inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 7.2

AIRCRAFT NOISE - A SURVEY METHOD FOR MEASUREMENTS OF FAÇADE INSULATION IN DWELLINGS AROUND ÅRLANDA AIRPORT, STOCKHOLM

C. Pagoldh, M. Hankanen

Ingemansson Technology AB, Box 47321, SE-100 74, Stockholm, Sweden

Tel.: +45 8 744 57 80 / Fax: +45 8 18 26 78 / Email: claes.pagoldh@ingemansson.se

Keywords:
AIRCRAFT NOISE, FACADE INSULATION, ARLANDA AIRPORT, STOCKHOLM, SURVEY MEASUREMENT METHOD

ABSTRACT
The Swedish Civil Aviation Administration has the commission to insulate all dwellings around Arlanda Airport which are exposed to 60 dB(A) or higher equivalent aircraft noise (in Sweden called FBN). To control an outside inventory carried out earlier, façade insulation measurements were carried out in 17 houses. In three of the houses the measurements were carried out both with aeroplanes and loudspeaker as a noise source. The goal was to be able to use a loudspeaker sending out continuous noise with a typical aircraft noise spectrum, and to measure A-weighted sound level indoors and outdoors simultaneously. Advantages with such a "Survey Method" are i) Independency of flying routes, wind-situation and aircraft types, ii) No influence from background noise, iii) Time efficiency. The loudspeaker and the microphone outdoors were mounted according to the standard ISO 140/5 (loudspeaker on the ground exposing the window with noise at 45 degrees angle incidence and flush mounted microphone on the façade). When measuring façade-insulation with aeroplanes as a noise source, the microphone outdoors was mounted on the façade and on the roof. The loudspeaker method and the method with aeroplanes as a noise source show quite good agreement when the microphone outdoors is mounted on the façade. The loud-speaker method gives up to 5 dB(A) lower façade insulation (with microphone on the façade) than the method with aeroplanes as a noise source (with microphone on the roof) when the façade is located perpendicular to the direction of the aeroplanes.

1 - INTRODUCTION
The Swedish Civil Aviation Administration has the commission to insulate all dwellings around Arlanda Airport in Stockholm which are exposed to 60 dB(A) or higher equivalent aircraft noise (in Sweden called FBN) outdoors. An Environmental Court of Justice has set 35 dB(A) FBN indoors as a goal for the insulation measures. In the commission measures are also to be taken when the maximum noise level from the aircraft is higher than 80 dB(A). The goal for the insulation measures is 45 dB(A) maximum noise level indoors in these dwellings.
National long-range goals for FBN indoors is 30 dB(A) and maximum noise level outdoors is 70 dB(A). It has been decided that when the Swedish Civil Aviation Administration change windows, add gypsum to the walls or roofs, add new glasses to existing windows etc, the goal shall be FBN 30 dB(A) indoors. If the house already fulfill 35 dB(A) FBN indoors no extra measures will be taken.
The measures are to be taken before the new, third track at Arlanda is used.
Last year, an outside inventory was accomplished, to make a preliminary judgement of the sound insulation in about 200 dwellings. This inventory is now being completed with an inside inventory. Properties mentioned below are noted:

- Windows; type, glass-thickness, size etc
- Walls; material, thickness etc

- Roof and ceiling; material, thickness etc
- Doors, type, sealings etc
- Ventilation; type

The result of the inventories is a judgement of the facade insulation in 5-dB-classes:

- < 20 dB(A)
- $20 - 25$ dB(A)
- $25 - 30$ dB(A)
- > 30 dB(A)

It is difficult to be more precize in the judgements, why (in critical houses) a measurement method was needed. To control the judgements of façade insulation measurements has been carried out in about 30 houses until now.

2 - GOAL

The goal was to be able to use a loudspeaker sending out continuous noise with a typical aircraft noise spectrum, and to measure A-weighted sound level indoors and outdoors simultaneously. Advantages with such a "Survey Method" compared with a method using aeroplanes as a noise source are:

- Independency of flying routes, wind-situation and aircraft types.
- No influence from background noise
- Time efficiency

3 - NATURE OF THE PROBLEM

There are standards for measurements of air traffic noise reduction of dwellings affected by noise from airborne aircraft and aircraft during landing and takeoff operations. In Sweden we are using Nordtest-method NT ACOU 074 [1]. The recommendations in this standard are to have an outdoor microphone position 10 m above ground near the house of current interest, not affected by reflected sound energy from any surfaces than the ground ("hemi-free field" position). If the purpose is to measure the noise reduction of one particular element of the house (for example façade, roof, etc.) the outdoor microphone shall be flush-mounted on the surface of the particular element. The indoor microphone is to be positioned in the room for which the reduction of air traffic noise has to be measured. The time-integrated sound pressure levels are measured outdoors and indoors simultaneous in 1/3 octave band from 100 Hz to 3150 Hz, or as A-weighted levels. If using A-weighted levels the measurement should be carried out during traffic with the most frequent aircraft types to ensure that the noise spectrum is typical. At least five aircraft operations are to be measured to obtain a mean value with acceptable accuracy. Additionally shall the atmospheric conditions in general comply with ISO 3891, 1 st. ed. Section 4.1.22 [2]. This means for example that the measurements should be carried out under downwind sound propagation conditions. If the elevation angle does not exceed 45 degrees to the passing aircraft the wind velocity should be $2 - 5$ m/s, with a direction from the aircraft to the microphone with an allowed deviation of $\pm$ 45 degrees. It is easy to understand that measurements according to this standard are very time consuming if you intend to do measurements of noise reduction in a lot of buildings all around an airport. This especially if the airports are using different runways depending on the wind direction for the moment. You can have to wait for several weeks for the proper wind direction. Another problem using this standard is the low indoors sound pressure levels when the aircraft are passing on quite a distance. Background level indoors affects the sound level due to aircraft if this level is less than 10 dB higher than the background level. If the difference is $3 - 10$ dB a normal correction can be made, but if the difference is less than 3 dB you can not use your measurement test results.
So we decided to develop a survey-method for measurement of the air traffic noise reduction of dwellings. The intention was that it should be fast and simple to get the requested figures, with acceptable accuracy, and to test this method in the Arlanda project including about 30 dwellings round the airport.

4 - DEVELOPMENT OF A SURVEY-METHOD

The aim in the project was to determine the equivalent aircraft noise value inside certain residential buildings close to the airport. From calculations made by the Swedish Civil Aviation Administration

we knew the A-weighted equivalent aircraft noise value outdoors those buildings. What we needed was difference in such a value and the corresponding indoor value. But why use aircraft as a source to get those values? Why not instead use a loudspeaker producing noise with a proper frequency spectrum?
Since the calculated outdoor value is a mix of the sound levels from take off and landing of the different type of aircraft in use at the airport, we had to determine a typical normalised frequency spectrum fore these events. We started with measurements according to Nordtest-method NT ACOU 074 at two houses situated 0.4 km and 1 km from runway, and approximately at a distance of 1.5 km. and 4.5 km. from the end of one of the runways.
These measurements were carried out in 1/3 octave band, both outdoors and in two different rooms indoors. The outdoor microphone was located on the roof, mounted directly on a sound reflecting slab of wood, 0.5 $\times$0.7 m^2. First we measured aircraft landing, and not until a couple of weeks later the wind was in opposite direction so we had the possibility to do measurements when aircraft were taking off. For each situation and place there were about 15 aircraft during the measurement. Every aircraft was identified regarding manufacturer and type. Figure 1 shows an example of A-weighted sound pressure levels outdoors and indoors in 1/3 octave band, measured when 7 different aircraft type MD-80 was landing.

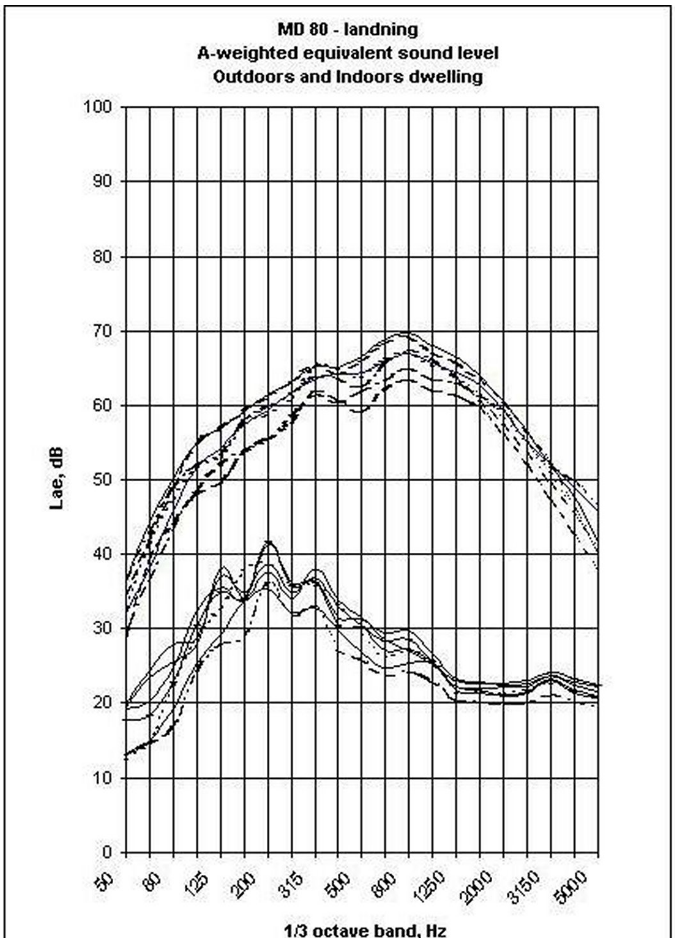

Figure 1: A-weighted SPL outdoors and indoors a dwelling with MD-80's landing.

Figure 2 shows an example of the results from the same kind of measurements as shown in figure 1, but with aircraft type MD-80 during take-off.
In this way all recorded measurements were analysed in order to get the average outdoor frequency spectrum, corresponding to a mix of take-off and landing of the most common aircraft using this airport. These analyses ended up in an average frequency spectrum shown in Figure 3.
Our intention was to use a loudspeaker as a source, producing pink noise filtered to the same shape as our average frequency spectrum. This spectrum is band-passed filtered from 80 Hz to 2000 Hz since it is obvious that the sound of aircraft in frequencies under 80 Hz and over 2000 Hz does not distribute to the total A-weighted sound pressure indoors. This means that the loudspeaker we are using does not

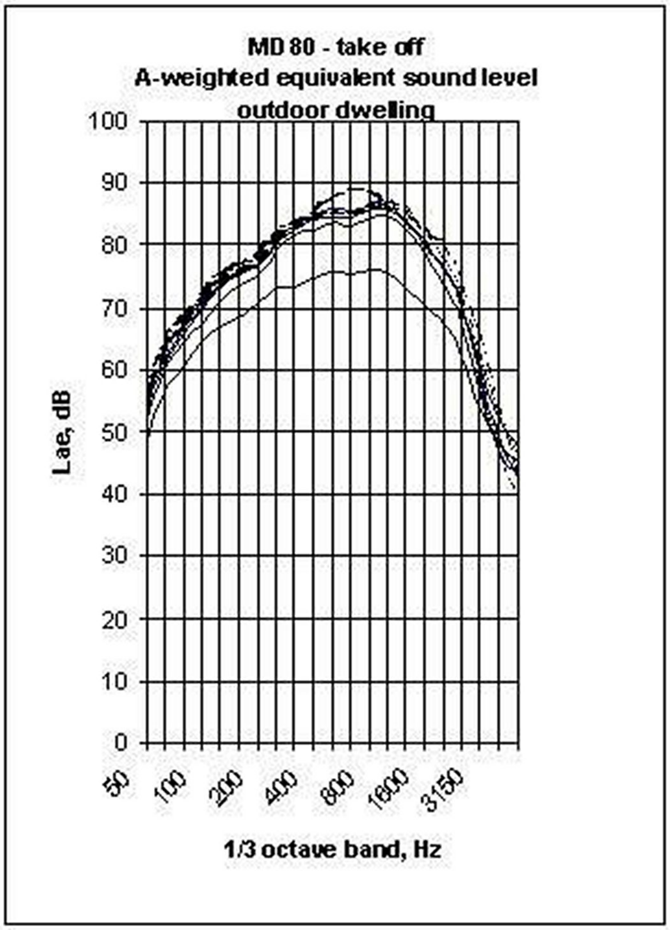

Figure 2: A-weighted SPL outdoors a dwelling from MD-80's take-off.

have to be particular powerful in the low frequency region. When using a loudspeaker we have followed the measurement standard EN ISO 140-5:1998 [3] concerning the position of the loudspeaker, giving the angle of sound incidence equal to 45° ± 5° to the normal of the façade elements (window), and a distance of at least 5 m. to that point. The outdoor microphone was flush-mounted on the surface of the façade element, using three different positions. Indoors we used a moving microphone, sweeping in the room. Figure 3 shows our average frequency spectrum and the one we measured outdoors, after some filtering corrections of the noise signal due to the frequency response of the loudspeaker we used. Testing this survey method on the same buildings we had measured the air traffic noise reduction using passing aircraft as a source, we got the same result in the difference between A-weighted sound pressure outdoors and indoors within some dB. When the façade element is perpendicular to the flight path the result of the measurement could be up to 5 dB higher with the traditional method compared to the survey-method.

5 - FIELD TESTS

In this project we used this survey-method investigating the air traffic noise reduction of façade in 30 dwellings around Arlanda Airport. The equipment for the measurements consists of two sound pressure level meters, type according to IEC 60651, acoustical calibrator, a loudspeaker with a built-in amplifier and a small CD player. On the CD was recorded our "aircraft noise filtered" pink noise. Since this noise was already A-weighted, the measurements indoors and outdoors were carried out with the sound level meters measuring the linear value. The outdoor microphone was mounted flush to the window and the indoor microphone was rotated in the room inside the window for 15 seconds, while the loudspeaker was producing the noise. The linear equivalent sound level during this period was measured with both instruments, and the result was noted as the difference between those values. Since the noise was A-weighted the loudspeaker and amplifier was easily able to create about 100 dBA outdoors, and consequently a high level indoors, there was no problem with background noise disturbing

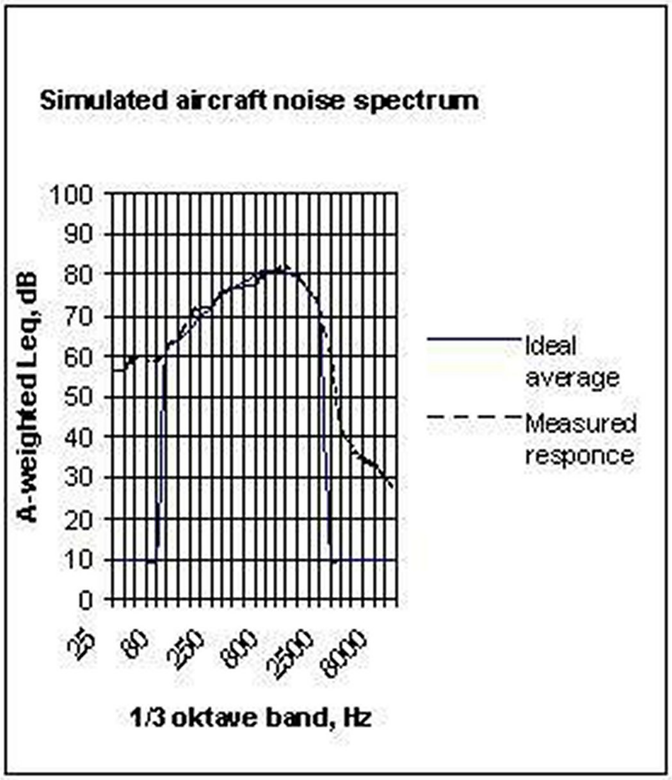

Figure 3: The ideal average aircraft noise spectrum and the one measured and used.

the measurement.

6 - CONCLUSIONS

Measurement with loudspeaker noise, filtered to correspond to the frequency spectrum of landing and take off of the noise dominating aircrafts in use, is a fast and easy way to measure air traffic noise reduction of dwellings. About $8 - 10$ different objects can normally be measured during a day by one measurement technician.

ACKNOWLEDGEMENTS

The authors would like to thank Mr Dan Hoffmeyer from Delta Akustik & Vibration, Denmark, for supervising this project. We would also like to thank Swedish Civil Aviation Administration for their sponsoring of the project.

REFERENCES

1. **Nordtest-method NT ACOU 074**, *Air traffic: Noise reduction of dwellings*

2. **ISO 3891: 1978**, *Acoustics - Procedure for describing aircraft noise heard on the ground*

3. **EN-ISO 140-5: 1998**, *Acoustics - Field measurements of airborne sound insulation of facade elements and facades*