# Sound Solutions

Increasing Office Productivity Through Integrated Acoustic Planning and Noise Reduction Strategies

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## Increasing Office Productivity Through Integrated Acoustic Planning and Noise Reduction Strategies

REVISED AND UPDATED

**A Professional Paper from**

American Society of Interior Designers
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Dynasound, Inc.
Milliken & Co.
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# NOISE

**Phones** ringing . . . an animate and intelligible **conversation** in the next workstation . . . the ink jet **printer** whirring . . . **keyboards** clicking . . . two **fax** machines beeping . . . file **drawers** sliding open, then shut . . . the jingly ring tone of a **cell phone** summoning someone somewhere nearby . . . raucous **laughter** from a nearby team meeting . . . a **speaker phone** from across the aisle blaring voice messages . . . a computer booting up with its **customized musical greeting** . . . and the mail being delivered by that mail cart with the **one squeaky wheel.**

# Introduction

When ASID undertook the development of *Sound Solutions* in 1995, noise was already a major problem in office environments. In an ASID/Yankelovich study of 1,000 office workers conducted that year, 70 percent of the respondents said their productivity would increase if their offices were less noisy.[1] Ten years later, noise continues to be a primary cause of distraction, frustration, stress and dissatisfaction among employees. Especially in open plan office spaces, the factors that contribute to distracting and unwanted noise have increased in the past decade with the proliferation of mobile technologies and collaborative work processes. A growing body of research has confirmed that these conditions have a negative impact on the bottom line, resulting in decreased productivity and higher incidences of absenteeism, illness and employee turnover.

Along with greater awareness of the detrimental effects of office noise, concern about speech privacy has grown as the result of the enactment of HIPAA in 1996 and the rising incidence of identity theft. Because of changes in building construction, even "private" offices are not all that private, studies have shown. Privacy is also a major security issue in some industries and professions.

One thing that has not changed is that good design, employing the proper products and technologies, can greatly improve the quality of the office environment for employees. That is why ASID and the four ASID Industry Partners who contributed to the original *Sound Solutions* paper—Armstrong, Dynasound, Milliken and Steelcase—felt the need to update this popular publication. The integrated approach presented in these pages can help reduce unwanted noise and improve speech privacy in today's offices. Together with the ASID paper on improving office acoustics, *Better Sound Solutions,* and that on protecting privacy, *In the Open,* this newly revised and updated *Sound Solutions* provides designers with the understanding and strategies they need to create healthier, more productive and, ultimately, more profitable office environments for clients and their employees.

# The Changing Workplace: Trends with Acoustical Implications

Noise has always been present in the workplace, but changes in the tasks today's employees perform and how they work make noise more of a factor than in times past. As the United States has shifted from a predominantly manufacturing economy to a service economy, more and more workers are employed in positions that involve the creation and transmission of information and knowledge. These jobs demand higher levels of concentration, reflection and creativity. Because sharing of information and knowledge is essential, these workers spend more time in conversations, meetings and other group activities. Having quiet time to do one's "own work" thus becomes highly prized.

The service economy has made quality customer service a crucial deliverable for every business. Consequently, workers usually find themselves multitasking—attempting to do other work while interacting with customers, suppliers and colleagues face to face, via telecommunications and via computers, often all at the same time. Under such conditions, any additional background noise, especially speech, becomes an irritant.

In addition, a confluence of other factors has resulted in office buildings becoming noisier and noisier in the past decade. Among the most prominent are the following:

- Open plan offices have become the norm in most industries, as they require lower start-up costs, provide greater flexibility, and encourage communication and collaboration. An estimated 70 percent of office workers perform their work in cubicles or other open work areas.
- Workstation densities have doubled as employers seek to reduce costs by minimizing needed floor space.
- Workstation area has significantly decreased. A typical workstation in 1995 was 10' x 10' (down from 12' x 12' in the 70s). Today's workstations average 6' x 8' or 6' x 6'.
- Workers are spending more of their time working in teams or informal groups with other workers, often in close proximity to coworkers engaged in "heads down" work.
- Conversation "leaking," attributable primarily to the widespread use of mobile phones and speaker phones, has increased dramatically.
- Phones, PDAs, pagers and other electronic devices that employ electronic ring tones and other audio alerts have become common workplace tools.
- Wi-fi and other wireless technologies have made it possible for employees to work in nearly any location in a building.
- Heating, ventilation and air conditioning equipment (HVAC) has become so quiet that it no longer provides enough white noise to adequately mask office conversation.

> Office design must satisfy both the needs of the organization and the individual. You have to accommodate both. They're not tradeoffs.
>
> —Michael Brill
> BOSTI Associates

Many of these modifications, tools and enhancements have been introduced in an effort to improve productivity and efficiency. By increasing the amount of noise and distractions in the workplace, however, they negatively affect the productivity of others.

Two trends in office design that have emerged in the past decade also have implications for controlling office noise. One is the popularity of open structure facilities, often referred to as "loft design." These facilities have much higher floor-to-deck heights (up to 20 feet) and often lack finished acoustical ceilings. The other is the growing use of raised access floors and under-floor air distribution. Raised floors increase footfall noise, while under-floor air usually makes buildings quieter, thus making conversation and other incidental noise more pronounced.

# The Case Against Noise: Research Findings Confirm Its Negative Effects

Workplace noise is not just a nuisance. Numerous studies conducted over the past 20 or more years have documented that conversational distraction and uncontrollable noise are primary causes of productivity loss within offices. Noise also contributes to absenteeism, illness and staff turnover.

In research conducted by BOSTI Associates between 1994 and 2000 involving 13,000 office workers, the ability to do distraction-free solo work was ranked number one for productivity, team performance and employee satisfaction.[2] Nearly two-thirds of those surveyed who worked in open spaces, and more than half who shared a private office with a coworker, reported being "often distracted" by others' conversations.

## Improvements Resulting from Increased Speech Privacy

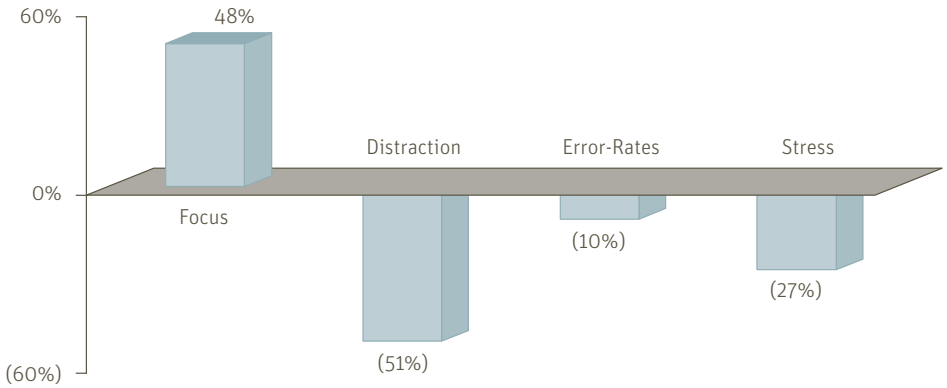
**Focus:** The ability of office workers to focus on their tasks improved by 48%.

**Distractions:** "Conversational distractions" decreased by 51%.

**Error-rates:** Performance of standard "information-worker" tasks (measured in terms of accuracy [error-rates] and short-term memory) improved by 10%.

**Stress:** When measured in terms of the actual physical symptoms of stress, stress was reduced by 27%.

— David M. Sykes, Ph.D.
*How Acoustics Affect Human Productivity*



A study published in the January 2005 issue of the journal *Ergonomics* reports that 57 percent of the workers said background noise caused "major deterioration" in their ability to concentrate.[3] Moreover, they did not get used to the noise over time. Rather, the longer they stayed in the office, the more disruption from noise they reported. Sources of distracting background noise mentioned included ringing telephones, other people's conversations (both face to face and on the telephone), printers, outside street noise, computer noise and keyboard noise.

> Satisfying employee needs is not an extraneous or frivolous concern . . . research . . . indicates clearly that open-plan office design influences the attitudes and actions of employees in ways that have important financial consequences for the organization.
>
> —J.A. Veitch, K.E. Charles and G.R. Newsham, "Workstation Design for the Open-Plan Office"

Armstrong conducted case studies of six major corporations in which they surveyed workers, replaced ceiling systems with more absorbent materials and added electronic sound masking, and then re-surveyed employee groups. In those surveys, knowledge and service workers consistently indicated that freedom from auditory distractions was the most important feature in efficiently and effectively accomplishing their work tasks. More than 80 percent of the workers believed they would be more productive if their workspace provided more acoustical privacy. And in circumstances where auditory distractions were actually reduced or eliminated, employees reported a 25 percent increase in satisfaction with the overall work environment and a 27 percent reduction in stress, and worker productivity increased an average of nearly 20 percent.[4]

Another case study involving a call center achieved even more dramatic results. Using a methodology similar to that of the Armstrong studies, the acoustical corrections resulted in a 300 percent increase in worker satisfaction with the reduction in speech or conversational noise and a 140 percent increase in satisfaction with the overall work environment. In addition, although workers had estimated a reduction in noise would increase their productivity or sales by an average of 8 percent, the actual increase at the end of the first six months was an average of 19.8 percent per worker.[5]

Noise not only affects concentration and productivity. Research shows that noise can also negatively impact employees' health and safety. The Canada Safety Council cautions that

> Even at low levels, unwanted sounds can constitute health and safety hazards by increasing stress levels, and impairing communication and concentration. Sudden unexpected noises can startle and cause accidents. At high levels, noise can cause such problems as headaches, nausea and hearing loss.[6]

A Cornell University study found that even low-level office noise increased levels of stress hormones, which can worsen some medical conditions, such as high blood pressure and diabetes.[7]

# Balancing Privacy and Collaboration: The Challenge of Achieving a More Productive Acoustical Environment

Achieving an appropriate acoustical environment in office buildings that incorporate open offices is a particularly daunting interior design challenge. However, design professionals are also in a particularly advantageous position to contribute significant value for their clients by successfully meeting this challenge. There are four separate yet related aspects to the challenge.

- Provide privacy for sensitive conversations.
- Promote communication and interactions.
- Prevent conversational and noise distraction.
- Promote productivity.

The challenge of providing speech privacy in open office environments is not an easy one to accomplish without a good understanding of acoustic design principles. At the outset, there are at least three recognized levels of acoustical privacy.

- **Confidential privacy** — Co-workers may overhear muffled words, but the meaning of the spoken message is not intelligible and they are not distracted from their own work.
- **Non-intrusive privacy** — Some phrases and sentences are intelligible to co-workers, but the volume level of the speech is not distracting to them and they can generally continue to work on their tasks without interruption.
- **Marginal/poor privacy** — Co-workers can overhear most words, sentences are intelligible and may be distracting to them; their concentration is disrupted, stress results and work performance is significantly decreased.

> Apart from loud noise from machinery — which is not usually a factor in office environments — numerous surveys have identified one particular factor as having the most impact on office workers and their productivity. This factor is "conversational distractions."
>
> — David M. Sykes, Ph.D.
> *How Acoustics Affect Human Productivity*

Most research in office acoustics, including the Armstrong studies mentioned earlier, documents that conversational noise from workers' face-to-face conversations and phone conversations is the most disruptive of all office noises. Even the telephone ringing is generally rated below the aggravation level of conversational noises from others in the same work environment.

The most serious distractions from productive work are caused by overheard conversations that can be clearly understood by individuals who are not intended to be part of communication flow. Such conversations engage even passive listeners from adjacent workstations and contribute to the heightened sense of being distracted, with a resulting loss of attention to tasks at hand, and thus at a cost to the passive listener's productivity.

The good news is that recent research in the field of acoustics—and the experiences of the design partners for this project—have shown that the most common acoustical design problems in the open office can be resolved by integrated planning, thereby promoting higher levels of worker productivity. It must be noted, however, that all of the resultant office acoustical design solutions are based on the assumption of "non-intrusive" levels of speech communication in the environment of interest. Raised voice situations and speaker telephones turned to high volume settings do not lend themselves to being resolved even with state-of-the-art integrated methods that have been designed by the collaborators in this project.

Today, technology is available to enable modeling of sorts, and to predict and measure performance of selected materials in advance of build out of the space, enabling designers now more than ever to design for intended performance.[8]

# Achieving "Non-Intrusive" Levels of Privacy in the Open Office Setting: The Performance Roles of Four Design Elements

It is generally quite difficult to achieve confidential speech privacy in most open plan office environments because of the use of high-density layouts. However, it is feasible and even economical to have as a goal the achievement of non-intrusive privacy for all workers. This level of privacy allows a worker to continue to be productive and attentive to the task at hand despite the presence of background conversational noise.

> In the end, employees assess a workplace in terms of how it feels to work in it and whether they believe it allows them to work productively, not whether it increases space efficiency and reduces real estate costs—or even whether scientific data show that the sound level should be acceptable.
>
> – Franklin Becker, Ph.D.
> *Offices at Work*

This report has focused on achieving a "non-intrusive" level of privacy for open plan office workers through the integrated application of four types of products. These are

- Ceiling Systems
- Sound Masking Systems
- Systems Furniture
- Carpeted Floors

Each of these four types of products has a specific role in achieving a "non-intrusive" level of privacy in an open office environment. It is important to keep in mind that altering any of the recommended performance guidelines for these systems (to be discussed below) will result in changes in the level of privacy achieved, with an associated reduction in the amount of productivity increases that can be expected to result.

## The ABCs of Speech Privacy

Acoustical consultants and engineers often refer to three proven methods as the ABCs of balanced acoustical design for achieving a “non-intrusive” level of speech privacy. All three must be used and integrated properly with one another to achieve the desired result.

| Method | Products to Use | Performance Indicators |
|---|---|---|
| **A**bsorb | acoustical ceilings, fabrics, carpet | AC rating, NRC rating<br>IIC rating, INR rating |
| **B**lock | furniture systems, panels, walls, partitions, screens, glass | STC rating, CAC rating |
| **C**over | sound masking — plenum-mounted or in-ceiling | dB/dBA rating |

# The Role and Performance Criteria for Ceiling Systems in Achieving "Non-Intrusive" Speech Privacy in Open Plan Offices

Sound tends to go up and then bounce down from the ceiling, not just travel horizontally from speaker to listener. The primary role of the ceiling system in providing a level of "non-intrusive" speech privacy within the open plan environment is to control the reflection of sound off the ceiling between adjacent cubicles, since the greatest distractions will come from close-by as opposed to distant occupants.

When choosing an acoustic ceiling for use in an open plan office, the designer needs to consider two important properties.

- First, the ceiling should have a high **AC rating**. The AC ("articulation class") rating of the ceiling is a measure of its performance in limiting the sound reflection off the ceiling plane over an angle of approximately 45 to 60 degrees, which represents most situations for adjacent cubicles separated by furniture panels. Since research has identified the most critical problem to be conversational noise, the ceiling tile selected must effectively absorb sound over the frequency range of speech, which is approximately 500–4000 Hz. The AC rating therefore includes a weighting factor based on the relative importance of speech frequency on the intelligibility of speech. The recommended ceiling tile for use in open plan offices is generally in the range of 210–170 AC, and more specifically for standard ceiling heights of 9.5 to 10 ft. an AC rating of 200–180 is preferred.
- Second, it should have a high **NRC rating**. Room interiors provide surfaces that can either absorb or reflect sound. The sound-absorbing capability of a material is expressed by the noise reduction coefficient. For more distant sources of noise, where the sound will have bounced off numerous surfaces, the NRC rating and, more specifically, the sound absorption coefficients over the frequency range of speech, is the most important rating, as shown below.

| Speech Frequencies Bands | Sound Absorption Coefficient (% of sound absorbed) |
|---|---|
| 4000 Hz | 0.85 minimum |
| 2000 Hz | 0.85 minimum |
| 1000 Hz | 0.85 minimum |
| 500 Hz | 0.65 minimum |

High performance ceiling products that meet both of the above criteria are readily available and should be incorporated in the design of open plan offices that require a "non-intrusive" level of speech privacy to enhance productivity. Some manufacturers now label high AC products with descriptors, such as "Open Plan," to make it easier to select the right ceiling panels to achieve the desired levels of speech privacy. Being "robust" in the choice of architectural components will ensure that the open plan system can be made to achieve the speech privacy goal with minimal addition of masking sound.

> Light fixtures can reflect sound and make ceilings less absorbent. Both the light fixture type and placement are important.
>
> —Cost-effective Open Plan Environment (COPE) Project

Having chosen an appropriate ceiling tile, it is important to preserve the desired ceiling performance to maintain the goal of a "non-intrusive" level of speech privacy, and this requires attention to specific details of the overall ceiling plane. It is important to avoid both the use of large air diffusers and flat lens lighting fixtures that can become significant reflectors of conversational noises. A better alternative to these are linear air bars for supply air and recessed 18- or 24-cell 2-by-4 parabolic lighting fixtures.

# The Role and Performance Criteria of Systems Furniture in Achieving "Non-Intrusive" Privacy in Open Plan Offices

The acoustic role of systems furniture in open plan offices is to prevent sound generated within one cubicle from intruding into adjacent cubicles by blocking and/or absorbing it. The workspace divider panel must contain sound from going over, through or around each furniture divider panel, and it should also absorb sound within the workstation.

> The layout of an open plan environment should consider not only the individual work station, but also the arrangement of the entire room. Similar functions should be grouped together, and communal areas should be planned to minimize the effects of conversations on other groups.
>
> – David Marsh
> *Sounds of Silence*

To enable the achievement of a "non-intrusive" level of speech privacy, the furniture divider panel should have a sound blocking capability of STC 18 to 20 and a minimum height of 60", with 72" being preferable. (The STC, or Sound Transmission Class, is a measure of the amount of sound reduced as it passes through a particular material in laboratory tests. Normal human speech can be understood quite clearly at an STC of 25.) As the furniture panel height increases, so must the STC, as they work in tandem. Furniture divider panel heights of 48" or lower are entirely ineffective in blocking conversational noise and do not support achievement of "non-intrusive" privacy. The sound travels right over the top of the panels into the adjoining cubicles. Studies show that work productivity is lessened when furniture divider panels are below a height of 60". Beyond 75", there are diminishing returns for sound blockage.

In addition to the STC, the designer needs to consider the NRC of a panel as a measure of the amount of sound it absorbs. For a panel to support the achievement of "non-intrusive" privacy, an NRC of 0.60 is recommended. Since sound is absorbed at different rates at different frequencies, it is also useful to consider the panel's Sound Absorption Coefficient over the frequency range of speech, provided by the chart in the preceding section on ceiling tile. Some studies suggest that a higher NRC is not necessary when an integrated approach to noise reduction, including sound masking, is used.

Certain furniture layout issues also contribute to the acoustical impact of systems furniture in open plan settings. With a goal of achieving a "non-intrusive" level of privacy, these interior design issues can be briefly summarized as follows:

- Avoid line-of-sight layouts between workers. When there is an open visual path between workers, sound can more easily pass along the same path and disrupt both. Standard glass, however, is an acceptable barrier.
- Provide a workstation design that provides maximum enclosure and blocks, as much as possible, direct pathways for sound transmission.
- If office teaming areas co-exist with open plan workstations, full-height demountable walls or substantially higher divider panels (80" or more) should be used to contain the team noise and ensure that other workers retain non-intrusive levels of privacy for their workspace.

Systems furniture works with other acoustical elements to ensure privacy and promote productivity. These features must be considered in relation to ceiling design/performance, floor covering materials, and the use of appropriate sound masking technology and equipment.

# The Role and Performance of the Sound Masking System in Achieving "Non-Intrusive" Speech Privacy in Open Plan Offices

The sound masking system is the third factor necessary for the achievement of a "non-intrusive" level of speech privacy in open plan offices. Studies have shown that it is one of the more critical elements in preventing conversational speech from being a distraction in the work environment because it raises background noise levels, thus addressing both the "too noisy" and "too quiet" ends of the sound spectrum.

It is very important that before the sound masking system can be tuned and used, the architectural system must first have been "robustly" designed to provide the capability of achieving the desired level of speech privacy. If the ceiling and landscape furniture panels are "value engineered" down to the lowest cost alternative, then it will very likely *not be possible* to tune the sound masking system to "make up" for the deficiencies in the architectural selections. Finally, an appropriate floor covering should be selected to limit the surface noises generated by walkers and rolling equipment, such as carts, etc.

> [T]he most gain can be achieved least expensively, most quickly and with the least disruption by . . . employing a low-voltage electro-acoustic background sound system of proven quality that has been designed and installed by qualified professionals to improve "speech privacy."
>
> – David M. Sykes, Ph.D.
> *How Acoustics Affect Human Productivity*

Electronic masking sound is a constant, low-level background sound with a specific frequency content in order to effectively mask conversational distractions and other unwanted noise. It sounds very similar to the noise produced by typical heating, ventilation and air conditioning (HVAC) systems. A typical electronic sound masking system consists of two parts: (1) an electronic "front end," which includes a broadband signal generator, a filter system for frequency shaping of the signal and an amplifier; and (2) an array of loudspeakers to distribute the sound within the space. The loudspeaker array will be either an older style plenum-mounted speaker system, where the speakers are installed within the ceiling plenum (i.e., above the ceiling plane and suspended from the deck above), or the newer "direct-field" or "in-ceiling" mounted speaker system, where the speakers are designed to be "dropped" directly into the ceiling grid. Plenum-mounted speakers must be tuned to take into consideration the type of ceiling tile used, obstructions, such as air ducts and piping within the plenum, and the type and orientation of the plenum speakers. In-ceiling speakers are not dependent on the ceiling tile or plenum obstructions, but they must be of a special design to radiate sound uniformly downward.

The electronic sound masking system is typically “tuned” to a specific frequency content and uniform level over the entire application area within the open plan office. This tuning process is accomplished after the office space is fully “fitted out” but before occupation. The frequency content of the masking signal is most often tuned to be either a traditional modified NC-40 or the new -4 dB/OB slope noise. The objective is to achieve a “bland” non-descript masking sound with a target level of 48 dBA ± 2 dB. Under no circumstance should the sound masking be tuned to a level above 50 dBA, as it will become annoying in and of itself beyond that level.

# The Role and Performance of Carpeting in Achieving "Non-Intrusive" Privacy in Open Plan Offices

Carpet serves to absorb airborne sound, reduce surface-generated noise (often called "footfall noises") and help block sound transmission to rooms below. Testing done by The Carpet and Rug Institute (CRI) indicates that acoustical properties of a flooring system are strongly influenced by the addition of cushion in the commercial workplace. New technology for manufacturing commercial carpet with integrated cushion allows for the greater use of cushion in the office environment, providing both superior acoustical and ergonomic properties.

Floor covering, like ceiling tile and systems furniture, is NRC rated — the higher the NRC rating, the greater the ability of the floor covering to absorb airborne noise. Data generated by an independent laboratory showed the following performance for a polyurethane cushion-backed carpet compared to bare concrete and conventional jute-backed carpet:

| Flooring Type | NRC Rating |
|---|---|
| Bare concrete only | 0.05 |
| Jute-backed 28 oz/yd$^2$ carpet | 0.20 |
| Polyurethane cushion-backed 28 oz/yd$^2$ carpet | 0.25 |

Tests conducted by CRI identified several other important factors related to NRC ratings.[9]

- Cut pile carpet provides a greater NRC than loop pile construction in otherwise identical specifications.
- The more permeable the carpet backing, the more sound energy can penetrate into the cushion and the higher the resulting NRC.
- Carpet over cushion gives better NRC values than carpet over concrete. Cushion with higher weight and thickness improves NRC.

The Impact Insulation Class (IIC) is a rating for the insulation from impact noise provided by a floor-ceiling assembly — the higher the rating, the greater the sound insulation. Independent testing showed the following performance:

| Flooring Type | IIC Rating |
|---|---|
| Bare concrete only | 34 |
| Jute-backed 28 oz/yd$^2$ carpet | 60 |
| Polyurethane cushion-backed 28 oz/yd$^2$ carpet | 62 |

CRI also uses an Impact Noise Rating (INR), similar to the IIC but employing a different numerical scale, to assess the sound insulation provided by a floor-ceiling assembly from an impact noise. CRI testing identified several factors that affect the INR ratings of various carpets.

- In tests of carpet on concrete slab, without a cushion, carpet with greater pile weights scored the highest INR.
- In tests with cushion, sponge rubber cushion, which had the lowest NRC rating, scored the highest INR. Weight for weight, foam rubber cushion delivered the largest INR number.
- Cushion materials, in general, add significantly to increased INR values.

In addition to its sound absorbing and blocking characteristics, carpet creates an aesthetic ambience conducive to lowered voices, heightened privacy, and reduced distraction.

> Properly specified carpet/cushion combinations have proven to handle the vast majority of sound absorption requirements in architectural spaces. Specifying for . . . open plan office areas may require full details of impact insulation properties and noise absorption characteristics.
>
> – The Carpet and Rug Institute
> "Acoustical Characteristics of Carpet"

# Additional Observations

Concern with the achievement of appropriate levels of speech privacy is not confined solely to open plan office settings. Acoustical privacy in closed office settings or in settings where closed and open offices are mixed has also received attention, and design recommendations have been developed to ensure that workers in these offices are not distracted from their work by noise or that information that is privileged or confidential is not overheard.

In closed offices, the Sound Transmission Class (STC) of walls and the Ceiling Attenuation Class (CAC) of ceilings are important considerations. Interior spaces, such as conference and boardrooms, private offices, bathrooms, corridors, or any other area that needs to be physically separated, are the primary focus for these planning decisions.

The performance levels specified for walls, for example, ranges from approximately 35 STC or 45 STC, depending upon the level of speech privacy required. Higher STC levels are necessary for private offices where confidential speech privacy is desired.

In closed office acoustical planning, considerable attention must be directed to ensuring that all sound leaks between spaces are sealed, for example, by providing seals around and under floors, window glazing, cracks at the junction of the ceiling, cracks at the junction of wall and floor, cracks at the junction of wall and window mullions, and baffling the return air plenums if not already directed. A major error in acoustical management often occurs by not matching the ceiling sound transmission (CAC) performance to the wall system (STC) performance, since the weaker of the two will control the performance of the composite system. The introduction of electronic sound masking will also contribute to the privacy attained.

> Typical private offices achieve only a "poor" speech privacy rating or classification. In this low privacy level, conversations can easily be overheard and understood from outside the room.
>
> – Fred Fulsom, executive vice president, Dynasound Inc.

In mixed office layouts, closed offices are enclosed with demountable wall systems, which reach only to the bottom of the ceiling system. Since the ceiling plenum is open, sound transmission is facilitated unless appropriate ceiling materials (CAC), sound masking and HVAC technologies are used.

# Conclusion

The research and experience of the design partners of this project has demonstrated that properly designed offices — whether closed, open or mixed plan — can be designed to support a broad range of individual and team workspace acoustic requirements. Such support requires attention to the mix and range of worker tasks, to the special needs of workers using advanced technology, to space planning issues, to the choice of architectural finishes and elements, to the choice of furniture elements, and to the background noise in the workspace. Design professionals are particularly qualified to provide the integration of vision and application necessary to blend these elements into productive workplace solutions.

There is little doubt that the needs of modern businesses will continue to evolve and change as a result of a changing world, changing business environments, new corporate visions, new technologies and new ways of accomplishing work in the 21st century. Whatever changes occur, however, it is clear that the ability of individual workers and teams of workers to work efficiently, effectively and to achieve high levels of productivity will continue to be essential to business success.

The incorporation of appropriate strategies and products for reducing noise in the workplace will continue to be an important part of designing and creating work environments where productivity is supported and enhanced. Indeed, if the past is any indicator, the incorporation of sound acoustical principles of design into work environments will be even more important in a future business climate where competition is even more keen, creativity and collaboration more essential, productivity more valued, and privacy more difficult to achieve and sustain in the midst of developing information and communication technologies dependent on the human voice. Design professionals are poised to make significant contributions to this issue.

# Notes

1. *Productive Solutions: The Impact of Interior Design on the Bottom Line.* American Society of Interior Designers, 1997. Pg. 14.

2. *Disproving Widespread Myths About Workplace Design.* Michael Brill, Sue Weidemann and the BOSTI Associates. Kimball International, 2001.

3. "Office Noise and Employee Concentration: Identifying Causes of Disruption and Potential Improvements." S.P. Banbury and D.C. Berry. *Ergonomics*, 1 (2005). Pp. 25-37.

4. *The Sound of the Effective Workplace.* Armstrong World Industries, 1997.

5. "ATCO International Co.: A Case Study of Office Speech Noise Distractions and Worker Productivity." ATCO International Co. and DynaSound Inc., 1997.

6. "Office Health and Safety." Canada Safety Council. 2002. www.safety-council.org/info/OSH/noise.htm.

7. "Stress and Open Office Noise." G. Evans and D. Johnson. *Journal of Applied Psychology*, 85:5 (Oct. 2000). Pp. 779-83.

8. Two such tools are Armstrong's Speech Privacy Predictor and DynaSound's Computer Aided Acoustical Design (CAAD). DynaSound reports that one of its clients, a Fortune 500 company, realized a saving of more than $2 million on one large office project using acoustical programming to maximize the number of personnel per work area.

9. *CRI Technical Bulletin: Acoustical Characteristics of Carpet.* The Carpet and Rug Institute. 2000. The data documents both the performance features of carpet and cushion on noise absorption, as well as the variations provided by different materials, thickness and applications.

# For Further Reference

The following publications provide additional detail and documentation of the information provided in this paper. See also the publications cited in the "Notes" section of this paper and the Research Summaries on acoustics, privacy and related topics in the InformeDesign® database at www.informedesign.umn.edu.


- *A Quiet Day at the Office: Attaining Speech Privacy in Both Open and Closed Plan Environments.* Armstrong World Industries, 2003.
- *Better Sound Solutions: Applying Occupant and Building Performance Measurement and Design to Improve Office Acoustics.* American Society of Interior Designers, Orfield Laboratories and Haworth, 2004.
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# Glossary

### Articulation Class (AC)

A measure for rating the speech privacy performance of a ceiling in an open plan environment where sound is reflected off the ceiling between two adjacent spaces divided by partial-height furniture panels. A ceiling system with AC < 150 is low performance, whereas one with AC > 200 is high performance.

### Background Noise

The noise level in a space, which is a composite of sound from HVAC, equipment, activity noises, etc., from both near and far excluding specific sources of interest, such as a person talking in an adjacent space (which would be considered the signal).

### Ceiling Attenuation Class (CAC)

A measure for rating the performance of a ceiling system as a barrier to airborne sound transmission through a common plenum between adjacent closed spaces such as offices. A ceiling system with a CAC < 25 is considered low performance, whereas one with CAC > 35 is high performance.

### Decibel, dB, dBA

A measure for rating the level of a sound that uses a logarithmic scale. The sound level in dB is often represented as dBA where the "A" indicates a specific frequency weighting used to represent how we perceive loudness as a function of frequency, since our hearing is non-linear with frequency. A sound level of dBA < 30 is a very low level, whereas dBA > 90 is a high level.

### Impact Noise Rating (INR)

A single figure rating of the sound insulation provided by a floor-ceiling assembly from an impact noise. Sound levels are measured in an isolated room beneath the ceiling with a standard tapping machine on the floor above, i.e., floor-ceiling assembly. The data is related to a minimum standard of "zero" INR. Assemblies rating less than zero (minus INR) are deemed unsatisfactory. Assemblies rating more than zero (plus INR) are deemed superior.

### Impact Installation Class (IIC)

The IIC rating system differs from INR, not in the test procedure, but in the numerical scale applied. IIC rates floor-ceiling assemblies with positive numbers only in ascending degrees of efficiency. The larger the rating, the greater the sound insulation.

### Noise Reduction Coefficient, NRC

A measure for rating the overall sound absorption performance of a material when used in an enclosed architectural space such as an office, where sound is being reflected at many angles of incidence. Specifically, it is the four frequency-averaged absorption coefficients @250, 500, 1000 and 2000 Hz, rounded to the nearest 0.05. A material with NRC < 0.50 is a poor absorber, whereas one with NRC > 0.80 is a very good absorber.

### Plenum

The ceiling plenum is the volume defined by the area above the back of the ceiling tile and below the bottom of the structural slab above. Within the plenum is usually found a combination of HVAC ducts, electrical and electronic conduits, water pipes, traditional masking sound speakers, etc.

### Sound Transmission Class, STC

A measure for rating the performance of a wall system as a barrier to airborne sound transmission between adjacent closed spaces, such as offices. A wall system with an STC < 35 is considered low performance, whereas one with an STC > 55 is high performance.

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