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## Open Office Acoustics and Workplace Design

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### Overview

### Résumé

Noise problems are one of the leading sources of dissatisfaction expressed in post-occupancy evaluations. Unwanted noise is annoying and distracting, and can lead to a reduction in overall job satisfaction and task productivity, and further reinforces the private office as a corporate status symbol. The acoustical design of open office space to achieve a productive work environment is a delicate balance between blocking, absorbing and masking unwanted speech sounds and controlling excessive ambient noise. While open office space is the focus of this review, there are other related types of spaces that make up the office environment and that each have their own special acoustical needs. Meeting rooms must have very low ambient noise levels and optimum room acoustics to maximize the efficiency of communication. For closed offices it is necessary to pay attention to the construction details of partitions so that an adequate level of acoustical privacy is obtained.

### Ambient Noise

Ambient noise is a critical concern in all types of office spaces. Maximum acceptable levels of ambient noise depend on the intended use of the space. It is very important that

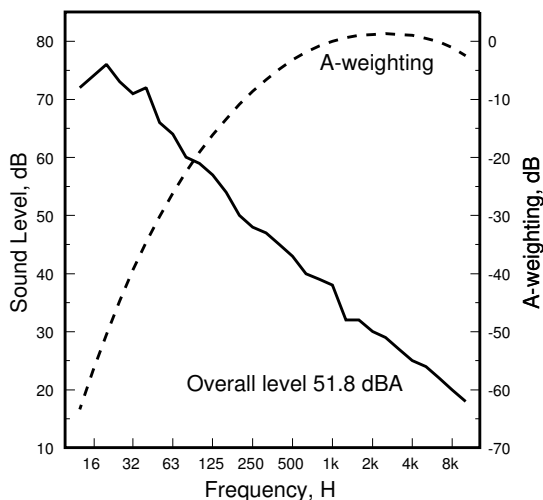


Figure 1. Noise spectrum and A-weighting contour.

ambient noise levels in meeting rooms are very low to avoid interfering with the speech sounds that listeners want to hear. However, in open plan offices, a modest level of neutral ambient noise can be helpful because it tends to mask unwanted speech sounds from neighbouring workstations. Because of the meaning associated with speech sounds, even quite low levels of speech can be quite distracting.

There are several procedures for rating ambient noises. The simplest approach is the 'A' frequency weighting that weights the lower frequencies as less important, similar to our own hearing. The noise spectrum shown in Figure 1 has an overall

A-weighted sound level of 51.8 dBA. Several more sophisticated indoor noise-rating procedures are based on the sound levels in a number of different frequency bands. Figure 2 shows the octave band sound levels of the same noise as in Figure 1 and the RC

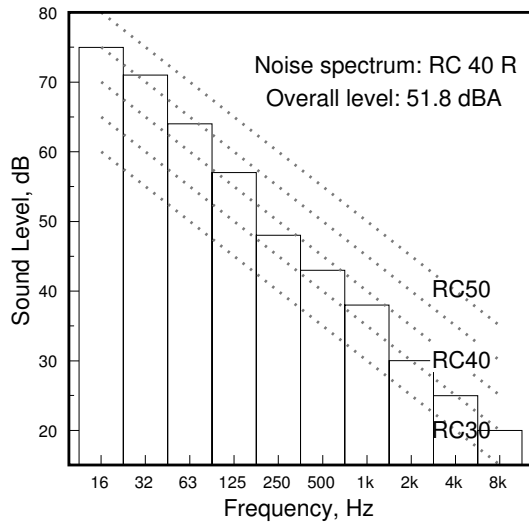


Figure 2. Octave band noise spectrum and RC rating contours.

noise rating contours [ASHRAE, 1993]. Using this procedure leads to an RC rating of 40R which indicates that the speech frequency bands average about 40 dB and that there is an excess of ‘Rumbly’ low frequency sound compared to a more neutral spectrum. That is, the rating is not a single number but combines a number with a letter describing the expected spectral quality of the sound.

Both the RC and NCB [Beranek, 1989] systems are relatively new and extend to quite low frequencies. However, the older NC [Beranek, 1971] and NR [Burns, 1968] systems are perhaps still the most widely used. Even more complex systems have been used to more accurately rate the

perceived loudness and noisiness of sounds. None of the procedures commonly used to rate ambient noise in rooms is the result of a systematic research study that included controlled subjective tests. Therefore, it is not at all clear which is the best predictor of the annoyance or acceptability of noises or even the expected interference with speech communication. This lack of clarity has held back the process of developing acoustical designs to optimize worker satisfaction and performance.

### Speech Privacy in Open Offices

In open plan offices, speech sounds from adjacent workstations can be annoying and can distract people from their work activities. To achieve acceptable speech privacy, an open plan office must be designed to block and absorb as much unwanted speech sound as possible. Any significant compromise to these design requirements will make it impossible to obtain an acceptable open office environment. Figure 3 symbolically illustrates the problems.

Screens and cellular office furniture must block the direct propagation of speech sounds between workstations. This is normally assessed from measurements of the sound transmission loss of these elements [ASTM, 1990a], and is usually reduced to the Sound Transmission Class (STC) [ASTM, 1987] single number rating. An STC of 15 or more is usually recommended for office screens.

Screens must also be high enough to minimize the diffracted sound energy that bends around the screens. Thus higher screens are more effective barriers to the speech sounds. It is also important that screens and furniture systems form complete barriers and do not have gaps either between panels or between panels and the floor.

The other dominant sound path is due to reflections from the ceiling. It is therefore very important that the ceiling be highly sound absorbing. Sound absorption tests [ASTM, 1990b] of ceiling tiles are typically reduced to the single number Noise Reduction

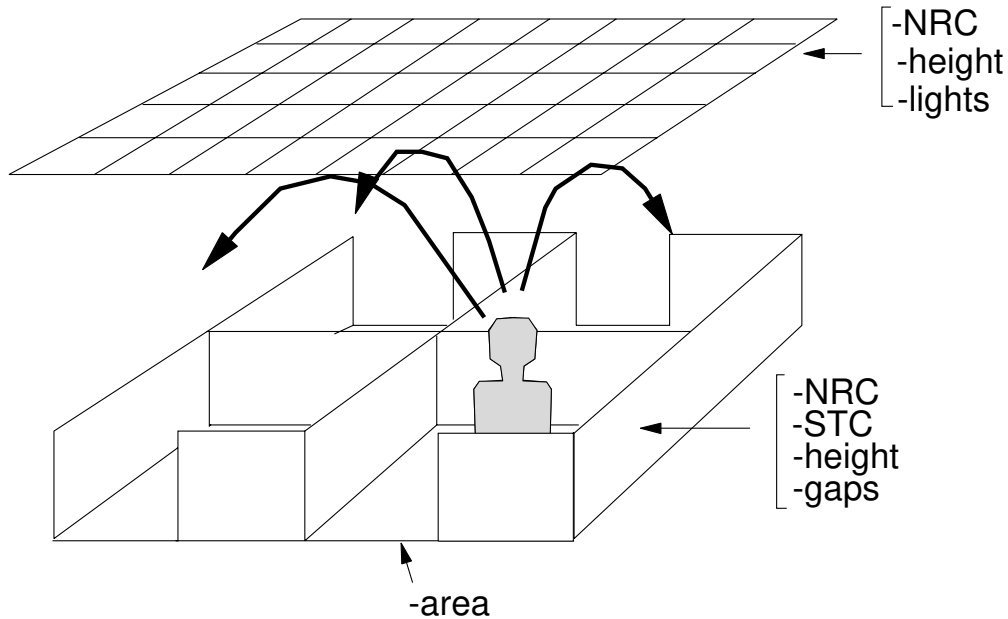


Figure 3. Open office component parameters influencing speech privacy.

Coefficient (NRC) rating, which can have values of 0.9 or more for highly absorptive ceilings.

Finally, it is important that all other large surfaces are sound absorbing to minimize reflected sound. Floors must be carpeted, screens and furniture systems should have absorbing surfaces, and other large surfaces such as walls should also be treated. Highly absorbing office screens typically have NRC values of 0.8 or better.

Even when everything possible is done to block and absorb unwanted speech sounds, acceptable speech privacy may not be obtained. It is often necessary to add moderate levels of neutral masking noise from loudspeakers in the ceiling void. Although this increases the total level of the noise, it is less distracting because of its neutral spectrum and because it masks or covers up the more distracting speech sounds. If the level of the masking noise is increased above about 48 dBA however, it is not helpful because people tend to raise their voices creating more noise and annoyance.

### Unresolved Issues and the Impact of Current Officing Trends

We have a reasonably good understanding of the effects of each component of an open office on the resulting speech privacy. However, there is not complete agreement on optimum values of the design parameters of each component of the office and we have no integrated design procedure for evaluating the expected speech privacy of a complete office design. It is thus difficult to quantitatively evaluate new designs. Similarly, in a renovation situation we cannot easily determine which component most critically limits the overall speech privacy, and hence we cannot prescribe the most cost-effective improvement. For example, in some cases the ceiling tiles may be the weak link, while in others higher screens might be the most effective improvement.

Several new developments will make it more difficult to obtain acceptable acoustical conditions in open offices. Proposals for smaller workstation footprints will bring workers closer together and make achieving acceptable speech privacy an even greater challenge. New philosophies for stronger team interaction recommend lower barriers and new more open furniture designs. These can only lead to reduced speech privacy and more distractions from individual tasks. Voice activated computers already exist and users now talk to their computers rather than type relatively noiselessly. This creates more potentially disturbing speech sounds. On the other hand, developing active noise control technology may make it possible to create localized areas of quiet for workers in open plan offices.

There are several other issues related to ambient noise. There is only rough agreement on acceptable noise level criteria for either natural sound sources or added electronic masking noise. The lack of agreement on the best rating procedure for indoor ambient noises makes it difficult to be precise about acceptable criteria and impossible to accurately rate unwanted noises.

### Recent IRC Acoustics Research

#### Transmission of HVAC noise through office ceilings

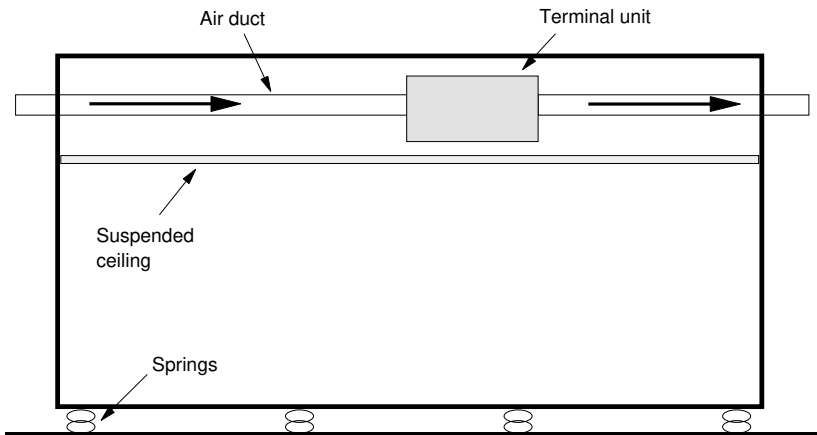


Figure 4. Section through the Room Acoustics Test Space as configured for the measurement of noise from VAV boxes above a suspended ceiling.

HVAC ducts and devices in ceiling plenums are often major sources of noise in the office spaces below. Devices such as Variable Air Volume (VAV) boxes radiate sound within a few centimeters of the ceiling, which readily propagates

into the office below. This project investigated the transmission of sound through a variety of ceiling types from several different VAV boxes to provide more reliable design information [Warnock, 1997].

Measurements were made in IRCs Room Acoustics Tests Space shown in Figure 3. This is an acoustically and vibrationally isolated test space that is easily re-configured to suit a wide range of different tests.

#### Annoyance of sounds with varying rumble

Noises with significant amounts of low frequency sound are said to be ‘rumbly’ in quality and such prominent low frequency content can make those sounds more annoying. HVAC system noises frequently have a ‘rumbly’ character and this low frequency sound

often fluctuates with time creating a very disturbing time varying noise. Unfortunately there are no standard noise measures to rate the added disturbance caused by such level fluctuations. This project examined the added annoyance by systematically varying the low frequency content, as well as the amplitude and frequency of level fluctuations. All of these factors influenced the relative annoyance and the results were used to devise suggestions for including these factors in noise rating procedures [Bradley, 1994].

### Sound propagation into an open office from an atrium

IRCs Atrium project has looked at all aspects of the indoor environment in several atrium spaces. Acoustical measurements, as part of this project, included an investigation of sound propagation from a large atrium into adjacent open office space. These measurements were made possible by using IRCs sophisticated Room Acoustics Measurement software [Bradley, 1996a]. The section through the atrium shown in Figure 4.

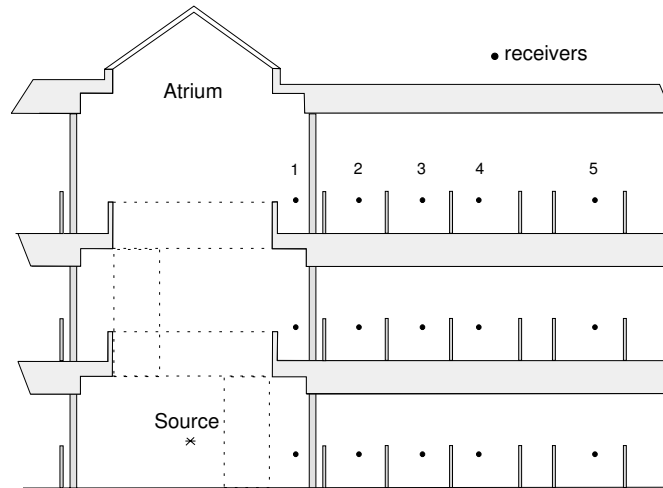


Figure 5. Section through atrium and adjacent open office areas showing test sound source and measurement locations.

illustrates the extent of the measurement positions that were used. In spite of the lack of full height barriers between the open office and the atrium, noises from the atrium were significantly reduced in level in the open office area. Simple calculation techniques were found to accurately predict the measured attenuations [Bradley, 1996b].

### Conclusions

The identified important acoustical issues, related to achieving productive office environments, include:

- Verifying ambient noise criteria for various types of spaces.
- Determining the preferred rating system for indoor ambient noises.
- Establishing the required properties of open office components.
- Developing an integrated open office design procedure.
- Designing for smaller workstation footprints.

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