runway axis, during take off ;
- Approach, at 2 km from the runway threshold, under the approach flight path.

Cumulative levels are defined as the arithmetic sum of the three certification levels.

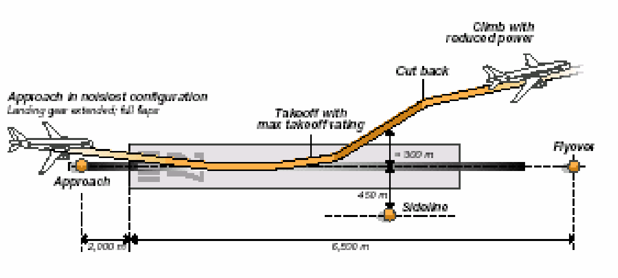

Figure 1

To measure these values, aircraft flies over, in several configurations (flaps / slats : in / out), above the microphone equipped area. These data are collected and analyzed in the frequency domain. Each fly over is called a run. One day of certification contains 40 runs, one certification can last 3 or 4 days.

The unit used to measure noise levels is EPNdB, that stands for “Effective Perceived Noise” and is expressed in decibels.

This noise level in EPNdB depends on intensity of sound, noise duration and tone components in order to take into account human ear specificity.

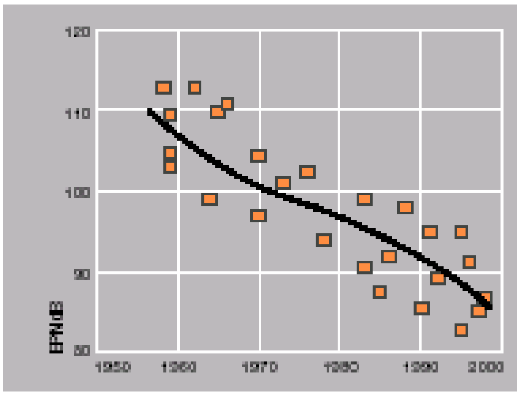

Figure 2

Orange square stands for aircraft type.
The more recent is the aircraft the quieter it is.

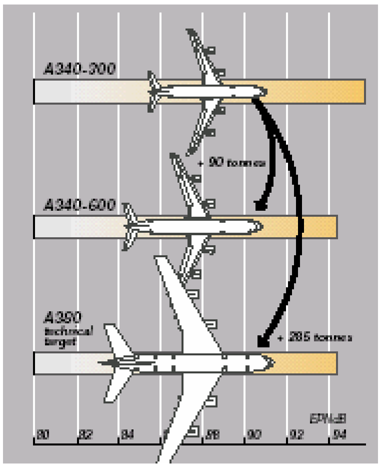

Figure 3

Noise reduction according to design date.

The currently applicable international regulation is known as chapter 3. Any aircraft type certified from 1977 must be compliant with this chapter 3.
A new chapter 4 will be applicable to all aircraft type certified after January 2006, it will reduce the authorized cumulative noise level by 10 EPNdB with regard to chapter 3.

As an example the figures 2 and 3 show the flyover noise according to generations of aircraft.

2. Test facility problematic

2.1 Atmospheric conditions and aircraft position

Acoustic certification procedure needs the knowledge of three kinds of parameters :

- Aircraft noise
- Weather conditions
- Aircraft flight path and flight conditions

Some weather conditions are used to correct the sound level according to air noise attenuation, others forbid acoustic certification when they reach specified predefined levels.

Weather conditions are used to calculate noise attenuation ; air temperature, hygrometry must be known between ground level and aircraft path.

They are currently performed by atmospheric soundings. These soundings use free helium inflated balloons and “one shot” sensors. Sensors are tied to balloon and are lost after each sounding.

Figure 4

Meteo sounding facility.

In the same way, aircraft flight path must be known to correct noise level received by microphone and to check that aircraft path is inside a predefined template as shown in figure 5.

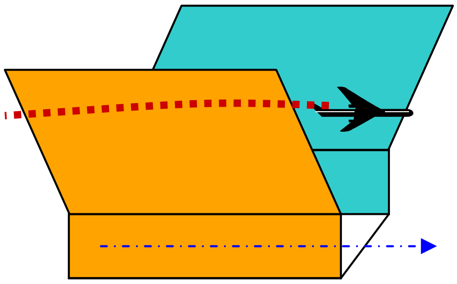

Figure 5

Moreover flight conditions like flaps, flats, landing gear position, engine rating have to be mentioned in the test rapport and checked during the test

All these information must be synchronized according to the OACI recommendation that is 5 ms.

2.2 Atmospheric noise attenuation

In order to calculate the air noise attenuation and to have access to the generated aircraft noise, we use similar tables as in figure 6 for each noise frequency.

For each central third octave band frequency and for each layer of atmosphere, between ground and aircraft the measured humidity and temperature give an air noise attenuation. The integration of all the layers between ground and aircraft altitude gives the global air noise attenuation and so the aircraft generated noise for the studied frequency.

Each third octave band is so characterized, and the generated aircraft noise can be calculated.

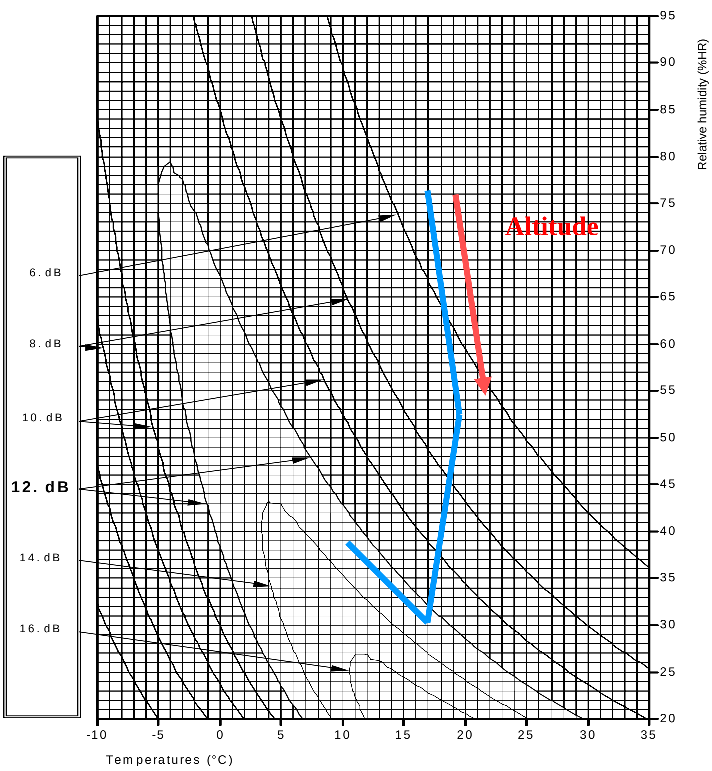

Figure 6

2.3 Sensors accuracy and noise attenuation

For the 8000 Hz frequency, an humidity variation of 20% leads to switch from 6 dB by 100 meters of attenuation to 8 dB by 100 meters of attenuation i.e. 2 dB more.

The same variation of 20% of humidity can lead to switch from 10 dB to 16 dB, i.e. 6 dB more for 100 meters of attenuation.

The same observation could be made for the temperature measurement, as it is illustrated in figure 7.

This implies that the more the attenuation is strong, the more the sensors accuracy must be precise to reach the right noise attenuation and so the right correction for the measured noise.

2.4 Current meteorological window

The current test facility and the used sensors allow Airbus to perform acoustic tests when all the way between microphone and aircraft has an attenuation between 0 dB and 12 dB for 100 meters. See figure 8.

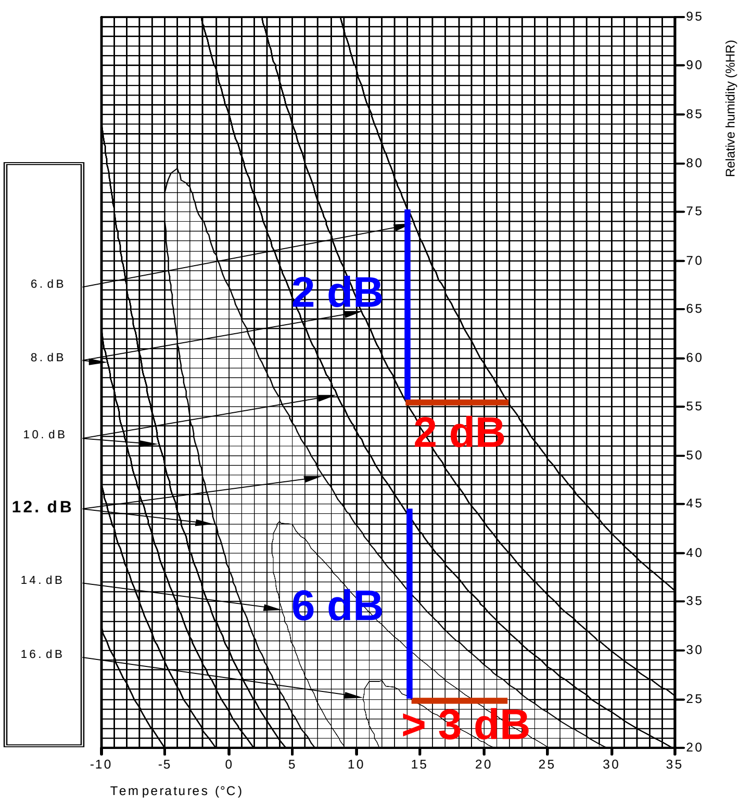

Figure 7

3. Meteorological window extension

3.1 The need for meteorological window extension

Time certification for new aircraft is now a strong economical factor. This implies a strong policy of allowed time for acoustic measurements reduction.

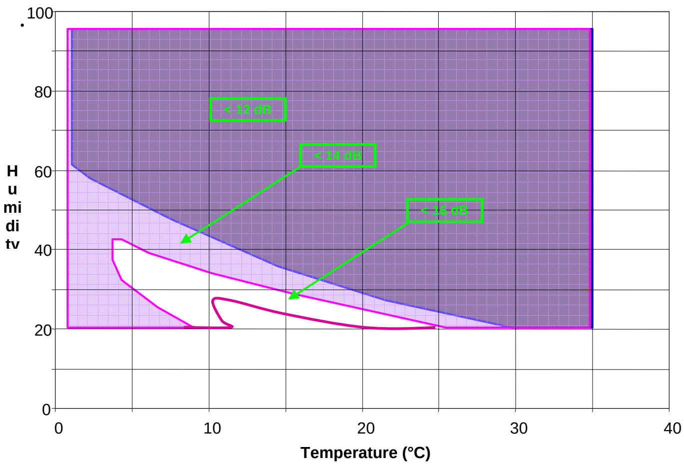

Figure 8

4. Meteorological measurements using light aircraft

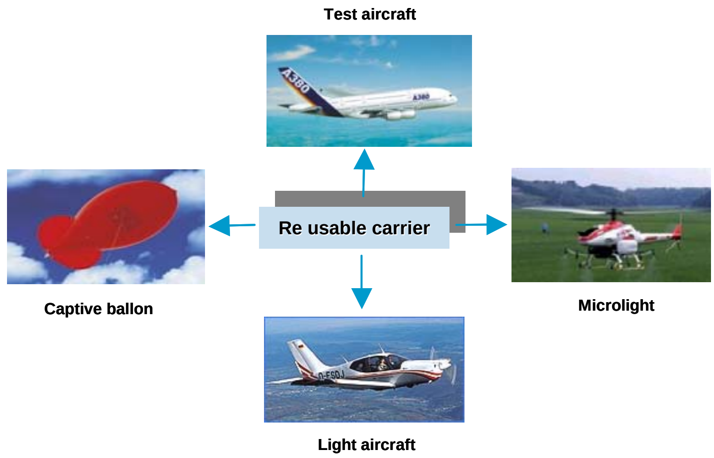

Figure 9

This leads to avoid or reduce delay due to meteorological unsuitable parameters and so directly to enlarge the acceptable meteorological window.

Moreover an extension of meteorological window will reduce the number of test interruptions due to meteorological parameters drift. The quality of the tests would be improved if the whole tests could be completed in the same session.

International noise measurement rules allow a meteorological window extension from 12 dB attenuation for 100 meters for 8 kHz noise, up to 16 dB attenuation for approach measurements and 14 dB for flyover measurements, as shown in figure 8.

This extension is subordinated to severe accuracy in the determination of noise air attenuation value.

3.2 Sensor accuracy and meteorological window

Up to now Airbus performs its test using a 12 dB attenuation windows for 8000Hz each 100 meters.
This is equivalent to use sensors with an accuracy of +/-1°C in temperature and due point measurements.

Using a 14/16 dB attenuation for 100 meters window is possible at a condition to reach an accuracy of +/-0.5°C for static temperature measurement and +/-0.5°C for due point measurement.
This meteorological window enlargement requires more accurate, and so, much more expensive sensors.
The current test facility using free helium inflated balloons with unrecoverable sensors can not be renewed.

4.1 Conceivable solutions

In order to respect economical and technical constraints Airbus studied different carries for the sensors.

The four conceivable solutions are summarized in figure 9.

Using the test aircraft itself does not allow an easy to use way of characterizing the whole path between the ground microphones and the test aircraft. Microlights are not enough reliable for the time saving policy on certification cycle. Other studied solutions concern captive balloon : but they are forbidden near airport where noise measurement tests take often place.

4.2 Airbus solution

The most suitable solution consists in equipping a light aircraft with accurate enough sensors.
The so equipped light aircraft will fly in a spiral flight path near the measurement area, in order to map the atmosphere between microphones and tested aircraft.

4.3 Light aircraft equipment

Equipping a light aircraft with sensors consists in first solving the sensors position problem.

The chosen installation must avoid vibrations and aerodynamic perturbations due to propeller and aircraft lift surfaces such as wings.
The vibration constraints forbid an installation on a long pole attached to the wing and pointing forward. Aerodynamic constraints forbid a fuselage installation due to engine perturbation and boundary layer dynamic pressure modification.

As show in figures 10 to 12, an under wing pod solution has been chosen. The light aircraft is equipped with a removable pod. This pod is studied to make not intrusive measurements.

Three sensors are mounted on the pod :

- a Pitot with a static and a dynamic pressure measurements
- a total temperature probe
- a due point probe.

Figure 10

Figure 11

Figure 12

Combining the measurements with the figure 13 equations, the static temperature and the humidity can be reached with the needed accuracy.

$$T_{static} = \frac{T_{measurated}}{\left\{1 + r_f\left[\left(1 + \frac{\Delta P}{P_{static}}\right)^{\left(\frac{\gamma - 1}{\gamma}\right)} - 1\right]\right\}}$$

$$ew(T) = \exp\left(\frac{a_0}{T + a_1 + T(a_2 + a_3 T) + (a_4 \log(T))}\right)$$

$$Hu = 100\frac{ew(T_d)}{ew(T_s)}$$

Figure 13

R_f = probe characteristic
Td = due point
Ts = static temperature

5. Conclusion

The 14/16 dB window extension will allow Airbus to reduce aircraft certification cycles, to improve its test measurements quality and to be fully compliant with up to date international noise rules.

This extension will be done using a light aircraft equipped with an especially design pod, itself equipped with accurate enough sensors.

This test means will be fully operational in summer 2005 and will be use for A380 certification.