ACHIEVING EFFECTIVE OFFICE
ACOUSTICS

An introduction to the
methods and **materials**
required to achieve effective
acoustics in your workplace.

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ACOUSTIC NETWORK

Studies show that acoustics are an essential consideration in meeting what is arguably the primary goal of the office: to provide a setting conducive to optimal work performance. Participants indicate that speech privacy and comfort are key to this type of environment, and that noise problems influence both their concentration and error rates by decreasing their ability to think clearly and communicate effectively. In fact, a survey of 400 business managers conducted by the Building Owners and Managers Association (BOMA) and the University of Maryland identifies noise control as the greatest opportunity for productivity improvements with an estimated average increase of 26 percent. The findings of another survey, commissioned by the American Society of Interior Designers (ASID), are similar. More than 70 percent of respondents said they would be more productive if their office was quieter.

Such statistics suggest that the benefits of an effective acoustic environment in terms of workplace satisfaction and profitability would be substantial. But what is an effective acoustic environment? Because many have an incomplete understanding of this concept, the acoustic performance of a facility is often left to chance… and is usually disappointing. This need not be the case. In all but the most difficult situations, effective acoustics can easily be achieved – first, by understanding the basic requirements for good acoustic performance and, second, by incorporating the methods and materials necessary to meet those requirements into the office design.

The first part of this paper introduces the goals of acoustic design, methods of noise control and how various interior design elements can help achieve good acoustic performance in an office setting. The second part explains, in acoustical terms, several of the principles behind the use of these techniques and materials. Through examples of how sound masking works in conjunction with absorptive elements, it also demonstrates that a combination of acoustic treatments is key to achieving the desired results.

Goals of acoustic design

The workplace should provide occupants with speech privacy, comfort and freedom from distracting noises, and enable them to work without disrupting others. The creation of such a space should be cost-effective, while maintaining the flexibility required to accommodate change.

Noise control methods

The formula many professionals use to achieve these results is the "ABC Rule," meaning Absorb, Block and Cover Up. In recognition of the fact that a combination of these three elements is required to create proper acoustical conditions, this guideline is also known as the "Rule of Threes." While it acknowledges the role of absorption, physical barriers and sound masking, this rule ignores one valid and frequently used method of addressing office noise: reducing noise at the source.

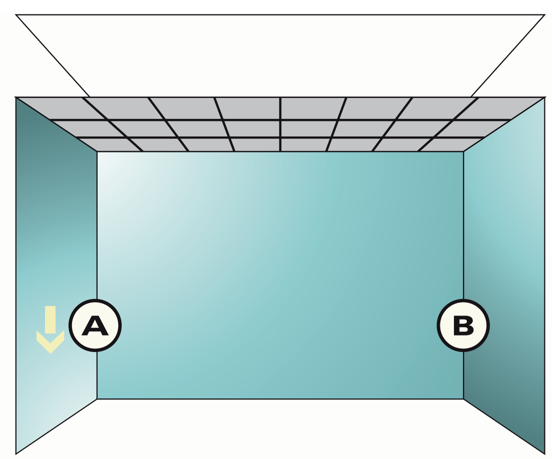


Diagram 1: Reduce Noise

Achieving Effective Office Acoustics

Reduce noise

This strategy requires the identification and subsequent reduction or elimination of unnecessary sources of noise in the office. This task can be accomplished by modifying employees' noise-producing behaviors and by replacing noisy office equipment with quieter technologies.

Despite its exclusion from the ABC Rule, noise source reduction has been one of the defining influences in creating the acoustic environment in modern offices. Building mechanicals, such as heating, ventilating and air-conditioning equipment, have become progressively more silent. Office equipment has followed the same path, progressing from typewriters and noisy copy machines to early printers, and, finally, to modern keyboards, laser printers and photocopiers. However, some new technologies, such as speakerphones, can actually increase noise levels, and their use should be carefully considered.

Changing behaviours can also significantly reduce the level of noise in the office. Reasonable office etiquette should be enforced, but it should be recognized that some necessary noise is created while employees perform their tasks. One of the goals of good acoustic design is to provide employees with a comfortable working environment that allows them to perform these tasks without feeling as though they are disrupting or irritating others within the space.

Reducing noise at the source has practical limitations. Any remaining noises in the office are there by necessity or because it is unfeasible to eliminate them using this method. These noises must be controlled in other ways. One such way is to add absorptive materials to the space and limit the number of reflective surfaces found in it.

Absorb noise

Adding absorptive wall materials, ceiling tiles and flooring reduces the energy and, therefore, the volume of sounds reflected off their surfaces back into the office space.

Because the ceiling is usually the largest unbroken surface in a facility, a good absorptive tile helps lessen the distance over which noises and conversations can be heard. Offices should invest in the best tile they can afford and ensure consistent coverage throughout the facility. Any partial treatment of a space will decrease acoustic control.

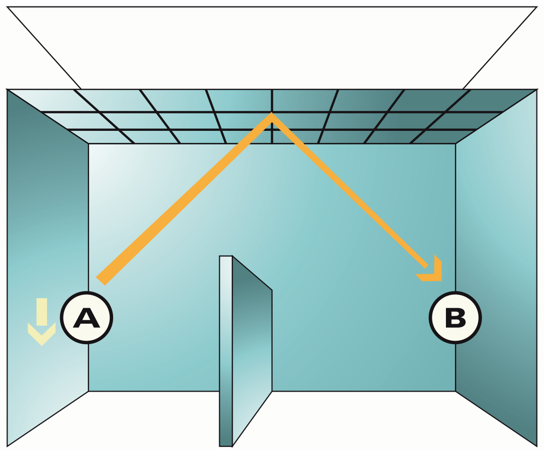


Diagram 2: Absorb Noise

Ceiling absorption is often rated using Noise Reduction Criteria (NRC), which essentially ranges from 0 (0% absorption) to 1.00 (100% absorption). The higher the NRC, the better. In decreasing order of acoustic performance, ceilings typically rank as follows: fiberglass tile, mineral tile, perforated metal tile, no dropped ceiling, drywall and solid metal tile. The last four types usually exhibit a significant decline in acoustic performance; however, there are mineral and perforated metal products that demonstrate better than average NRC ratings. The thickness of a mineral or fiberglass tile will affect its acoustic performance. Generally, the thinner the tile, the more transparent and less absorptive it will be. Foil backing on a fiberglass tile helps contain sounds within closed offices. Foil also increases the dispersion of a sound masking signal, ensuring greater consistency in masking levels throughout the space. Placing fiberglass insulation above the ceiling tiles has only marginal acoustic benefits and will hinder access to the ceiling.

Lighting components can increase the acoustic reflectivity of the ceiling because they replace these absorptive ceiling materials with hard surfaces. In order to limit the lighting system's impact on the absorptive performance of the ceiling, select a system that incorporates a minimum number of ceiling fixtures while still meeting the specified lighting requirements. From an acoustic perspective, indirect lighting systems are best because they are suspended from the ceiling and maintain the maximum surface area of the acoustic ceiling tiles. When it is not possible to install an indirect system, consider using a deep parabolic lens instead of the traditional solid plastic lens. Standard acrylic lenses are highly reflective and, because they can take up to 20% of the ceiling, they have an obvious effect on sound transmission.

Though they are used less frequently than acoustical ceilings, absorptive wall materials can also play a significant role in office acoustics. Absorptive panels are effective when applied to large vertical surfaces and to key reflective locations, such as atrium walls or walls that reflect noise from the foyer up into the office space. They can also be used in areas where the ceiling treatment is not absorptive.

Workstation partitions can also perform an absorptive function. To reduce sound paths, minimize openings between and around the workstation panels, as well as underneath them if carpeting has not been used. Also minimize the number and size of reflective surfaces, such as glass, metal and drywall components, in the workstation because they will increase the reflection of noise and conversation, causing them to be heard over greater distances.

Absorption and the reduction of footfall noise are the main acoustic considerations when selecting flooring. Hard flooring is highly reflective and results in a more reverberant environment. Carpeting greatly reduces footfall noise, but typically provides only minimal absorption of frequencies in the range of human speech. Flooring will have a greater absorptive effect when special under-padding is used.

While the inclusion of absorptive materials in the office is necessary, their use lowers the ambient or background sound level, actually making the environment sound noisier and less private. Conversations will be more distinguishable and intelligible. In other words, absorption addresses one acoustical problem while making another worse.

Block noise

Another method of controlling noise is to block sound transmission. Closed plan designs achieve the majority of noise control in this manner, but blocking is also a relevant consideration in the open concept office. There are several strategies to review.

The most basic barrier is a wall, though efforts to increase the flexibility of offices and reduce construction costs have reduced their use in most offices. However, walls should still be used in areas where absolute confidentiality is required. Ensure doors are well sealed and that there are no gaps between the walls and the suspended ceiling. When walls are built along the building's perimeter, do not allow spaces to remain between the wall and the window mullion, because they provide a clear path for the transmission of sounds from one office to another. If not properly designed or treated, HVAC components can also provide a path for noises and conversations to travel through the walls.

Plenum barriers are used to block sound transmission over walls that extend only to the suspended ceiling. They can be expensive and somewhat difficult to properly install. Breaks – either from initial installation or from subsequent damage – significantly reduce the effectiveness of lead, drywall or rigid fiberglass barriers. Furthermore, the use of plenum barriers can require the installation of expensive acoustic air return ducts in order to limit the transmission of sound through the ductwork while maintaining airflow.

In open plan environments, the office layout can be used to maximize blocking of sound to prevent noise from interfering with office occupants' ability to concentrate. Locate noisy office machines and areas with high activity and noise levels, such as call centers, in remote or isolated areas. Try to maximize the distance between employees because the volume of noises and conversations will decrease over distance.

Blocking in open plan areas can also be achieved through the use of physical barriers such as workstation partitions. Minimize direct paths of sound transmission from one person to another by seating employees facing away from each other on either side of partitions. The height of the partitions is also acoustically significant. Partitions lower than 50 inches (1.25 meters) essentially provide an office with the same acoustic benefits from one workstation to another as no partition system. Generally speaking, 64 inches (1.60 meters) is effective because it extends beyond seated head height. Partitions higher than 70 inches (1.75 meters) offer decreasing acoustic benefits relative to their cost; however, using slightly higher partitions in high traffic areas can be beneficial.

In the end, however, an over-reliance on physical barriers can raise costs and render an office relatively inflexible, while still failing to satisfy all occupants' acoustical needs.

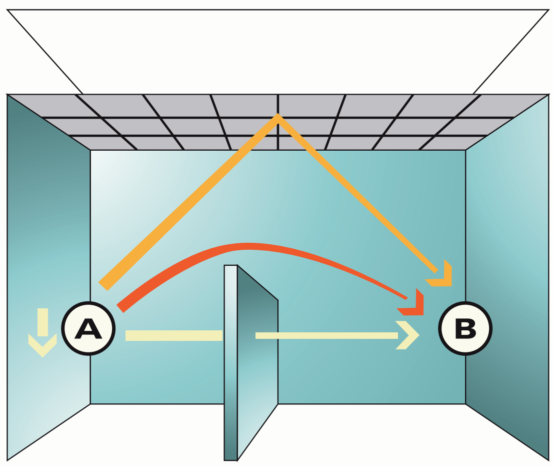


Diagram 3: Block Noise

Cover up noise

Though sound masking systems have been used for over twenty-five years and in hundreds of thousands of facilities worldwide, they remain novel to many people; therefore, it is useful to provide a brief description of this technology.

Basically, a sound masking system consists of a series of speakers that distribute an electronically generated background sound within a facility. Many people refer to such systems as "white noise systems;" however, this is a misnomer. The term "white noise" describes a very specific type of sound used in early masking systems developed in the 1970s. These systems were unsuccessful due to their inflexibility and the irritating hissing quality of the sound they produced, but the name became widely adopted. Newer sound masking products do not use a white noise signal; rather, they offer an engineered sound that is much more comfortable, unobtrusive and effective.

Sound masking addresses the lack of sufficient background sound that is characteristic of most office spaces. It is the only acoustical treatment that reduces noise disruptions and speech intelligibility by increasing the noise floor. All other treatments cause a reduction in the level of the noise itself. Masking works because the ear cannot perceive simultaneous sounds of similar volume and frequency. As will become clearer in the second part of this paper, the masking system adds a constant background sound across a wide frequency range in order to reduce intelligibility, decrease the dynamic range, provide an acceptable background sound level, and minimize the differences in the quality and level of sound across the facility. The result is that unwanted noises are more difficult, or impossible, to hear or comprehend.

As with all acoustical treatments, the benefits of a masking system are maximized when used in conjunction with other noise control methods. Since sounds decay over distance, masking requires some distance to become effective, and this distance is minimized when sufficient physical barriers and absorptive materials are used in the design of the office. Furthermore, if absorption is increased, the masking system's volume can be reduced without affecting its performance level. Furthermore, if absorption is increased in the space, the masking system's volume can be reduced without affecting its performance level.

Use of a sound masking system can reduce costs by eliminating the need for additional insulation, extra layers of drywall, plenum barriers, high-spec walls, or permanent walls around private offices. In this way, masking also maintains the flexibility of the office space for future renovations and changes. In open plan spaces, masking can help maintain a level of acoustical control as density increases and workstation partitions become lower.

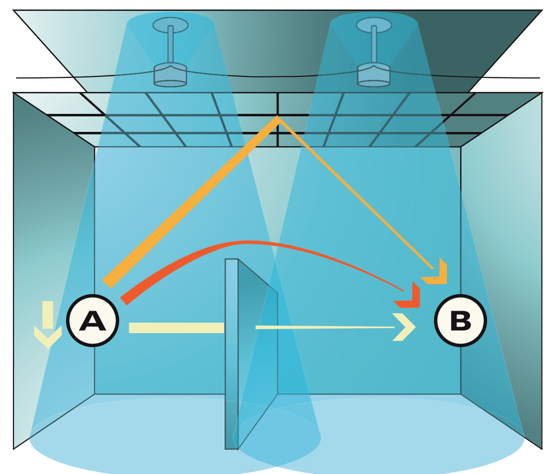


Diagram 4: Cover Up Noise

Key acoustic requirements

Many come to the conclusion that only one or two of the methods or materials described above can resolve the noise problems in their office. In reality, no single acoustic technique or product can create an environment that is conducive to speech privacy and concentration. A combination of noise control methods and materials is required because each one functions in unique ways. This fact becomes clear when we consider several key acoustic requirements and use a real world case study to illustrate how sound masking works in conjunction with absorptive elements to fulfill them.

A space with poor acoustics

A company recently completed their new headquarters in Europe and was unhappy with the results with respect to noise. The office was finished with reflective surfaces on ceilings, walls and floors and no sound masking system was installed. While sound masking and absorptive materials had been introduced during the planning stages of the project, they were eventually excluded based on poor advice from one of the professionals involved.

After the company moved in, they discovered that noise levels in their office were quite high due to the reflection of sounds from the hard surfaces back into the space. Sounds traveled a great distance as they bounced off the ceilings, floors and walls. The space was very difficult to work in. It was hard to concentrate. There was a modest amount of privacy, but only due to the high levels and quantity of noise.

The company was forced to reevaluate and renovate their new facility. How would you resolve these issues?

Acceptable noise floor

The first requirement is to create an average sound level that is high enough to mask noises and yet low enough to be comfortable.

Neither the average sound level nor the noise floor (i.e. the lowest sound pressure levels present in a space over a period of time) should be too high or too low because overly loud environments are irritating and tiring, while overly silent environments provide little noise control or speech privacy. In a library, for example, the slightest level of activity instantly eliminates the apparent quiet provided by near silence. Since offices exist for active purposes, silent environments are not an option. Yet the typical response to acoustic issues such as those in our case study is to try to achieve silence by using only the first three of the four methods of noise control: reducing and blocking noises, and adding absorptive materials to the space.

In our example, the company was advised that they could lower the noise levels in their office by completely renovating the area with absorptive materials. The result of the renovation was a 12dB drop in the average sound level, but they were still unhappy.

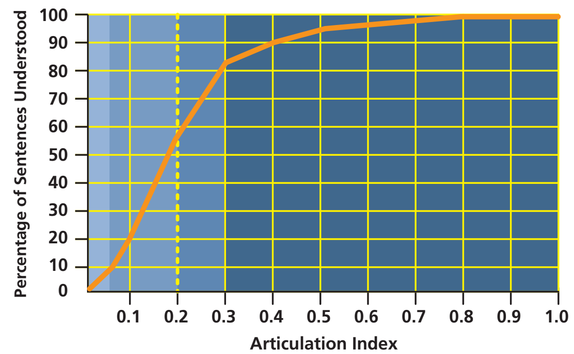
Low signal to noise ratio

Adding absorptive materials had been a positive first step, but it was not sufficient to provide an acceptable acoustic environment. Reducing the average sound level in the office made the office somewhat more comfortable, but it also eliminated the modest degree of speech privacy that had existed in the space. Conversations had become more intelligible over a greater distance.

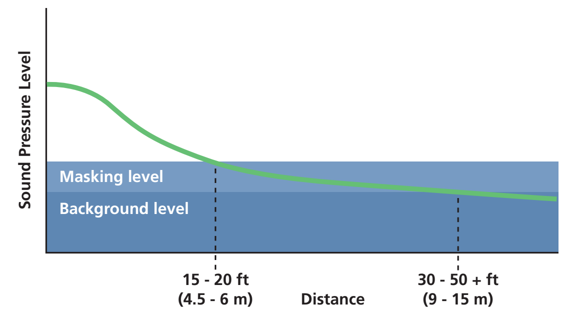
Speech privacy is gauged using the Articulation Index (AI), which is a measurement of the intelligibility of conversations from one point to another. AI is not measured over a standard distance, but rather from any point-to-point in a facility. The Index has a range of 0.00 (no intelligibility) to 1.00 (perfect intelligibility), which is divided into four qualitative privacy categories, including Confidential (0.00 to 0.05), Normal (0.05 to 0.20), Marginal (0.20 to 0.30), and None (0.30 to 1.00). The relationship between AI and actual comprehension is not linear; therefore, an Index measurement of 0.5 does not mean 50% privacy. Rather, the relationship is dictated according to Graph 1. Along the side axis, this graph shows

the percentage of words or sentences understood, while AI is shown along the bottom axis. You can see that at 0.5 on the AI, the actual comprehension is about 95%. This explains the requirement to achieve low Articulation Index readings to obtain real privacy. In fact, you likely need to achieve a level of 0.2 or better to really begin to reduce distractions due to others' conversations and to provide any real privacy.

is a good expectation. It can be shorter. Over shorter distances, masking may not prevent you from hearing that someone is speaking, but it will inhibit your ability to understand what is being said. This is a key benefit because comprehensible speech is the most distracting and least private. Graph 2 illustrates the decay of the human voice and the degree to which masking can reduce the distance over which the speech is intelligible.



Graph 1: Articulation Index and Intelligibility



Graph 2: Effective Acoustics Over Distance

The signal to noise ratio, or the volume of conversation or sound relative to the background level or noise floor, influences occupants' level of speech privacy and their ability to concentrate. The greater the sound relative to the background, the more noticeable and understandable it is. While sounds decay in volume over distance, low background levels also mean that they can be clearly heard from afar. The background sound level in offices is often so low that voices carry intelligibly over a distance of 30 to 50 feet (9 – 15 meters) or more.

A masking system dramatically reduces this distance by raising the background sound level. Any voices or sounds that have decayed to a level below the masking will be covered up and go unheard. The exact distance will be affected by the office layout and other acoustic treatments used within it, but 15 to 20 feet (4.5 – 6 meters)

When we consider the implications of this graph in a real world scenario, the benefits of sound masking are clear. Consider the person sitting at the desk marked by the orange dot in Diagram 5 (on the next page). In an untreated office, voices carry a conservative distance of 40 feet (12 meters). That puts over thirty people and two meeting rooms well within the range of this person's voice. It also exposes this person to the conversations and noises generated by all of these people. Sound masking can reduce the range to 20 feet (6 meters) (again, conservatively) and the number the number of people within the radius of intelligibility to about 10.

Low dynamic range

Referring again to our case study, the company's use of absorptive materials also failed to meet the third acoustical requirement, which is low dynamic range. This term is defined as the variation in the volume of sound over time or the difference between the peak sound levels and the noise floor in the space.

Human senses are designed to detect such changes and it is difficult to ignore them; therefore, the higher the dynamic range, the harder it is to "block out" noise. In fact, studies have shown that spaces with high volumes and low dynamic range are more comfortable than spaces with low volumes and the same or higher dynamic range.

The absorptive materials used in the European headquarters had the effect of lowering the average sound level within the space, but the perception of a noisy environment remained because the dynamic range remained high. Office occupants found the severe variation in the sound levels over time to be irritating and distracting. If masking were applied, the average sound level would increase slightly, but because the lowest level of sound to occur in the space would be that generated by the masking, the variation in the sound level would be dramatically reduced. All sounds beneath the masking level would be effectively masked and become unintelligible or imperceptible. Sounds would become less distracting and the office would seem quieter.

In the end, the sound masking distributor was called back to evaluate the effect masking would have on the European headquarters. The result of the acoustical study indicated a dramatically reduced dynamic range (about 50%) with only a marginal increase in the average sound level. The impact on both employee privacy and comfort would be significant.

As shown in Graph 3, the average sound level increases to 48dBA when the masking is set to 45dBA, but the dynamic range decreases to 5dBA because the masking provided a sound floor. It is impossible for the sound levels to be below this floor. If peak levels are minimized through reducing noise at the source, blocking and absorption, the result will be an even more comfortable and consistent acoustical environment.

Diagram 5: Sound Masking's Effect on Intelligibility

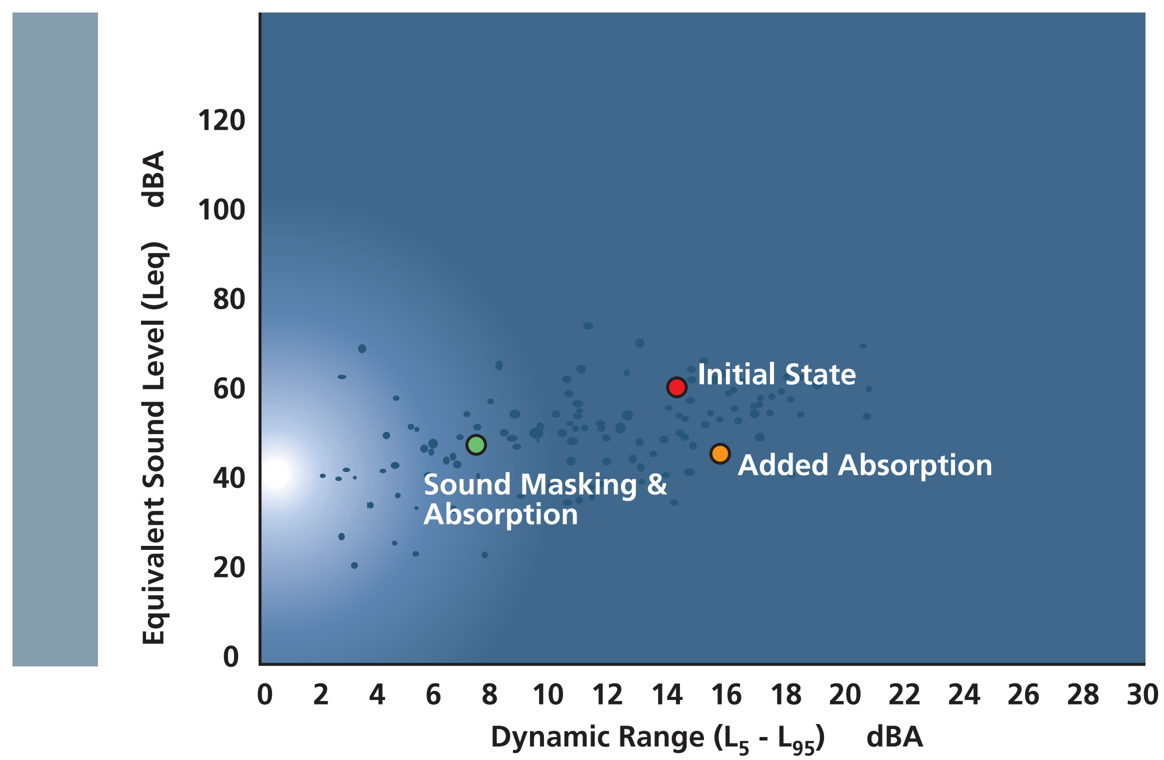
A very similar result could have been achieved in this example with far less expenditure and time lost, if the facility had been planned with absorption and masking from the start.

Maximum acoustic consistency

There are a wide variety of acoustic environments in any facility. The type of ceiling (tile or drywall), open air return grills, HVAC ducts or equipment, and office machinery all affect the acoustic characteristics of a space. Variations in lighting, temperature and humidity are controlled and kept within certain comfort parameters, and, similarly, the fourth requirement for effective office acoustics is to minimize variations in both sound volume and frequency. This acoustic consistency allows individuals to move freely within the office and to work in multiple locations with minimal impact. A sound masking system is unique among methods of noise control in its ability to minimize acoustic variations because it introduces a specific background sound at controlled levels across the space. However, in order to achieve uniformity, the masking system itself must be flexible enough to adjust frequency and volume output for small areas. This level of control is essential to the system's success. To be effective, a masking system should be audible when listened for, but as unobtrusive as possible. If the level and sound quality were to change as you moved through a facility, it would call your attention to the masking system. Rather than eliminating distractions, the system would contribute to the variations in the acoustics and become an irritation.

A combined approach is needed

As we saw from our case study, most evaluations of the acoustical environment have only focused on the quantity, or volume, of sound. In so doing,



Graph 3: Low Dynamic Range

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noise control strategies have been pursued in what we call the "Quest for Silence" – the notion that good acoustics are achieved when the sound levels in a space are as low as possible, with zero being the best. This is a flawed assumption. Just as with ergonomic factors such as temperature, light and humidity, there is a comfort zone for the volume of sound. The desired range of sound levels for most spaces is between 42dBA and 48dBA.

Absorptive treatments are often used in the "Quest for Silence." While absorption is a vital acoustical component, it is insufficient to satisfy all of the acoustical requirements we have outlined. Absorptive ceiling tiles and furniture partitions reduce the average sound levels in a space by decreasing the volume of noises reflected back into the office; however, they also reduce the noise floor and can actually produce a space that is too quiet. The dynamic range will remain high or become higher and the acoustics will still be inconsistent from one place to another.

Only masking systems can be used to attain a proper noise floor level. Masking reduces the dynamic range, creates an acceptable average sound level (not too high and not too low) and covers up noises that occur beneath the level of the masking. In addition, masking reduces the signal to noise ratio for sounds still above the masking level, thereby making them less noticeable and distracting. Another benefit of sound masking is the ability to maximize the consistency of the acoustic environment across the entire office space. Masking can also reduce, though not necessarily eliminate, the requirements for other acoustic treatments, though adding sufficient physical barriers and absorptive materials to the office design can further minimize the distance over which noises are heard and the masking system's volume can be decreased without affecting its performance level.

Armed with a better understanding of the determinants of effective acoustics, we see that an environment conducive to speech privacy, concentration and productivity can only be created through the balanced application of the methods of noise control we have described: reducing noise at the source, absorbing noise, blocking noise transmission, and masking noise.

info@logison.com www.logison.com 1.866.LOGISON