ICSV13 - Vienna
The Thirteenth International Congress on Sound and Vibration
Vienna, Austria, July 2-6, 2006

AN ACOUSTICAL METHOD FOR THE LOCALIZATION OF FIRE PROPAGATION RISKS IN BUILDINGS

Leif Rydén

Ingemansson Technology AB
Kungsgatan 16, SE-753 32 Uppsala, Sweden
leif.ryden@ingemansson.se

Abstract

After a couple of devastating fires, where it was found that fire had propagated through unknown cracks and ducts, the Swedish National Property Board initiated a research project with the object of developing a method for finding risks that are not found by visual inspection. The Property Board administers the national building heritage, e g palaces, museums and theatres - often old buildings that have been rebuilt many times. During rebuilding, old ventilation ducts and chimney flues might have been boarded up without any indication of where they are. In the case of a fire there is a very real risk that these ducts might conduct hot fire gases, spreading the fire to other parts of the building.

After discussions and preliminary tests, it was agreed that the best method to try was an acoustic one. The first field-tests of acoustical methods were performed in the Royal Palace in Stockholm and the system was found to work well. Three methods were investigated: sound insulation measurements, listening tests and scanning with a semi-enclosed microphone. With all three methods, a loudspeaker in the sending room was used to produce a high level wide band noise.

A semi-enclosed microphone with the microphone - enclosed in an acoustically damped cup with a sealing lip - was developed during the the project. In that way, sound coming from the room is reduced when scanning the surface. The cup is mounted by an articulated fitting to a telescopic handle. The microphone is connected to a sound level meter which indicates the sound pressure level within the cup.

Scanning surfaces with the semi-enclosed microphone indicates localization and size of the leakages. This is a fast method that has proven its usefulness also for solving other acoustical problems.

INTRODUCTION

This study was undertaken to find a method to detect faults and leakages that might be potential fire propagation hazards in buildings. The demands on the method was that it should be

- Practical
- Non-destructive
- Economical
- Fast
- Safe

There are two kinds of leakages: *Open leakages* that have a direct connection between two rooms and *hidden leakages*. Hidden leakages occur when cracks, openings or ducts are hidden behind boards, wallpaper etc - making them hard or impossible to find by visual inspection. In the case of a fire, the covering will be burnt through and the crack might then conduct hot fire gasses to other areas of the building.

Several methods for finding the leakages were discussed, like testing of airtightness with tracer gas and studies of blueprints combined with visual inspection, but after some tests it was agreed that an acoustical method was the most promising one [1].

Sound insulation measurement method

The first hypothesis was that faults and leakages in the building would reduce the sound insulation and that it should be possible to find these problem areas with the help of sound insulation measurements.

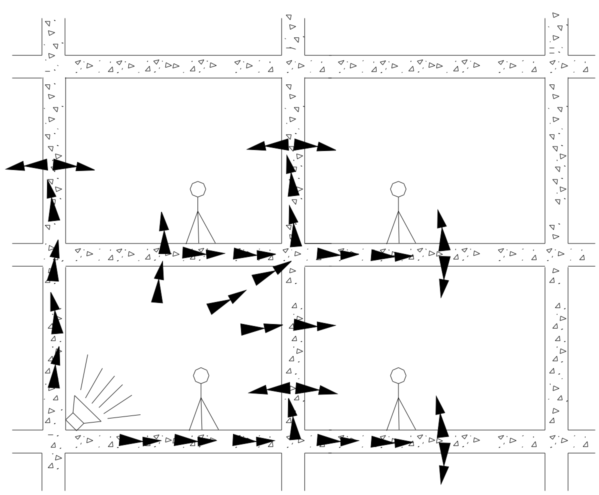

Figure 1. Measuring sound insulation in a building.

To measure sound insulation between two rooms (that might be adjacent to each other or far away), a loudspeaker and a microphone is first placed in the sending room. The loudspeaker emits a high level, wide band noise. The sound level is measured in third octave bands. The microphone is then moved to another room, the receiving room, where the sound level is measured next. The level difference, compensated for the partition area between the rooms and the acoustical absorption in the receiving room, is the sound reduction. This is given in a diagram as a sound reduction curve in third octave bands [2].

Sound insulation decreases if a leakage occurs between the two rooms, usually within a limited frequency range. This is often seen as a trough in the sound reduction curve. The position of the trough, frequencywise, depends on the type of leakage. Large area leakages, like boarded up doors, are seen at low frequencies while narrow cracks show themselves at high frequencies.

A lot of sound insulation measurements were performed for a Master's thesis, leading to a catalogue of curve shapes for different types of leakages and faults [3]. The type of leakage can be decided from the shape of the curve and the position of the leakage can be found by listening in the receiving room. However, this method was found to be somewhat complicated so we searched for an easier method.

Listening test method

As coustical consultants we often perform sound insulation measurements in buildings for verification of the requirements in the building code. If the insulation is lower than expected the reason for that has to be found. Our first measure in such cases is to listen in the receiving room. If the partition is then found to be of an unsuitable design, the sound will be slightly louder than expected. A leakage gives the sound a different character from the normal even noise, indicating a leakage. Walking along the walls listening to find the area from which this special sound emanates can often reveal the site of the leakage.

As sound travels with little damping in ducts, the listening method works not only for adjacent rooms, but also for rooms that are connected by ventilation shafts and chimney flues and which might be situated several floors or rooms away from each other.

Obviously some practice is needed but our experience is that one learns rather quickly to listen for and locate areas that sound different.

The following equipment is needed to perform the tests:

- a noise source
- 50-100 m cable
- an amplifier
- a loudspeaker

Figure 2. The equipment needed for the listening tests: active loudspeaker, CD-player and a large roll of cable
.
The noise source can be a noise generator or a portable CD player with suitable software. In the course of the project a CD containing the following bands was recorded:

1. Pink noise
2. White noise
3. Noise in the octave bands 125 - 4000 Hz
4. Pulsed noise, white noise pulsed at 1 s noise and 1 s silence

White or pink noise is used to listen for the existence of a leakage, which is discerned as a colouration of the sound. Usually, it is also possible to locate the leakage with wide-band noise. As discussed earlier, leakages of various kinds can transmit sound best at different frequencies. Octave band noise can be useful as the right octave band can highlight the leakage. Our ears are also very sensitive to transients which means that pulsed noise, or simply turning the noise on and off, is useful to get the direction to the leakage.

The loudspeaker should have a frequency range of no less than 100 - 5000 Hz and it should be able to give 110 dB at 1 m. Low bass is unimportant so the enclosure can be of moderate size. A loudspeaker with a built-in amplifier, like an active PA speaker, will be most practical.

The noise source and the amplifier/loudspeaker should be connected by a cable of sufficient length so that the noise source can be operated from the receiving room. In this way, the operator can switch between different noise types and turn the noise on and off while listening.

The test is made in the following steps:

1. The loudspeaker is placed in a room.
2. Listening is done in rooms where a potential fire risk is deemed to exist. As the method is fast, it is often possible to listen in all rooms.
3. An existing leak can be localized by closer listening in the area where it is heard.
4. After all receiving rooms have been tested, the loudspeaker is placed in the next room and the procedure is repeated. Listening must be done in both directions . to find all possible fire propagation risks for each pair of rooms between which there is a connection.
5. If hidden leakages are found, they must be opened up to enable closer inspection.

Semi-enclosed microphone

If more than one leakage path between two rooms exist, only the largest is usually heard. The smaller leakage is masked by the sound from the larger one. Sometimes it is possible to find the smaller one by close listening but often it is not heard until the big leakage is sealed off. This is a practical problem that we solved in the following way.

Scanning with a sound level meter along the room areas and watching the level change has been tried before, but due to the reverberant sound in the room overpowering the sound from leakages, the results are not so clear. For better performance, the microphone was placed in an acoustically damped cup with a sealing lip to screen it from the room sound. A cup from a hearing protector with a hole drilled for the microphone was ideal for this purpose.

Figure 3. The leakage finder. A telescopic handle has been fitted to make it easier to scan large areas.

A wall can be quickly scanned with the semi-enclosed microphone. The figure below shows an example. The loudspeaker was placed in the office and the wall was scanned from the outside. The response to areas of different sound insulation is very clear, with level differences of 20 dBA. In practical use, areas can also be examined in detail and the size of a boarded up door opening can be estimated.

The semi-enclosed microphone has also been found useful for solving other problems in building acoustics and noise control like finding acoustically weak spots in buildings and in industrial enclosures.

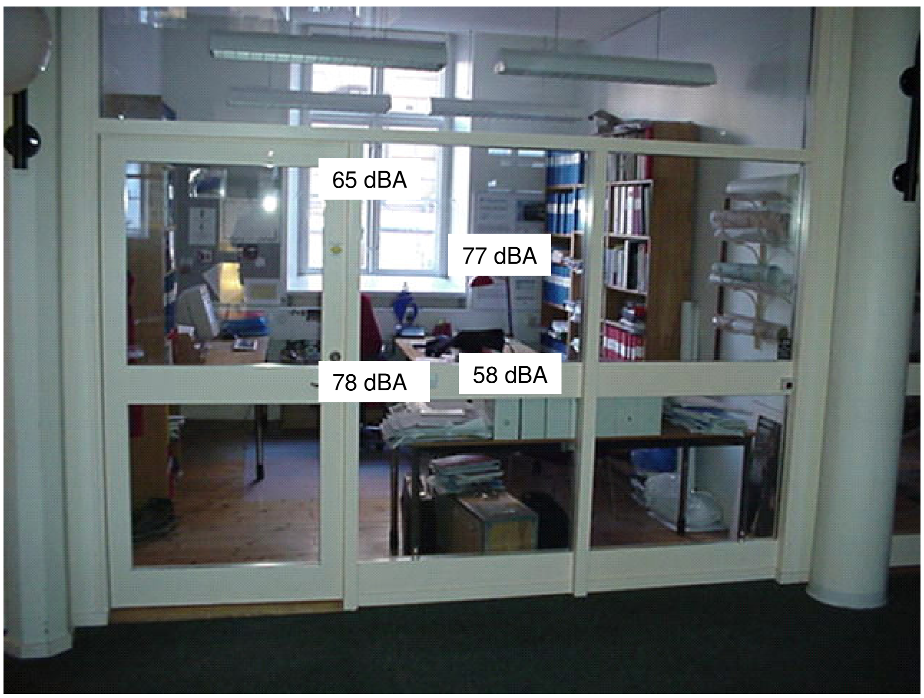

Figure 4. Sound levels at different locations on a wall measured with the semi-enclosed microphone. The sound source is inside the office. The level is highest at the door lock where there is a leakage and on the thin glass. It is lowest on the solid wood part while at the door chink at the top of the door it is in between.

CONCLUSIONS

Leakages that are potential fire propagation risks can be found by listening tests as described. This is a fast and efficient method although it takes some practice to learn. The semi-enclosed microphone is used for more detailed scanning of room surfaces. This can give the position and size of all leakage areas in a room.

REFERENCES

[1] Johannesson, C-M. et al. Acoustic methods for locating fire spread paths in old buildings. NDT & E International, Vol 31, No. 4, pp. 299 – 305.

[2] ISO 140-4 Acoustics, Measurement of sound insulation in buildings and of building elements – Part IV: Field measurements of airborne sound insulation between rooms, 1998.

[3] Lins, J. and Olsson, F. Localization of fire spread paths in old buildings. Use of acoustical methods for localisation of possible paths for hot gas propagation. Division of Building Technology, KTH, Master of Science Thesis No. 262, 1996.