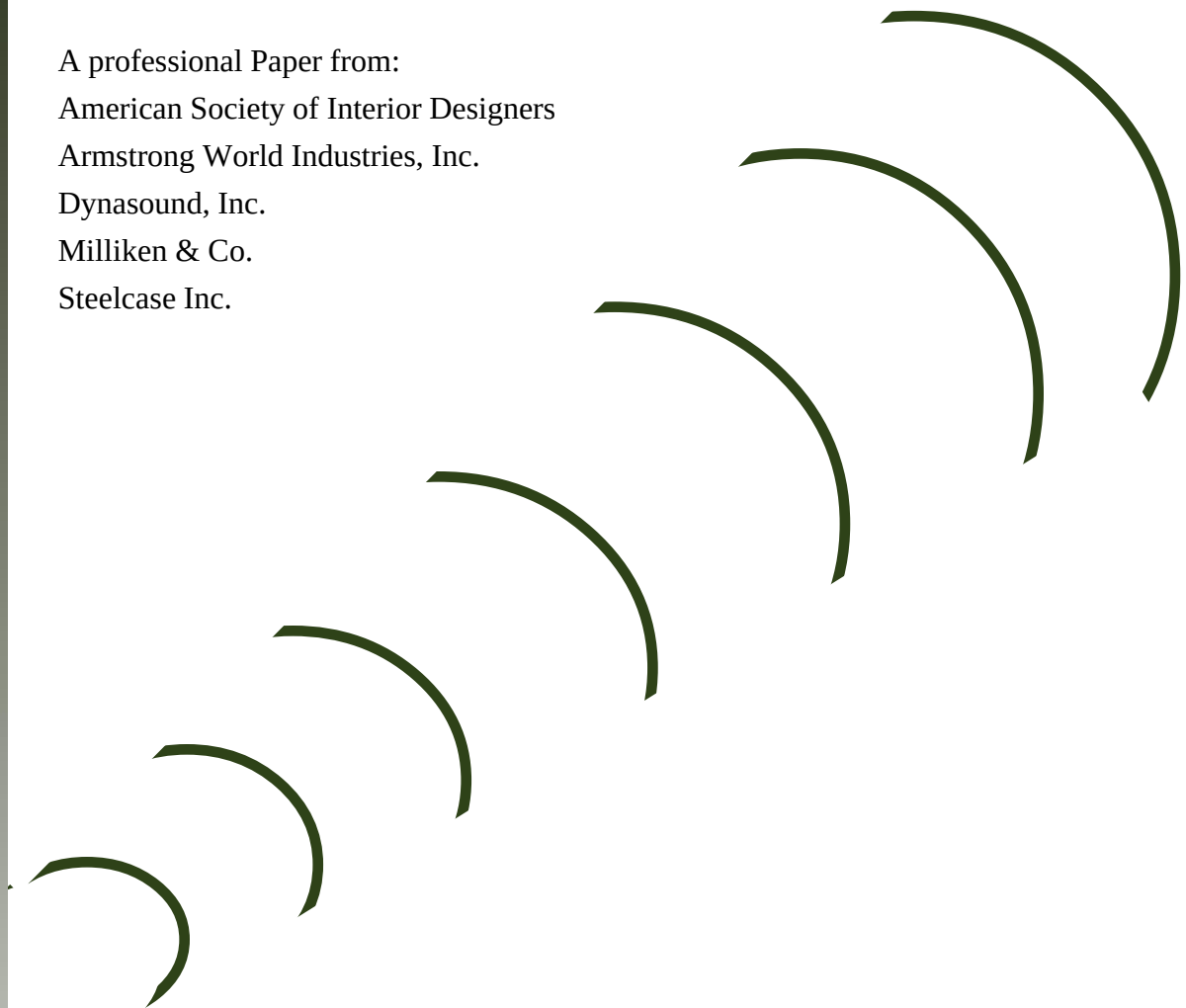
ASID

Sound Solutions

Increasing Office Productivity Through Integrated Acoustic Planning And Noise Reduction Strategies

A professional Paper from:
American Society of Interior Designers
Armstrong World Industries, Inc.
Dynasound, Inc.
Milliken & Co.
Steelcase Inc.



Foreword

The past decade has brought trends like downsizing, outsourcing, and hoteling to the office workplace. Closed office settings have changed to open plan environments that promote teaming. The traditional workplace is quickly disappearing and companies trying to accommodate these trends need the skills of an interior design professional to help them deal with challenges like increased noise that negatively affect worker productivity.

A recent study completed for ASID by the Yankelovich Partners found "noise reduction" to be a major concern of office workers. In fact, 70 percent of the respondents indicated their productivity would increase if their offices were less noisy. A follow-up study of business executives, conducted for ASID by L.C. Williams and Associates, revealed that business executives were largely unaware of noise problems in the workplace and, in fact, 81 percent were unconcerned about office noises! Clearly, business decision makers in today's workplace need to better understand the importance of noise and its relationship to productivity. It's a problem that directly affects their "bottom line."

This paper demonstrates not only that noise problems exist, but also that integrated planning and implementation of interior design solutions can reduce noise levels and increase worker productivity. Interior designers, acting as project managers, provide coordination and work directly with vendors and other service providers. They are the experts who can develop a "sound solution" that takes into account the total office environment.

— Penny Bonda, FASID
National President
American Society of Interior Designers

Noise

Phones ringing…an animated and intelligible **conversation** in the next work station, the ink jet **printer** whirring, **keyboards** clicking, two **fax machines** beeping, **file drawers** sliding open, then shut, a **pager** summoning someone somewhere nearby, raucous **laughter** from a nearby team meeting, the multimedia computer program booting with its **special musical effects**, and the mail being delivered by **that mail cart with the one squeaky wheel**.

Overview

Noise is not a new problem in office environments, but workers' concerns about noise have recently grown louder, more insistent, and more difficult and costly for business to ignore.

Numerous new studies, for example, clearly identify noise as the greatest single negative factor impacting worker productivity in offices across the nation. Not surprisingly, issues related to noise are more evident and frequently more disruptive in open plan offices than any other work environment.

In fact, as the use of open plan office environments has grown over the past three decades, workers' concerns and complaints about the negative impacts of noise on their work performance have also increased dramatically. By late 1995, the scope and severity of these concerns about noise problems in the workplace had reached such proportions that ASID and four of the leading manufacturers developing and marketing products for office environments - Armstrong, Dynasound, Milliken, and Steelcase - were motivated to create the industry's first-ever partnership to develop joint strategies for improving workplace productivity by eliminating or reducing conversational distractions and uncontrolled noise and improving acoustics in today's offices.

Because design professionals make such a significant impact on the configuration of today's workplace, these ideas have particular relevance for their consideration and application. This paper provides the key findings of the association and industry partnership effort, including:

- *A brief analysis of trends now re-shaping the workplace which affect noise reduction and related acoustical issues*
- *Insights from the key studies which link office acoustics to worker productivity, and the identification of key issues*
- *A description of the four elements of an integrated approach to noise reduction and some performance recommendations*

Additional research detail and corporate case studies will be subsequently published as well as outcomes of corporate studies on cost pay-back.

The Changing Workplace:
Trends With Acoustical Implications

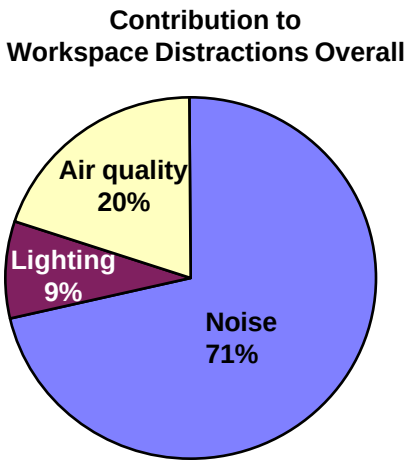
Considerable attention is being directed to a variety of trends which are re-shaping the workplace. Among those with the greatest relevance to noise reduction are the following:

- *Companies are downsizing, becoming smaller, employing fewer people*
- *Hierarchical organizational structures are giving way to other organizational structures, the foremost among these is the network of specialists*
- *Technicians -from computer repair experts to radiation therapists -are becoming the worker elite*
- *The vertical division of labor is being replaced by a horizontal division*
- *The basic paradigm of doing business is shifting from making a product to providing a service*
- *Work itself is being re-defined, with emphases on life-long learning, higher order thinking, and more self-directed work schedules*

In addition a confluence of other factors has resulted in office buildings becoming noisier and noisier over the past five years. Just a few of these factors include:

- *Significantly higher workstation densities, with more people occupying the same physical space, working in closer proximity to one another in open offices*
- *The widespread use of speaker phones and the tendency of office workers to speak more loudly when using them*
- *Greater use of video conferencing equipment, adding more noise and concentrating louder noise levels in specific areas of the workspace*
- *Creation of office team areas which require more interpersonal interactions, combined with reduced height furniture systems which allow more speech noise to pass over office divider panels*
- *The advent of voice-activated computers, with their potential to contribute to the level of noise as individual workers input and receive information in* verbal form
- *An increase in the size of computer screens, from a 13" standard to 17" standard, with a resultant increase in the reflection of noise within the individual workspace*

Each of these trends and factors requires that the productivity of individual workers - especially those who are involved in knowledge and technical production - be enhanced and maintained at a very high level. Of particular relevance to a discussion of acoustics are the extensive changes which are already well underway in the nature and processes of work in offices everywhere. Today's business environment is more competitive, globally focused, and lean than ever before. At the corporate level, constant change has become the norm, and flexibility a hallmark of the most successful companies.

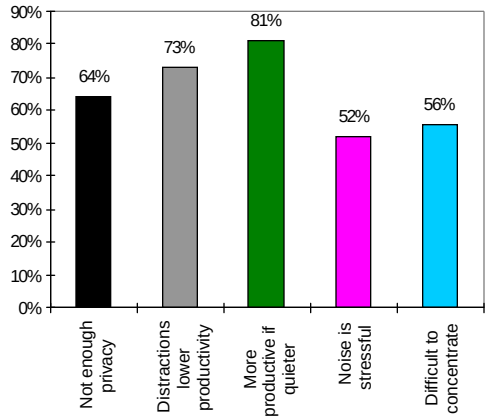


Corporate flexibility is more and more often being translated into the design of corporate office buildings and their interior office spaces. These office designs must be able to accommodate rapid changes as a result of technology, re-engineering, and novel or emerging patterns of work. For example, this new emphasis on flexible physical space has recently been expressed through the creation of interactive work areas which support "teaming" as an important method of accomplishing work. This, in turn, has created a need to collocate private spaces for individual worker's concentrated effort, with collaborative spaces simultaneously available for group work. The new norm has become smaller furniture workstation sizes (often with lower height panels), with greater ability to move within the overall work area. A new expectation of today's office environments are that they, too, must contribute to the corporation's achievement of its business goals of satisfying customer needs, increasing worker productivity, and supporting the entire organization to operate efficiently.

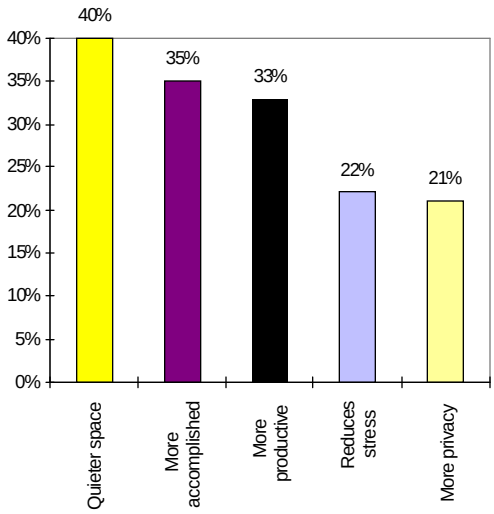
Unfortunately, some aspects of these new environments have introduced a variety of new acoustical characteristics to the workplace, including significantly greater amount of conversational distraction and uncontrolled noise and its associated negative impact on worker productivity.

What's Noise Got To Do With It?
... And How Does It Affect Productivity?

Workplace Perceptions and Attitudes



Workplace Perceptions and Attitudes After Noise Reduction Techniques Were Implemented



The relationship between increased levels of noise and decreased levels of office worker productivity is one which has only recently begun to receive attention, although it is a relationship which is fairly uncomplicated and easy-to-understand. This new interest comes, in no small part, from a growing recognition that the ability of companies to compete in world markets is dependent upon their ability to significantly increase the productivity of their existing work forces. As Peter Drucker noted in *The Harvard Business Review* at the beginning of this decade, the most pressing social and economic challenge for developed countries now is to raise productivity among knowledge and service workers. It is in the quest for raising productivity of these workers that serious attention has been directed for the first time at the impact of conversational distractions and uncontrolled noise on the ability to achieve high levels of work performance within open office environments.

A series of studies conducted over the past 12 years has convincingly documented that conversational distraction and uncontrolled noise is the primary cause of productivity loss within offices. For example, Armstrong conducted studies in five major companies, surveying workers, replacing ceiling systems with more absorbent materials and adding electronic sound masking, and re-surveying the employee groups. In those surveys, knowledge and service workers consistently indicate that freedom from auditory distractions is the most important feature in efficiently and effectively accomplishing their work tasks. More than 80% 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, worker productivity increased, often dramatically. A 1986 renovation of the Reno Nevada Main Post Office produced similar data. After the installation of improved lighting and a lowered, acoustical ceiling, mail sorting productivity increased 8% the first 20 weeks.

Design Insights... The Challenge of Achieving A More Productive Acoustical Environment

Achieving an appropriate acoustical environment in office buildings which 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:

1. *Provide privacy*
2. *Promote communication*
3. *Prevent conversational and noise distraction*
4. *Promote productivity*

The challenge of providing privacy in open office environments is not an easy one to accomplish. At the outset there are at least three recognized levels of acoustical privacy.

- *Confidential privacy - coworkers can overhear muffled words, but the meaning of the spoken message is not intelligible and they are not distracted from their own work*
- *Normal privacy - some sentences are intelligible to coworkers, but the volume level of the speech is not distracting to them and they can generally continue to work on their tasks*
- *Transitional privacy - coworkers can overhear most words, most sentences are intelligible, and distracting to them; their concentration is disrupted, stress results, and work performance is significantly decreased.*

As is evident, these levels of privacy center around the use of the human voice as an important medium of communication. 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 problems with distraction 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 its resulting loss of attention to tasks at hand, and thus at a cost to the passive listener's productivity.

The good news is that most recent research in the field of acoustics - and the experiences of the design partners for this project - has shown that the most common acoustical design problems in the open office can be resolved by integrated planning to eliminate or significantly reduce most of the common acoustical problems in today's open office environment, 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 "normal" levels of voiced 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 which have been designed by the collaborators in this project.

Achieving Normal Levels Of Privacy In The Open Office Setting: The Performance Roles Of Four Design Elements

It is often quite difficult to achieve the level of confidential privacy in most open plan office environments because of the use of higher density layouts. However, it is feasible and even economical to have as a goal the achievement of normal levels of privacy for all workers. A normal 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.
This project has focused on achieving a normal level of privacy for open plan office workers through the integrated use of four types of products simultaneously. These are:

Ceiling Systems
Systems Furniture
Sound Masking Systems
Carpeted Floors

Each of these four types of products has a different performance role in achieving a normal level of privacy in an open office environment. It is important to keep in mind that altering any of the recommended performance guidelines of these systems (to be discussed below) will result in changes in the level of privacy achieved with associated reductions in the amount of work productivity increases which can be expected to result.

The role and performance criteria of ceiling systems in achieving normal privacy in open offices

The primary role of the ceiling system in promoting normal privacy is to absorb the sound that strikes the ceiling plane and keep it from reflecting back into the workspace. In open offices, the most critical problem is conventional noises, which include human speech. The recommended absorption performance criteria for the critical human speech frequencies are expressed in terms of the percentage of sound absorbed by the ceiling material utilized. To achieve normal privacy, the following absorption criteria are recommended.

Speech Sound Frequencies	Absorption Coefficient (% of sound absorption)
500 Hertz	.65 minimum
1,000 Hertz	.85 minimum
2,000 Hertz	.85 minimum
4,000 Hertz	.85 minimum

In addition to the absorption coefficient, many acoustical consultants recommend the use of a ceiling material's "articulation class" to determine its suitability for achieving normal privacy. Articulation class measures the ability of a ceiling material to absorb sounds that strike the ceiling at angles between 45 and 55 degrees. These figures are used because most sound waves pass over the top of furniture panel dividers from seated workers at these particular angles. The articulation class also emphasizes the role of sound frequencies most important for speech intelligibility and privacy. The generally accepted articulation class (AC) for normal privacy is between 180 and 200. Several high performance ceiling materials satisfy this criteria and should be incorporated into office designs which require normal privacy to support worker productivity.

Additional considerations for ceiling design with a goal of achieving normal privacy include avoiding large air diffusers which can reflect conversational noises, and avoiding hard plastic lenses on ceiling mounted recessed light fixtures (as well as small 1Ú2" plastic cube designs). More acceptable alternatives to these include recessed lay-in parabolic fixtures. Specifically, the popular 18- and 24-cell 2x4 parabolic units, with individual cell sizes of 3" to 8" meet the acoustical criteria required.

The role and performance criteria of systems furniture in achieving normal privacy in open offices

The acoustical role of systems furniture in open offices is to prevent sound from going through workspace divider panels; to contain sound going over or around each panel; and to absorb sound reflecting over or around the workstation.

To achieve normal privacy through sound blocking, an STC (Sound Transmission Class) performance rating of approximately 20 or greater is recommended, while to contain sound, the recommended height of the furniture panel should be 65 inches. Panel heights lower than 53 inches are largely ineffective in blocking or absorbing conversational noise and they generally do not support achievement of normal levels of privacy. Work productivity is lessened by panels which are below this height standard.

The ability of a panel to absorb sound is described in terms of NRC or Noise Reduction Coefficient. For a panel to support the achievement of normal privacy, a NRC of .60 is recommended. More specifically, a panel should provide a Speech Frequency Sound Absorption average at .80 or greater.

Certain furniture layout issues also contribute to the acoustical impact of systems furniture in open plan settings. With a goal of achieving normal levels 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.*
- *Provide a workstation design which provides maximum enclosure and blocks, as much as possible, direct pathways for sound transmission*
- *If office teaming areas coexist with open plan workstations, full-height demountable walls or substantially higher divider panels should be used to contain the team noise and ensure that other workers retain normal 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 normal privacy in open offices

Sound masking is a precisely contoured, constant, broad band, low level background sound that masks conversational distractions and unwanted noise.
It is similar to the sound of a HVAC system air diffuser. These systems generally consist of electronic devices which generate a sound signal, shape or equalize a signal, and amplify a signal. This signal is then distributed to an array of speakers that are normally positioned above the ceiling in the plenum on 12- to 16-foot centers.

Sound masking systems are one of the more critical elements in preventing conversational speech from being a distraction in the work environment. They are necessary even when high performance ceiling systems and furniture systems have been installed because they ensure that when the variable air volume systems are moving low quantities of air enough background ambient sound is present to prevent conversations from being overheard and understood. Sound masking provides electronically generated background sound to achieve normal levels of privacy.

Sound masking systems are typically set at a sound level of NC 40 which corresponds to 48 decibels (dBA) +/- 2db. This sound level generally ensures conversational privacy without causing a distraction itself. In combination with appropriate systems furniture and ceiling components, sound masking systems contribute to the creation of work environments where acoustic distractions are minimized. Appropriate floor coverings complete the overall design picture.

The role and performance of carpeting in achieving normal privacy in open offices

Carpet serves to absorb airborne sound, reduce surface noise generation (often called “footfall noises”), and helps block sound transmission to rooms below. Work done by the Carpet and Rug Institute 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.

The Noise Reduction Coefficient (NRC) is a measure of the effectiveness of a material in absorbing sound over several frequencies. The higher the NRC, the greater the ability of the floor covering to absorb airborne noise. The test method used ASTM C 423-84a. 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	0.015
Jute (28 oz/yd2 carpet face)	0.20
Polyurethane cushion (28 oz/yd2 carpet face)	0.25

Impact Insulation Class (IIC) is a rating of the insulation from impact noise provided by a floor-ceiling assembly using ASTM E 492-77. The larger the rating, the greater the sound insulation. Independent testing showed the following performance:

Flooring Type	IIC Rating
Bare concrete only	34
Jute (28 oz/yd2 carpet face)	60
Polyurethane cushion (28 oz/yd2 carpet face)	62

In addition, carpet creates an aesthetic ambiance conducive to lowered voices, heightened privacy, and reduced distraction. The Carpet and Rug Institute 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.

Additional Observations

Concern with the achievement of appropriate levels of privacy is not confined solely to open 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 which 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 board rooms, private offices, bathrooms, corridors, or any other area which 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 to 44 STC, depending upon the type of privacy required. Higher STC levels are necessary for private offices where very high levels of confidential privacy are desired.

In closed office acoustical planning, considerable attention must be directed to insuring that all sound leaks are sealed, for example, by caulking or sealing doors, and cracks around and under doors, 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 and/or masking the return air plenums. A major error in acoustical management often occurs by not matching the ceiling sound transmission performance to the wall system performance because the weaker of the two will control the performance of both systems. The introduction of sound masking also contributes to privacy.

In mixed office layouts, closed offices are enclosed with de-mountable 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, 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 acoustical requirements. Such support requires attention to the mix and range of worker tasks, to the special needs of worker using advanced technology, to space planning issues, to the choice of architectural finishes and elements, to the choice of furniture elements, and to the ambient sound 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, 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.

For Further Reference

The following reference materials substantiate the information presented in this paper and provide additional detail:

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- *"Design For Change," Stephen Yavrouian, Building Operating Management*
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- *Better Acoustics by Design: Practical Choices for Office Acoustical Treatments and Finishes, K.P. Roy, Lancaster, PA: Armstrong World Industries.*

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Glossary of terms

NRC

"Noise Reduction Coefficient" - rates the ability of an office panel or other construction to absorb rather than reflect sound. NRC is the fraction of sound energy, averaged over all angles of direction and from low to high sound frequencies, that is absorbed and not reflected.

Sound Absorption Coefficient

Within a specified frequency band (identified by its center frequency) the fraction of sound power randomly incident on a material or construction that is absorbed or otherwise not reflected. Sound absorption coefficients are measured following the procedures of ASTM Standard Test Method C 423 for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method.

STC

"Sound Transmission Class" - rates the ability of an office panel of other construction to block sound. STC is a decibel measure of the difference between the sound energy striking the panel or construction on one side and the sound energy transmitted from the other side. This includes sound from all angles of direction, and from low and high sound frequencies.

Speech Frequency Sound Absorption Average

A single-number rating of the ability of an office panel or other construction to absorb rather than reflect sound over the range of sound frequencies most important for speech intelligibility and privacy. Specifically, the arithmetic average. rounded off to the nearest .05, of the sound absorption coefficients for the sound frequencies of 1000, 2000, and 4000 Hertz.

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