Speech Privacy

Exploring Improved Solutions

Focus: Health and Human Services

A Collaborative Study Conducted by:

SMED International • Armstrong World Industries • Dynasound Inc.

IFMA FOUNDATION

Since its inception in 1990, the IFMA Foundation has pursued a vision to provide funding for education and research to promote excellence in the workplace and for the advancement of facility management.

In accordance with our mission, we are pleased to have sponsored the following research, Speech Privacy in Flexible Settings. This topic was submitted to the Foundation for funding by IFMA's Healthcare Council in 1998. Although healthcare is the setting for this research, the implications reach far beyond hospitals and medical offices. Speech privacy problems abound in corporate offices and other types of facilities. The findings of this research will help owners and facility managers understand better ways to measure and assure confidential speech privacy in closed office settings.

Our thanks go to all those involved in this research effort. The Foundation contributed a considerable sum to this project, but there were other sponsors, too. Several of IFMA's corporate sustaining members, Armstrong World Industries, SMED International, Collins & Aikman Floorcoverings Inc., and Dynasound, along with the Health Care Facility Research Consortium, provided additional support in the way of funding and technical and scientific expertise. The Coalition for Health Environments Research (CHER) provided peer review analysis of the research methodology, and the Health Care Facility Research Consortium conducted the subjective research and analysis. Scripps/Mercy, a healthcare provider, built and monitored the modular Constructive Solutions™ healthcare facility used for this study.

We encourage facility managers, architects, designers, owners and providers to understand the implications of "whole systems thinking" and to make use of these research findings as they design closed offices requiring speech privacy. This research demonstrates that proper planning, product specification and construction provides predictable and consistent results, works better and does not necessarily cost more.

We hope this research will be a useful tool to everyone involved in creating and managing flexible settings requiring speech privacy.

Marc Adelman, CFM, AIA
IFMA Foundation Chair

Coalition for Health Environments Research

The coalition for Health Environments Research (CHER) is a not-for-profit organization with a mission of identifying and publicizing health environments research that will benefit consumers, providers, architects and others. Although we do not endorse specific products, we do identify significant research that is sponsored and financed by academic organizations, professional associations industry and manufacturers but is nonproprietary in nature.

The International Facility Management Association (IFMA) healthcare council sponsored a study of acoustical performance of exam rooms and related closed office settings. The research received substantial support from SMED International, Armstrong World Industries, Dynasound and The Health Care Facility Research Consortium. The study is now complete. CHER formed a peer review panel consisting of architects and interior designers to evaluate the study during its final stages of completion.

The CHER peer review panel thought that this IFMA study was scientific and well documented research with a useful outcome. We are pleased to commend the study for use as a guide to providers and architectural and interior design practitioners, their engineers and healthcare providers.

W.H. (Tib) Tusler, FAIA
President, Coalition for Health Environments Research

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In the health and human services sector, poor acoustic performance can compromise a patient's treatment and care. In 1999, an IFMA (International Facility Management Association) Healthcare Council field study at various clinics in the North Eastern United States revealed that "physicians complain about being able to hear the conversations of patients who are waiting just outside their exam rooms. Patients complain about hearing voices from adjacent spaces, and worry about being overheard during their exam, interview, and consultation." Consequently, patients may conceal or be less forthright in providing information vital to their treatment and physicians may experience distraction.

The privacy problem arises from the traditional approach of having diverse manufacturers and trades-people independently design, produce or construct interior components for one particular space.[1]

The reason most private offices fail to provide speech privacy

When designing space, architects typically specify the acoustic performance of a room's component parts. Ceilings and wall systems, for example, are selected on the basis of how they perform separately in lab tests and the resulting wall Sound Transmission Class (STC) rating and Ceiling Attenuation Class (CAC) rating. Despite the best efforts of architects and designers, more often than not, the system fails to perform as intended. When the system does not work it is not easy to correct.

As technology is upgraded, or changes to it are made, contractors must constantly remove and replace ceiling tiles to access wiring. The resulting wear and tear on the tiles and grid may compromise the attenuation provided by the ceiling. The plenum - the space above the ceiling where most wiring and services are located - serves as one of the major avenues by which sound escapes and travels to a neighboring space.[2]

1 In the paper Sound Solutions, The American Society of Interior Designers (ASID) noted that, "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."

2 In a particular physician's office studied by the IFMA Healthcare Council, researchers noted how return air grilles located near the door allowed sounds to easily pass into the hallway and plenum, and then travel "through the registers in each and every space in the clinic." In another facility, "drywall was cut and fitted around each and every pipe in the plenum . . .. These details are minimally effective if other areas in the plenum are completely open."

Also, the opportunity to test the entire space in advance, with all variables present, seldom presents itself. Accordingly, SMED International, Armstrong World Industries, and Dynasound Inc. set about to engineer an integrated closed-plan office system that fully took into consideration the numerous construction deficiencies that very often compromise closed-plan speech privacy.

Why was this research conducted?

This initiative is a result of research conducted in 1998 for the IFMA Healthcare Council, which recognized that STC measurements on individual components were failing to provide speech privacy, and that a new solution for closed-plan office systems was required. The initiative was partially funded by a grant from the IFMA Foundation.

The researchers discovered that it was technically possible to take commercially available manufactured products and combine them into a flexible, pre-engineered system that would consistently provide a predictable and high level of speech privacy. Interest in formal research for a systemic approach to acoustic solutions arose when the three solicited companies realized that none could provide a complete acoustic solution independently.

Why is this research important?

The results of this research will be of interest to healthcare professionals and managers of similar facilities because it is now possible to offer a solution for a major concern: speech privacy.

What a Potential Healthcare Buyer or Specifier Must Understand

The following variables all affect sound and speech privacy:

1. Sound "leaking" through construction components.
2. Acoustical absorption within the receiving and source spaces.
3. Talker's voice level.
4. Background noise level in listening space.
5. Gender of talker.*
6. Hearing ability of listener.*
7. The language, dialect and accent spoken.*

**not measured in testing standards current at the time of the research*

The variables affecting speech privacy

Of these, STC and CAC test individual construction components in isolation, not together, and do not incorporate variables 2 - 4. Another more compelling measurement, called the Privacy Index (PI), measures 1 through 4 together.

The research conducted by SMED International, Armstrong World Industries and Dynasound Inc. used the Privacy Index and concluded that a speech privacy solution providing confidentiality is available.

Testing conducted in the lab proved that adequate Privacy Index measurements are attainable with the modular construction elements employed. However, would the measurements correspond to people's perceptions of what is confidential? And, could those results be reproduced in a "real world" situation?

The Privacy Index is a valid measurement

The researchers conducted further testing using human subjects to answer those questions. They found that indeed the lab results and the human subject results concurred.

Next, they conducted Privacy Index testing in functioning clinics designed to ensure speech privacy. Again, the researchers were able to measure superior levels of speech privacy. Further, comments by occupants of the facilities indicated that the measurements were again valid. The Privacy Index was found, therefore, to be a reliable and accurate measurement of speech privacy between adjacent closed rooms.

STC ratings are not enough

A healthcare facility designer must understand the difference between an STC and CAC rating and the Privacy Index when specifying component parts. Acceptable STC ratings on individual parts will not guarantee speech privacy when the parts are brought together. Conversely, minimum STC ratings alone should not imply that these products cannot achieve desired speech privacy in the proper context.

* STC and CAC ratings are a lab measurement conducted separately on individual parts.
* Privacy Index is a "real world" measurement of an entire built environment; it is a system performance measurement.

A specifier must understand that it is the Privacy Index that measures all variables necessary for speech privacy testing not individual component STC ratings.

Results of Testing

Subjective and Objective testing: what it means

Subjective testing describes the measurement of human response to the built environment. The hearing ability, attention span or sound level interpretation of the listener cannot be strictly controlled, unlike the size of the room or the construction components used. Conversely, objective testing involves the measurement of the performance of the space using instruments and subsequent calculations which determine the Privacy Index. In this project, the subjective responses of human juries were used to validate the measured Privacy Index. (Refer to the Technical Appendix for detailed test procedures.)

How the Privacy Index is measured

Understanding the Results: The Privacy Index and Speech Levels.
In a closed room construction, sound emanating from a source is reflected and absorbed by a variety of materials including ceiling tiles, wall panels, carpets, and furniture. After absorption and reflection, a certain amount of sound will escape from the enclosed space and reach the ears of a listener in an adjacent space. The Privacy Index measures privacy levels by percentage: 0% equating to full intelligibility and 100% equating to full speech privacy.

Levels of speech privacy

There are four recognized levels of speech privacy:[3]

1. Confidential Privacy: Privacy Index (PI) of 95% or better. Speech can be detected but not understood; less than 10% word and 5% sentence intelligibility. (This is the recommended level for exam rooms and doctor's offices.)
2. Normal Privacy: PI from 80% to 95%. Effort is required to understand speech. (This is a common existing condition in many healthcare facilities and is not satisfactory from a privacy point of view.)
3. Transitional Privacy: PI from 60% to 80%. Speech is mostly understood and can be distracting.
4. No Privacy: PI less than 60%. Speech is clearly understood.

3 Defined in ASTM E1374 Standard Guide for Open Office Acoustics and Applicable ASTM Standards.

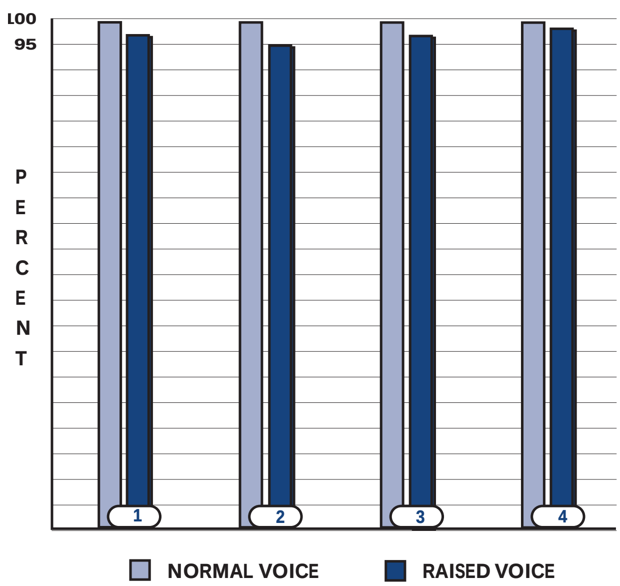
Results of the Objective Testing: Laboratory, Office and Functioning Clinic

Lab results

Assuming a normal speaking voice level, and sound masking tuned to suit the acoustic characteristics of the walls and ceiling products, a Privacy Index rating of 100% was consistently achieved. The researchers, however, remained concerned that the healthcare setting is likely to include people speaking with raised voices, so the Privacy Index was also calculated assuming raised voice levels to provide added assurances that true privacy was achieved. In this case, it was demonstrated that a Privacy Index with a minimum 95% threshold could be achieved. These results were better than those of nearly every conventionally constructed healthcare site surveyed for this research project.

Figure 1

FIGURE 1 illustrates the Privacy Index achieved in the lab for 3 types of wall panels, one ceiling and on both carpeted and vinyl floors.



1 SMED LifeSPACE™ Electrical Wall Panel, Armstrong Ultima Ceiling, carpeted floors
2 SMED LifeSPACE™ Glazed Wall Panel, Armstrong Ultima Ceiling, carpeted floors
3 SMED LifeSPACE™ Double-Glazed Wall Panel, Armstrong Ultima Ceiling, carpeted floors
4 SMED LifeSPACE™ Electrical Wall Panel, Armstrong Ultima Ceiling, sheet vinyl flooring

Test Site 1: An Office

Objective Test Results for Normal and Raised Voice Levels

Results from objective tests conducted at SMED International's corporate headquarters revealed speech privacy ratings between 90 and 100% for normal voice levels.

Test Site 2: A Functioning Clinic

Initial room-to-room noise reduction test measurements conducted in a newly-constructed medical clinic, combined mathematically with normal voice levels and the lab-developed masking spectra and levels, indicated that normal voice privacy levels of 95-100% and raised voice levels of 90 - 95% had been achieved. However, when calculated with the masking and background sounds as actually found in the space, the initial Privacy Index levels were, in most cases, substantially lower.

Further investigation of the site indicated several variations from the design contributed to lower masking levels and reduced noise reduction levels:

* The rooms at the clinic were substantially smaller than in the lab, resulting in lower noise reduction levels.
* The masking speakers were spaced at 16-foot centers, while several of the exam rooms were less than 8 feet wide, yielding excessive variation in masking levels among the rooms.
* The masking spectrum was below the lab-developed spectra in overall level, and was substantially lower than the lab spectra at several critical high-frequency bands.
* The air handling system was not always operating, resulting in lower background sound levels when the system was off.
* The unusual shape of the plenum, incorporating the pitched roof of the building, created special challenges for tuning the masking.

Re-tuning of the masking, adjusting the levels in the rooms, and adding speakers where required reduced these effects. By simply making these adjustments, the PI levels rose above the 95% threshold at normal voice levels (see Figure 2).

Figure 2

Privacy Index Results: Clinic

Location	PI, Normal	PI, Raised
Room 319 to Room 317	100 %	97 %
Room 319 to Room 320	97 %	88 %
Room 322 to Room 320	99 %	92 %
Room 322 to Room 324	99 %	89 %
Room 324 to Room 326	96 %	85 %

Results of the Subjective Testing: Laboratory, Office and Functioning Clinic

Lab results

Conducted at Armstrong World Industries acoustical labs, listeners in the receiving room reported that they could detect speech as much as 40% of the time, but could understand virtually nothing. Further, of what they heard they could understand only 2% of the words and no phrases or sentences. In no instance could anyone establish the topic of conversation (see Figure 3). This is consistent with confidential speech standards outlined earlier.

Figure 3

Continuous Discourse Results: Lab and Field Tests

Of total test period...	Lab	Field
percentage of time voices could be:		
Heard	40	56
Understood	2	1
of what was heard, what was understood?		
Words	2	6
Phrases	0	0
Sentences	0	0.7
Conversations fully understood	0	0

Test Site 1: An Office

Conducted at the corporate headquarters facility of SMED International, of the 36 participants, 28 said they could understand nothing of the conversation in the source space. Eight participants said they could understand 5% of the discourse. Of those eight people, only one heard something being said 50% of the time. The participants said they could understand no phrases or sentences, and only the occasional word. Again, none of the participants could identify the topic being discussed. This is consistent with confidential speech standards outlined earlier.

Test Site 2: A Functioning Clinic

Conducted in a functioning community healthcare clinic and following tuning of the sound masking system, the staff working in the clinic indicated a high degree of satisfaction with the privacy of the space particularly when compared to other spaces they had occupied. In addition, medical assistants indicated that they could not understand any of the conversations taking place in the adjacent examination rooms. This is consistent with confidential speech standards outlined earlier.

Conditions of field study facilities

To further verify a potential solution to the problems facing healthcare providers, researchers visited a series of healthcare facilities operated by nationally recognized providers to test the acoustical performance of their existing spaces.

Although generally well-crafted architecturally, the buildings visited had an average Field Sound Transmission Class (FSTC) of about 30. Many caregivers and patients expressed frustration or concern over the lack of privacy.

One of these facilities represents the best conventional example of quality healthcare interior construction tested. The demising walls are deck-to-deck drywall and were intended to be constructed to STC 44. Despite the care of construction, however, numerous design problems stand out: window-mullion to wall connections are poor, background sound levels are unusually low, door undercuts are high, and furniture placement both inside and outside of rooms allows conversations to be easily overheard.

Another facility, meanwhile, occupies previously constructed space and is somewhat typical of the manner in which clinical space is now being developed. The fixed walls offer a mix of construction approaches, with some being deck-to-deck, and others stubbed 6" above the ceiling plane.

The Privacy Index measurements for these spaces confirmed that the speech privacy performance was highly variable and generally poor.

Field Evaluations: FSTC and Privacy Index

Figure 4

Location	FSTC	PI, Normal	PI, Raised
Healthcare Clinic			
1B	28	87	68
1C	32	96	88
2B	32	98	88
2C	28	92	73
Hospital			
122 to Corridor	24	77	55
122 to 123	38	100	91
150 to 147	32	100	95

Summary and Conclusions

The research program demonstrated that:

* It is possible to build adjacent closed rooms offering predictable levels of speech privacy using entirely pre-manufactured, pre-tested, flexible and movable components.
* Achievement of confidential speech privacy in adjacent closed rooms constructed with suspended ceiling systems and movable walls requires walls and ceilings that are balanced in acoustical performance.
* Typical fixed drywall partitions beneath suspended ceiling systems offer in themselves no inherent privacy advantage over movable wall systems. Both require adequate and properly tuned background sound levels to achieve confidential speech privacy.
* It is possible to predict privacy levels in adjacent closed spaces using the Privacy Index from laboratory testing, and to have the lab results substantially validated in field tests.
* The Privacy Index is a far more reliable indicator of acoustic systemic privacy than component measurements such as STC.
* A tunable sound masking system is required to ensure speech privacy, and can be used to accommodate slight performance variations in construction components.

The research undertaken by SMED International, Armstrong World Industries and Dynasound Inc. reveals that it is possible for manufacturers to design a pre-engineered system that offers both flexibility and acoustical privacy.

GLOSSARY

Articulation Index (AI) — A measure of the intelligibility of speech sounds reaching a listener that takes into account the speaker's voice level and the background sound level in the listener space.

ANSI — American National Standards Institute

ASTM — American Society for Testing and Materials

CAC — Ceiling Attenuation Class

Similar to STC, but for ceilings. This rating assumes that sound energy passes through the ceiling plane twice - once to get out of the source room, and again to enter the receiver room.

FSTC — Field Sound Transmission Class

The same as STC, but measured in a "real world" setting. FSTC ratings are usually significantly lower than the STC ratings for the same construction, but this difference is not strictly predictable.

IFMA — International Facility Management Association, and the IFMA Foundation

Intelligibility — The amount of speech which can be detected and understood.

Normal Voice — The voice level used in normal conversation. (Voice level of 58 dBA.)

NVLAP — National Voluntary Laboratory Accreditation Program

Privacy Index (PI) — Measurement of speech privacy derived from Articulation Index (AI), where PI=(1-AI)x100%

Raised Voice — A voice level often used when addressing more than one person or with a person hard of hearing. (Voice level of 64 dBA).

STC — Sound Transmission Class

A single number rating of the acoustical performance of a material, such as a wall. Typical STC ratings specified by architects for private offices are in the range of 40 to 45, and for conference rooms in the 45 to 49 range. The higher the rating, the greater the ability of the wall to block sound passing through it.

Spectra — In the context of background sound levels, spectra is the sound energy level at the range of frequencies significant to speech privacy.

Speech and Frequency — Frequency refers to the wavelength produced by a sound, and is often referred to as "pitch". The frequency of speech which is significant to intelligibility ranges from 500 to 4000 Hz.

Vowels are sounded at lower frequencies and transmit little speech content. Consonants, by contrast, are sounded at higher frequencies and transmit more speech content. Higher frequencies (above 1600 Hz) contribute more to speech intelligibility.

Additionally, the human ear is more sensitive to higher frequency sounds. Whether a person can hear a sound depends on the intensity (measured in decibels, or "dB") of the sound and its frequency. A sound of high intensity, for example, may be imperceptible at a low frequency, but perceptible at a higher frequency of the same intensity.

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I. INTRODUCTION

To evaluate the performance of the proposed approach, a research program was undertaken which would test interior spaces constructed using pre-fabricated components. These components possessed the potential of providing confidential speech privacy.

First, such spaces would be constructed and tested in the controlled setting of a laboratory, according to standard test methods.

Next, the same products would be used to construct similar spaces in the "real world" followed by further testing.

Finally, both laboratory spaces and the constructed offices or clinics would be evaluated subjectively in an effort to better understand how closely the standards reflect public perceptions of privacy.

II. PRODUCTS USED IN TESTING:

Armstrong World Industries

Ceiling panels

* 2x2 Ultima lay-in panel
* 2x2 Tundra lay-in panel
* Prelude 15/16” Exposed Tee
* Silhouette 9/16” Bolt–Slot

Dynasound Inc.

* Electronic sound masking system

SMED International

LifeSPACE™ movable wall system

* Solid panels complete with electrical boxes
* Doors and glass panels
* Installation over carpet and/or sheet vinyl flooring

III. Testing Procedures

Objective Test Procedures

Laboratory

Laboratory tests were carried out at the Armstrong Innovation Center, Lancaster, Pennsylvania, a certified test facility. The lab tests served as blueprints for testing procedures carried out at the field locations of SMED and the clinic.[4]

The goal of the laboratory test program was to simulate (as closely as possible) a field environment.

Office Site

The test setup comprised two adjacent rooms constructed over carpeted floors, a continuous suspended ceiling, and continuous plenum space. The rooms were constructed of unitized, re-locatable wall panels. The list of components included supply and return air grilles, associated ducting, sound attenuation boxes over the return air grilles, light fixtures, electrical boxes, wiring and wall devices, and solid-core wood doors. Variations created by different wall panel specifications and different ceiling features were also explored.

Functioning clinic site

For the clinic, the researchers worked closely with the owner and the design architect to create a flexible healthcare facility using the systemic design approach to closed room acoustics. This facility has become a primary test site for the approach.

As with the lab tests, adjacent room pairs were chosen for use as the source space and receiving space respectively. Unlike the ideal lab conditions, however, researchers were faced with three critical differences from the lab space.

4 To the greatest extent possible, the test procedures followed those outlined in ASTM E1130, Standard Test Method for Objective Measurement of Speech Privacy in Open Offices Using Articulation Index.

First, walls in some areas separated rooms with different floor coverings: carpet and vinyl. Second, none of the clinic rooms were completely formed by LifeSPACE™ walls, but in fact were formed by at least one exterior wall. However, the additional junction between construction elements would be typical of all installations and was addressed in the wall system design. Finally, the rooms varied considerably in size. Thus, the acoustical absorption of each of the rooms varied and so did the noise reduction. This, coupled with the very small size of some exam rooms - some as small as 8' x 10' - was a challenge.

Researchers chose a series of doctor's offices and exam rooms in one corner of the facility. Measurements followed the lab procedure discussed above.

Subjective Testing Procedures

Laboratory

Participants comprised 31 individuals: 17 male and 14 female. The sound masking was tuned to the characteristics of the space. Testers recorded a "doctor" having three different hypothetical conversations with both male and female "patients." The recording was then transferred to a compact disc, and re-played at a "raised" voice level. Participating individuals were circulated through the receiving space.

Participants were asked how much they could understand of what was being said in the source room, including the number of words they could understand. Then, by the number of words understood, was it possible for them to establish the meaning and context of what was being said?

In seeking to gauge intelligibility the tests took into consideration that one can sometimes hear something being said, but can't make out the exact words. Although people may understand certain words, the information may prove insufficient to establish content.

Test Site: Office

Participants comprised 12 individuals divided into groups of three. Two of these groups combined to form one jury, while the other two groups formed the second jury. During testing, three jury members sat in the source room and took turns reading a series of newspaper clippings. To simulate the raised voice level, readers were instructed to speak "as if they were speaking into a speaker phone about three feet (one metre) away". The other three jury members sat in the receiving room and tried to hear what was being said next door.

In a manner similar to the subjective testing conducted in the laboratory, jury members were asked how much they were able to hear at the time of the test, how much they understood, and whether they could discern the topic of conversation from what they heard.

Test Site: Functioning clinic

Detailed subjective testing at the clinic base site was not possible due to the busy working schedule of the staff and clients of the clinic. However, following about six months of operation, in a series of interviews conducted with staff members, researchers solicited feedback on the perceptions of staff regarding the privacy offered by the exam rooms and offices throughout the space. There was unanimous agreement that there was indeed excellent speech privacy.

IV. Addressing churn systemically

With churn an inevitable product of growth and reorganization, the pre-engineered system must be designed to withstand changes that could compromise its acoustical performance. IFMA surveys indicate an average of 16% facility churn in healthcare facilities per year, with over 25% of respondents reporting churn rate of 20 - 25%. Further, more than three quarters expected their churn rate to remain the same or increase.

Characteristics of a system that addresses or responds to rapid churn rates:

* Constructing a "warm" shell of a building where services are all in place.
* The ceiling is a continuous running element.
* Lights and return air ducts are already built into the ceiling, but are easily movable. Suspended indirect illumination is recommended.
* Supply air ducts are run off flexible ducting that can be easily adjusted.
* A wall is positioned on top of the floor or cellular floor and clipped to the underside of the ceiling; the wall element can be easily disassembled and relocated throughout the space.
* All fixtures, ducts, and intersections are pre-engineered to minimize sound leaks.
* The electrical, data, and plumbing systems are already set up within the wall panels, eliminating the need for further labor that could jeopardize the Privacy Index rating.

Such a system is able to perform at the client's required level of speech privacy, provided that appropriate products and materials, such as the products used in this study, are selected.

Contact information

The following contacts are available at each organization that participated in the research. These may be contacted for further information:

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