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Acoustical Effects of Screens in Landscaped Offices

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Please note

The open-planned, landscaped office has rapidly become an accepted means of accommodating large numbers of office staff. As with any departure from familiar techniques, however, new problems have unfortunately arisen that have not everywhere been understood or solved. A common complaint in such offices is the intrusiveness of speech and other sounds. Acoustical privacy is extremely dependent on several elements, and one of the most important in open-planned offices is the partial barrier or screen. Such screens are available in heights ranging from slightly under 5 feet to, on occasion, over 6 feet. They comprise an internal acoustical barrier covered on both faces with a layer of absorbing material, and the whole assembly is finished with fabric for appearance.

Properly placed between two adjacent work stations a screen will help to reduce intrusive speech sounds. Whether sufficient reduction is achieved depends primarily on the construction and position of the screen and on the rest of the office furnishings, especially the ceiling. Strictly speaking, the screen and ceiling interact so closely that it is difficult to separate them and they should be considered as a unit.

The primary acoustical function of the screen is thus that of a barrier, but it is constructed so as to provide useful absorption that reduces sound reflection in the office space. This Digest will examine some of the basic properties of screens as they are used in open offices. The underlying physical phenomena point to the correct design criteria to be met in achieving an acceptable working environment.

Properties of Isolated Screens

To make the important screen design parameters clearer it is first necessary to consider the acoustics of the screen in isolation, with no ceiling above the work stations. If there is no dividing barrier between two work stations, only the natural reduction of sound with distance reduces the amplitude of signals between stations. Erection of a barrier or screen has the effect of attenuating the direct sound, which must now pass through it. There remains, however, a residual portion of transmitted sound that bends round the edges of the screen to reach the next work station. This bending phenomenon is called diffraction and the diffracted sound received by the listener is reduced in amplitude with respect to the sound incident on the screen in a way that depends on the geometry of the situation.

These two effects can be considered separately and are both amenable to simple theoretical treatment. For plane waves normally incident on an impermeable barrier with a mass of M lb/ft^2 the transmission loss is given by

TL (dB) = $-28.6 + 20 \log_{10} Mf$ (1)

where f is the frequency of interest. Clearly, the heavier the screen material the greater the transmission loss for sound propagating through it.

For an infinitely wide screen between a source S and a listening point R the insertion loss is given by

$$X = 20 \log_{10} \left(\frac{\sqrt{2}\,\pi N}{\tanh \sqrt{2}\,\pi N} \right) + 5 \text{ dB}$$

(2)

for $N \geq 0.2$

where $N = \frac{2f}{c}(A + B - d),$

c = the velocity of sound,

d = straight line distance from S to R,

A = distance from S to top of screen, and

B = distance from top of screen to R.

X is the insertion loss in dB relative to the level at the receiver in the absence of the screen. Here the higher the screen the greater the insertion loss. (A similar consideration applies to the width of a finite screen.)

These two effects must be combined to determine the total insertion loss for the screen. Diffraction losses depend on screen size and determine ideal performance. The closest practical approach to this is obtained by specifying a minimum value for surface density (M) so that the transmission losses do not degrade the over-all screen performance.

The intelligibility of received speech is a function of the sound level of the speech, the level of background noise, and the frequency content of both. The higher speech frequencies around 2000 Hz contain the greater part of the information necessary for distinguishing the different consonant sounds that render speech intelligible. With this in mind, the criterion chosen to determine the minimum acceptable value of M is that at 1000 Hz the transmission loss should be 6 dB greater than the theoretical diffraction loss. The insertion of this criterion in equations (1) and (2) leads to the following formula for surface density M:

$$M\ (lb/ft^2) = (1/3)\sqrt{(A+B-d)}$$

(3)

Table I shows typical values that this equation predicts. They have been determined for infinitely wide screens and can be reduced somewhat for real screens because the effects of diffraction around the screen edges will reduce diffraction losses. In practice, a value of 0.25 lb/ft^2 seems to be an acceptable minimum value for the barrier component of screens up to 6 ft in height.

Table I. Minimum Required Value of Surface Density for Infinitely Wide Screens

Screen Height (ft)	5.0	5.5	6.0	6.5	7.0
M(lb/ft^2)	0.14	0.2	0.27	0.33	0.4

High screens, i.e. those over 6 ft, are not generally used in landscaped offices for aesthetic reasons, but they could be useful where extra privacy is needed or where a rest area is unusually noisy. If higher screens are used, then as Table I shows the mass of the barrier layer should have a higher minimum value.

For economic reasons a screen manufacturer might decide to use a barrier constructed of two layers of light material separated by an acoustical absorber. It is difficult to give precise requirements for the physical parameters of such an assembly and one must instead give a performance requirement for the effective transmission loss. The system currently in use for rating walls uses the Sound Transmission Class (STC) contour. This contour has a shape somewhat different from the theoretical transmission and diffraction loss curves, but one that emphasizes the frequencies most important in speech. Hence, it can be used to specify a minimum performance for the barrier. The theoretically predicted STC for a barrier with a mass of ¼ lb/ft^2 is 13; and to provide a small safety margin and a more convenient number it can be increased to 15. For screens higher than 6 ft the required STC rating should be further increased by five points.

Another point worth noting is that since a screen has four edges, diffraction can take place at all of them. A finite screen width must be accepted in practice; but diffraction under the screen can be eliminated by having the bottom edge rest directly on the floor. If for practical reasons, for example, floor cleaning, a gap is required between screen bottom and floor, then it should be kept down to 3 in. or less. Curved screens are often used, but the curvature does not alter the acoustical performance.

As the geometry of the speaker-screen-listener assembly determines the degree of privacy obtained in an open office, it is appropriate to examine this aspect of screen performance further. This subject is also dealt with from a different viewpoint in **CBD 139**.

Influence of Screen Parameters on Speech Privacy

A convenient quantitative index of speech intelligibility may be obtained by measuring the fraction of speech sounds perceived above background noise as a function of frequency. These signal-to-noise ratios are weighted to take account of the importance of the different frequency bands and their sum is called the Articulation Index (AI). The Articulation Index ranges from zero to one, with a value of less than 0.15 generally considered acceptable privacy. Assuming an idealized voice at average level, a typical noise level of 48 dB (A), and a speaker-listener separation of 12 ft, then Figure 1 illustrates how the screen parameters influence the degree of privacy obtained. Figure 1(a) shows that as the screen height is increased the degree of privacy increases; Figure 1(b) shows the improvement that can be obtained by increasing screen width; and Figure 1(c) shows the changes introduced by changing the position of the screen. This figure still assumes that there is no ceiling. The information contained in it may be summarized thus: the larger the screen and the closer it is placed to either speaker or listener, the greater will be the degree of speech privacy obtained.

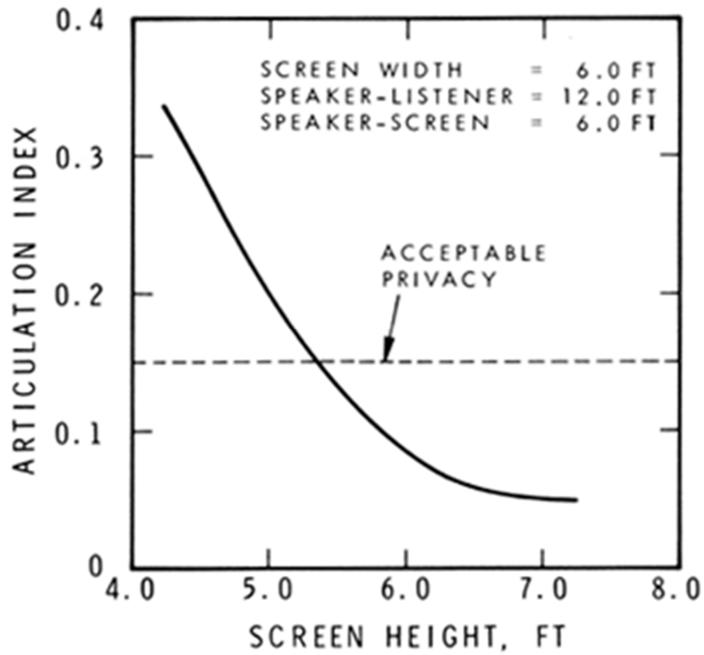

Figure 1(a). Articulation index versus screen height (no ceiling).

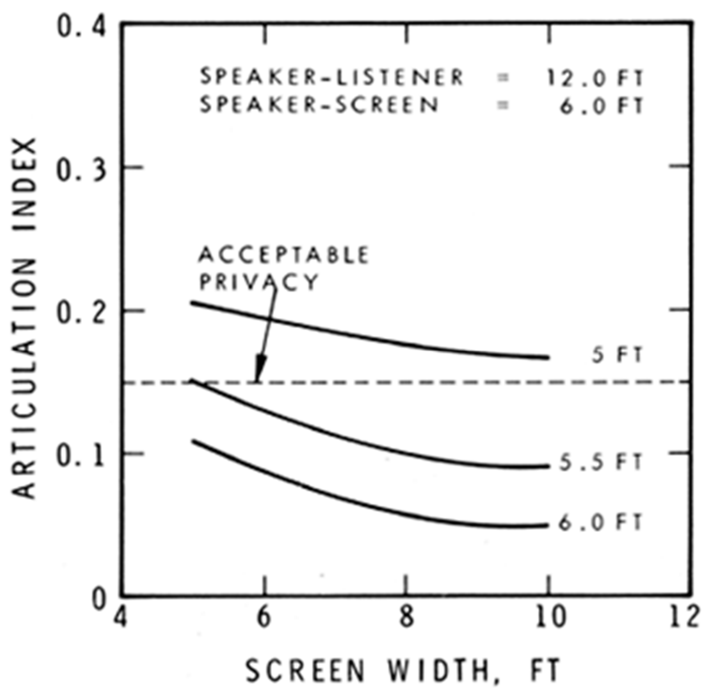

Figure 1(b). Articulation index versus screen width for three screen heights (no ceiling).

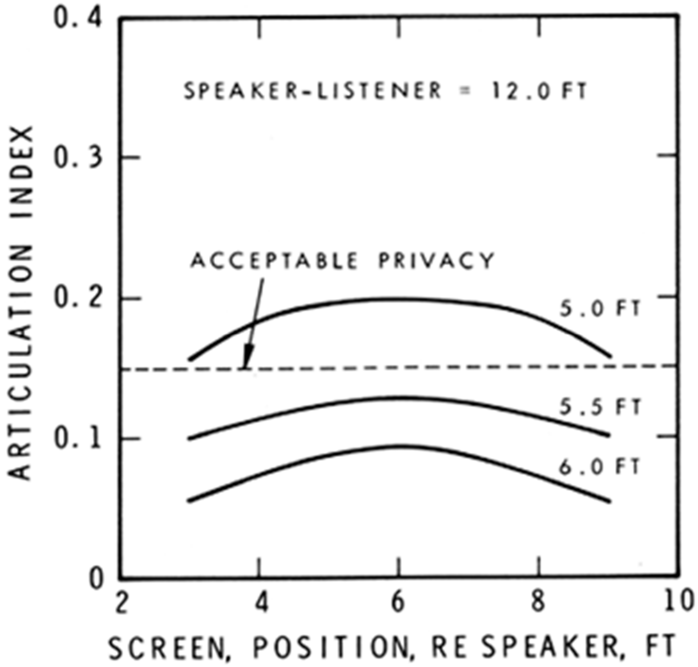

Figure 1(c). Articulation index versus screen position for three screen heights (no ceiling).

Another point that becomes clear with Figure 1 is that screens with a height of less than 5.5 ft do not provide acceptable privacy under the conditions assumed for these calculations. In practical cases the performance of low screens will tend to be even worse. The background noise level and spectrum shape assumed are close to optimum for use in a landscaped office. Any decrease in background noise level will increase speech intelligibility, whereas an increase will probably meet with occupant disapproval. A change of 3 dB in noise level will cause a corresponding change of 0.1 in Articulation Index. If a speaker has a louder than average voice, this also will reduce the isolation between work stations. More important is the effect of sound reflections from ceiling and furniture. These may bypass the screen and markedly reduce the level of speech privacy created by it.

Practical Limitations of Screen Performance

An inadequate ceiling is perhaps the single, most common acoustical flaw in an open office. The sound that reflects from the ceiling down to the adjacent work space can drastically increase the level of received speech sounds. In order to calculate the level of a sound signal reflected from the ceiling one must know the reflection coefficient for the frequency and angle of interest. At this writing there is no simple test procedure that provides this information. For typical flat ceiling assemblies one may assume without serious error that (reflection coefficient) = 1 - (absorption coefficient). Absorption coefficients are measured in a standard reverberation room test, which averages all angles of incidence in selected frequency bands. Again, no azimuthal information is available. To illustrate the importance of a low reflection coefficient or high absorption coefficient one can assume that the reflection coefficient is independent of frequency and calculate the Articulation Index in the presence of different amounts of ceiling reflection.

Figure 2 shows the effect of ceiling reflection on Articulation Index and makes clear the reason for specifying highly non-reflecting ceiling assemblies. Again, as the higher speech frequencies are most important, it is the absorption coefficients in the octave bands 500, 1000, 2000 and 4000 that must be high.

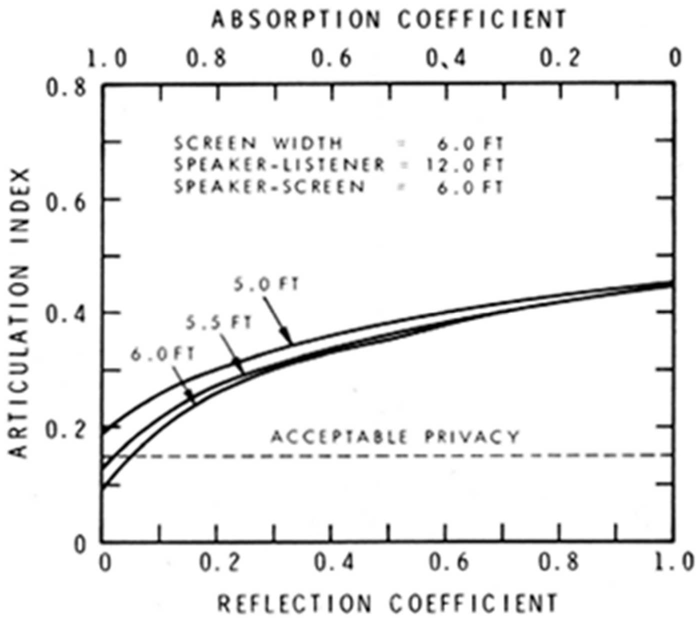

Figure 2. Articulation index versus ceiling reflection coefficient for three screen heights.

Vertical surfaces such as columns and cabinets and, of course, walls can provide a reflecting area for flanking transmission and are best treated with absorbing material. Carpeting is very durable and is often used for such surfaces, but measurements have shown that it is not very effective on its own. A more absorptive material has to be used, either alone or under carpeting, with a woven backing to provide free passage for the sound.

Screen Absorption

The absorptive properties of the screen have not yet received consideration. The screen itself is a large, flat, vertical surface and may act as a reflector of sound waves. To prevent this and to keep the office environment as anechoic as is practical, screens are generally faced on both sides with a highly efficient sound-absorbing material. A typical specification is that the Noise Reduction Coefficient of the screen, when tested as a free-standing object, should be not less than 0.8. A requirement such as this combined with one for equivalent transmission loss provides a basic specification for a screen.

Summary

Assuming an adequate ceiling, the office designer must strike a compromise between the concept of space and the degree of privacy desired by the occupants of an open-planned office in arranging for appropriate screening and physical layout. Although this Digest has been mainly concerned with the basic properties of screens, it has been necessary to mention the effects of reflections from ceilings and other surfaces. In fact, the degree of privacy obtained behind a screen is dependent on many physical factors, specifically, on background noise level and frequency content, speech level, speaker orientation, screen size and placement, and the amount of flanking transmission. It is only by paying careful attention to all physical design details that individual components in a landscaped office, in particular screens, can work close to their potential effectiveness.

Finally, it must be recognized that when the best practical design has been achieved, the degree of success will depend, essentially, on the occupants of the space — on the disturbance they create and the degree to which they are disturbed by the activities of their neighbours.