Portable Quiet Room for Very Important Personnel Protection

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This case study analyzes the design, construction and testing of a lightweight, easily transportable, speech isolation room capable of providing substantial anti-eavesdropping countermeasures for use by high-level government and intelligence agencies as a secure meeting and communications center that can be readily deployed worldwide. The performance criteria specified a minimum-field STC-35 utilizing a modular, scalable mechanical design capable of repeated assembly without the use of tools, a maximum total design weight of 3.29 lbs per square foot, a 2-inch nominal wall thickness, and use of active and passive ventilation. A robust, multilayered composite panel and joining system with ancillary components was developed. A combination of nonmetallic limp mass and rigid metallic barriers separated by decouplers of varying properties in an aluminum shell, brake-formed to distort natural resonances, achieved a significant TL (up to 45 dB) in the speech frequency range equaling the performance of commercially available products of nearly twice the weight and bulk. Interior room acoustical characteristics were optimized by using modular demountable sound absorptive units.

The United States Secret Service (USSS) along with the United States White House Communications Agency (WHCA) have long been responsible for providing multi-disciplined security for very important persons (VIPs) of the United States federal government, including members of the executive branch, State Department, cabinet members, some members of Congress and select members of foreign governments with friendly nation status. In addition to the somewhat publicly well-known physical personal safety and security measures and concerns addressed by these agencies, they are also responsible to develop and provide a wide range of countermeasures to protect and ensure intelligence and communications security for these VIPs wherever they require it. These include but are not limited to electronic data transmission, telecommunication, video transmission and speech privacy.

This article reviews the requirements for, and solutions developed to provide transportable, acoustically secure work areas (quiet rooms) for VIPs at domestic and foreign locations where they conduct classified and sensitive communications. These quiet rooms (QRs) function as temporary work areas that house secure telecommunication equipment and VIPs conducting sensitive meetings, conversations, data transmissions, etc., and must provide the occupants a moderate level of acoustical isolation intended to interfere with speech intelligibility from the outside to impede or prevent passive acoustic eavesdropping.

The typical QR use scenario arises when VIPs travel from their normal base of operations (White House, Capitol or Pentagon, for example). A team of security agents travels to and prepares a location in advance of the VIP arrival to be used as a communications center for the duration of the trip. This includes building a QR at the host location, which may be inside a hotel room, office building, airport hanger, or other secured location. This major logistical operation involves moving large amounts of equipment and personnel, usually by air transport, to a wide range of global destinations ranging from urban to remote environments. Oftentimes the assembly locations require that the components of the QR be carried manually through buildings, up stairways, etc., particularly in foreign locales. Therefore, a significant emphasis is placed on minimizing the weight and size requirements of any equipment used while, simultaneously requiring a high degree of product durability. These parameters played a significant role in developing the construction and performance criteria of the QR.

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Room Performance Criteria

The USSS and WHCA developed a statement of work that specified the following performance criteria goals for the QR:

- Modular design and construction, allowing easy assembly, disassembly, packing and transport (maximum packaged cargo volume was also specified).
- To the extent possible, all components should be interchangeable.
- Modular design to be scalable, allowing for varying work space configurations from 4 × 6- to 7 × 12-foot units with the ability to combine units into adjoining minisuites.
- Design of modular components requiring no tools for assembly.
- Assembly of basic 7 × 12-foot unit able to be completed by two persons in a maximum time span of two hours.
- Include interior acoustical (sound absorptive) treatment with the ability to tune the interior environment to suit user preferences.
- Include integrated forced-ventilation and cooling systems.
- Robust construction required to withstand a minimum of 25 deployments and survive the rigors of global transport.
- Include tamper-evident features.
- Provide data and telecommunication connections.
- Base unit to achieve on-site acoustical characteristics equal to STC-35 with emphasis on disrupting speech intelligibility from the outside.
- Nominal wall thickness of 2 inches.
- Maximum system design weight not to exceed 3.29 lbs per square foot.
- Include option for radio frequency (RF) shielding of 90 dB at 1 GHz.

System Design Considerations

Given the requirements for transportability, scalability and site assembly, it was immediately recognized that a pre-engineered, prefabricated modular system of interchangeable wall and ceiling panels with appropriate assembly and ancillary components would be the most cost-effective concept to pursue. A cursory review of the physical size and modest transmission loss requirements would indicate that there are many readily available modular room constructions that will yield STC-35 in a 2-inch-thick profile. But when considering the requirements for repeated non-tool assembly and the low total system design weight of 3.29 lbs per ft^2, construction of the basic modular panel section and joiner was recognized as the primary design challenge for this project. The primary components of the system to be reviewed were:

- Modular wall panels
- Modular ceiling panels
- Panel-to-panel joiners
- Base and corner connectors
- Personnel access door
- Integrated ventilation system
- Interior finishes and acoustical treatments

Our principal challenges were to:

- Design the basic building blocks of the system (modular wall and

Table 1. Sound transmission loss (STL) data for INC 2-inch-thick standard Panl-Wall®.

Frequency, Hz	125	250	500	1000	2000	4000	STC
STL, dB	20	22	32	42	50	57	35

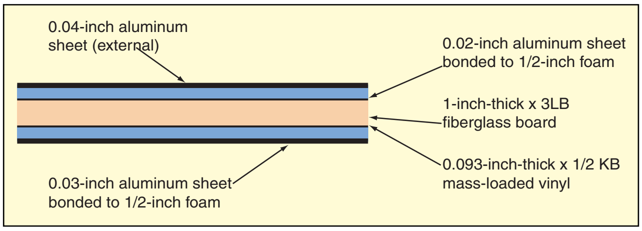

Figure 1. Cross section of low-mass, quiet room modular panel construction.

ceiling panels) to achieve the acoustical characteristics required within the design weight limits in a robust unit construction.
- Design system assembly components that would allow repeated field assembly within the specified parameters while maintaining the acoustical integrity of the room throughout the design life of the system.
- Provide for a tunable interior acoustical environment with finishes commensurate with VIP usage.

Basic Component Design

Considering the transmission loss (TL) criteria and the requirements to minimize speech intelligibility to be the controlling design parameters, a review of the idealized speech spectrum for male voices[1] set our goal to maximize TL in the 125-4000 Hz range. Since our firm already had a fully developed, non-homogeneous, double-walled, modular, acoustical, panel product line (Panl-Wall®) in place, design review for the QR started by comparing the project-specific performance criteria to the features and performance characteristics of our existing line to determine which, if any, existing components or design concepts could be incorporated into the QR project design.

We looked at the TL data for our existing 2-inch-thick, STC-35, modular, acoustical, metal-panel construction shown in Table 1. Although this construction does provide the required acoustical characteristics, the total base system design weight of this product construction (and other similar commercially available product lines) is 5.655 lbs/ft^2. Subtracting the system weight of the assembly and ancillary components results in the base double-walled panel itself to have a design weight of 4.495 lbs/ft^2. Using similar allowances for the QR assembly components results in a design weight goal for the base double walled acoustical panel for the QR to be about 2.297 lbs/ft^2. Therefore the challenge was to design a panel construction that would provide TL characteristics similar to our existing unit but with 49% less mass; in other words, a panel whose TL characteristics would exceed those expected based on the mass of the panel.

In addition, our standard product line, while allowing for assembly and disassembly, is not designed for the degree of repeated assembly required for this project, nor could it be assembled without tools. Therefore, we could only use the general concept of modular, interchangeable, acoustical, panel units to be incorporated into the required configuration through the use of a series of pre-engineered joiners and trims for the QR project. The individual components would need to be designed specifically per the project requirements.

Basic Modular Panel Design. The design of the basic wall and ceiling module is a square-edged, double-walled, composite panel (sandwich construction) consisting of multi-dissimilar mass layers within a box shell separated by dissimilar porous materials acting as both decouplers and constrained layer dampers. The cross section of the basic modular panels is shown in Figure 1.

Aluminum Type 3003 flat sheets are used due to their low weight and high strength as well as their relatively low natural resonant frequency characteristics and inherently good damping properties. During product development, in-house TL tests were performed on various configurations of the aluminum skins and interior barriers and decouplers leading to the final selection of materials and composite build techniques. These tests highlighted the problem of significant coincidence dip between 1000 and 4000 Hz that commonly occurs with relatively thin sheet metal panels and led us to a simple method of mitigating this characteristic.

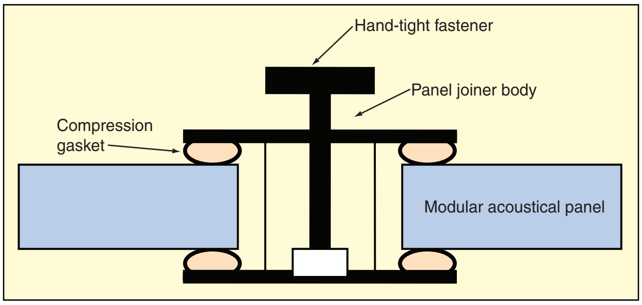

Figure 2. Cross section of two-piece panel joiner assembly.

The interior and exterior panel surfaces are diagonally form-creased prior to assembly to introduce structural rigidity and disrupt the natural resonance characteristics of the aluminum sheet. All four edges of the exterior panel sheets are press-braked into flanges to create half shells. The interior layers of aluminum sheets with bonded foam (foam adhered to sheets with viscoelastic adhesive layer), are held in place after final panel assembly and act as constrained layer dampers and decoupled barriers. The center limp vinyl mass is not constrained and acts as a very low resonance septum barrier with good TL. The panel assembly is held together by riveting along the external edges on all sides. All overlapping riveted edges are sealed with a viscoelastic epoxy used primarily as a tamper-evident feature for security purposes.

Panel Joiner and Assembly Component Design. To allow for proper joining and sealing of adjacent panels and to meet the design goals for field assembly, we developed a unique (patent-pending), two-piece, bolt-together "H-joiner" that structurally and acoustically couples adjoining panels using hand-tightened knurled fasteners (see Figure 2). Made of aluminum sheeting, the joiner includes integrated, flexible, resilient, acoustic seals that are compressed during assembly as well as captive threaded inserts for hand-tightened knurled lock fasteners. During field assembly, adjoining panels are locked together by the compressive force of the joiner being tightened against the panel surfaces. This force creates and maintains the acoustic seal between panels. The joiner design also allows for a reasonable degree of self-alignment to accommodate inconsistencies in the flatness or level of field conditions at host locations.

Additional system assembly components like base channels, corner trims, etc., are also fabricated using sheet aluminum. Integrated acoustical gaskets are included where required. Where structural or locked connections are required, such as at corners and wall-to-ceiling intersections, closed-end threaded inserts are set into panels, and connections are made using hand-tightened fasteners.

Personnel Access Door. Each QR includes one personnel entry door/panel that can be located and interchanged with any wall panel. The door is constructed using the same basic design parameters as the wall panels but with heavier gauge exposed surfaces to provide greater resistance to damage due to high use. Double-compression-type acoustical seals are employed on all four perimeter edges, creating an unbroken positive seal that requires a step up into the room. Uniform compression is achieved by using pneumatic latches and panic exit hardware. Hinges are level-swinging and lift-off in design.

Integrated Ventilation. The QR ventilation system requires continuous fresh air exchange and, when needed, cooling to maintain a maximum interior temperature of 72° F. This is accomplished by using an external exhaust fan and mobile self-contained air conditioner connected to the QR by flexible fabric ducts. Air flows into and out of the QR through integrated silenced ventilation ducts built into the interior corners of the room. To provide the required air flow and maintain the acoustical envelope, these ducts are designed to run vertically the full interior height of the room; they have a pentagonal cross section and contain horizontal baffles lined with absorptive media.

Interior Acoustical Treatment and Finishes. The interior surfaces of the basic QR are solid aluminum and acoustically reflective. To allow for tuning the interior environment to suit the preferences

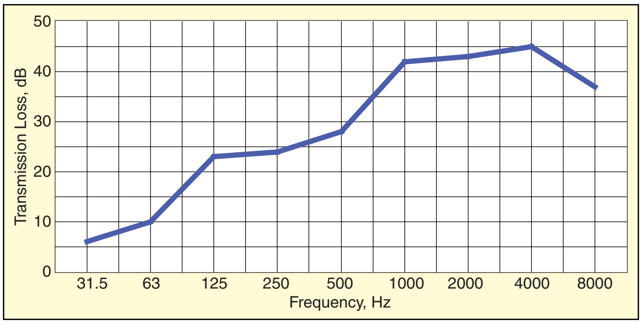

Figure 3. Field-measured transmission loss of quiet room.

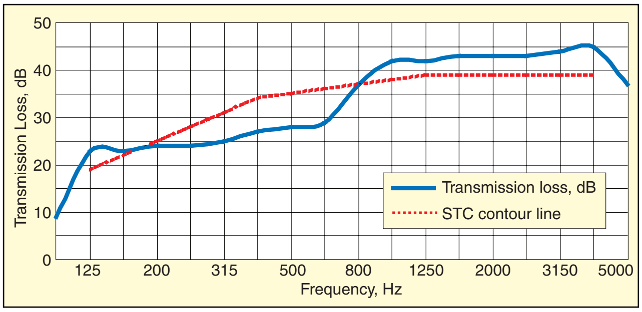

Figure 4. Field-measured transmission loss of quiet room plotted against STC 35 contour.

of the occupants and allow for variances in the acoustical environment as the number of occupants changes or the activity changes, we developed a system of interior sound-absorbing modules. These can be located throughout the interior space at various locations in varying number and with adjustable mountings. The units are 1.75-inch-thick, sound-absorbing fiberglass core panels finished with attractive fabric coverings. Integrated mounting brackets on the absorbers mate with an interior wall rail system, allowing placement of the modules on the interior surfaces of the QR. These modules can be installed with a flush mounting or with up to a 2-inch stand-off. The absorbers (NRC = 1.0) are supplied in modules that provide approximately 12.0 sabins of sound absorption each, allowing for a wide range of adjustment in the interior reverberation characteristics of the QR.

Interlocking floor tiles manufactured of a 0.75-inch-thick, dense, resilient, rubber compound are provided to be installed throughout the interior space of the QR directly over the host floor. This not only adds a uniformly finished walking surface, but also serves to improve the TL of the host floor, seal any potential gaps and leaks, and also provides a small amount of interior sound absorption. In addition, a series of track-mounted interior task lighting, convenience receptacles and emergency lights are included. All utilities terminate at an integrated jack panel.

Optional RF Shielding. A required optional feature is to incorporate a method or material that will allow the QR to achieve RF shielding of 90 dB attenuation at 1 gigaHertz. The solution is the addition of an RF shielding material to the modular panels to improve the already natural shielding characteristics of the aluminum construction. This is accomplished by lining the interior of the panel cavity during manufacture prior to installing the composite layers with a high-conductivity fabric (tin/copper-coated, plain-weave nylon). With a nominal thickness of 0.0025 inch, the insertion of this material into the panel composite has essentially no impact on the manufacturing process, thickness or panel weight.

Table 2. Field transmission loss test measurements.

	Frequency (Hz)								
Location	**31.5**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Interior*	68	66	89	91	80	85	90	85	74
Exterior**	62	56	66	67	52	43	47	40	37
Trans. Loss, dB	6	10	23	24	28	42	43	45	37

* Sound level (dB) generated using calibrated lab tape of broadband white noise.

** Sound level (dB) measured at 3 feet from exterior surface of QR.

Acoustical Performance

Field testing to determine on-site sound transmission loss was performed on several quiet rooms at varying locations after typical assembly-disassembly-assembly. Note that all testing was done using calibrated equipment and good engineering practices to ensure accuracy; however, the testing was not done in strict accordance with the ASTM Field Test Criteria.

Each test consisted of generating a calibrated broadband sound source inside the QR, with overall sound levels significantly greater than human speech and adequately greater than the exterior ambient (host room) levels. Using calibrated Type II sound level measuring devices, resulting sound levels were measured on the outside of the QR at 3 feet from the exterior surfaces at several locations around the perimeter of the room. See Table 2 for typical sound pressure levels at octave band frequencies from 31.5 to 8000 Hz. Figure 3 shows a graphical representation of the field-measured TL, and Figure 4 plots the measured TL against the ASTM E413 Standard STC-35 contour.

Summary

Through the use of innovative combinations of commonly available materials and manufacturing methods, we were able to manufacture a lightweight system capable of transmission loss characteristics in excess of what would be expected based on the mass of the construction. We learned that a thin-profile composite panel with several layers of materials, each with widely varying acoustical characteristics, could be combined to achieve sound barrier properties equal to composite designs of much heavier or thicker construction. All of the project performance goals were met or exceeded. S|V

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