Technical Features − Sound Construction
Research Evaluates Role Of Density In Acoustical Insulation Performance

PREVENTING NOISE INTRUSION FROM SPEECH AND MUSIC IS SIMPLIFIED WITH OPTIMAL DENSITY OF DRYWALL PARTITION CAVITY INSULATION

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Many factors influence the acoustical performance of gypsum board partition systems. Air cavities, resilient members, sealant details, and various types of acoustical insulation are some of the variables that have a significant effect. USG has conducted extensive research into one of these important factors— acoustical insulation density—to determine the optimum density for THERMAFIBER Sound Attenuation Fire Blankets.

The research included evaluations of mineral−fiber THERMAFIBER Insulation in densities from 2 lb/cu.ft. to 12 lb/cu.ft. and thicknesses from 1 to 12 in. THERMAFIBER Insulation is not currently manufactured in densities less than about 2.0 lb/cu ft., so the evaluation for lower densities used glass−fiber material at 0.7 and 0.8 lb/cu.ft. Tests were conducted with a variety of partition designs. The best overall acoustic performance was achieved with a mineral−fiber blanket in the 2.5 to 3.0 Ib/cu.ft. density range. Densities above 3 lb./cu.ft. provide more sound attenuation at high frequencies, but low−frequency performance starts to suffer at higher densities. Mid and high−frequency performance goes down significantly as insulation density falls below 2.5 lb/cu.ft. The conclusion to manufacture standard THERMAFIBER Sound Attenuation Fire Blankets (SAFB) with a nominal density of 2.5 lb/cu.ft. was based on the acoustic research, cost−to−benefit ratios, fire performance and handling characteristics.

Drywall partitions with THERMAFIBER SAFBs in the stud cavities consistently outperform those that include mineral−fiber insulation with densities less than 2.5 lb/cu.ft. In fact, tests conducted at Riverbank Acoustical Laboratories showed that partitions with 2.5 lb/cu.ft. THERMAFIBER SAFB’s can provide STC ratings up to 4 points higher than those in which low−density glass fiber 1/2 to 1 in. thicker is used. The acoustical benefits of cavity insulation as well as the effects of insulation density vary with frequency, the basic partition design and the insulation thickness. The effect of insulation density on acoustical performance must be determined for each partition design.

Partitions For Sound Isolation

Three primary sound source types typically occur in buildings:

(1) speech or speechlike, (2) music, and (3) machinery or mechanical equipment. With any of these sound sources, the degree of privacy that will be achieved with a given partition can be evaluated simply. One adds the sound pressure level of the background noise in the space subject to intrusive sound and the sound attenuation provided by the separating structure and then compares this sum to the sound pressure level of the source. This technique is used in the following sections to show the importance of insulation density when isolating speech and then music. To simplify the discussion below, it is assumed that no flanking paths are involved and that the laboratory sound transmission loss is the sound attenuation that is actually achieved.

Density And Isolating Speech

The critical frequencies requiring isolation when speech is the sound source are from 250 Hz (approximately middle "C") through 4,000 Hz (see Fig. 1 on next page). The dot field in Fig. 1 is a graphic representation of male speech (raised voice level in a 100−sq.ft. enclosed office—approx. 68 dB). The dot field is used for graphic calculation of intelligibility by the Articulation Index (Al) method. Speech at any given loudness level falls in a 30 dB loudness envelope (vertical scale) since different words and letters are produced with different energy levels. The number of dots on each vertical line gives a pictorial view of the relative contribution of that 1/3−octave band on speech intelligibility. The most energy (loudest) is in the 250 to 1,000 Hz frequency range. Note, however, the denseness of the dot array above 1,000 Hz. These are the frequencies that give clarity to speech, so hearing only a small portion of the speech energy in these frequencies can result in loss of speech privacy. Drywall partitions, especially single−layer systems, tend to be weak sound isolators in the 2,000 to 4,000 Hz frequency range, due to the thickness of the gypsum board and its natural physical characteristics. This weakness zone can be seen in Fig. 1. The A and B curves are the sum of the RC−20 noise level assumed for this example and the sound transmission loss of two different partition designs employed here. The A curve is for a partition consisting of 3585T studs 24 in. o.c. with a single layer of 5/8−in. SHEETROCK® Brand FIRECODE "C" Gypsum Panels on each side. The B curve partition is the same except 3−in., 2.5 lb/cu.ft. THERMAFIBER SAFB’s have been added to the cavity. The measure of intelligibility (Al) of the partition without the SAFB’s can be determined simply by counting the dots above the A curve. There are about 48 dots above this curve which translates to approximately 70% sentence intelligibility for these conditions. There are about 15 dots above the B curve which translates to approximately 10% sentence intelligibility. In order for the speech to be totally inaudible, the A or B curve would have to be 5 to 10 dB above all the dots.

Adding THERMAFIBER SAFB’s improves performance about 8 dB across the frequency spectrum for this particular design. The improvement with other designs can be more or less. The graph illustrates the need to maximize partition performance in the 250−4,000 Hz frequencies when isolating speech.

Table 1 shows the improvement in performance attributable to the density of the cavity insulation. THERMAFIBER SAFB’s consistently provide higher sound isolation than low−density glass fiber over the entire 250−4,000 Hz frequency range, with 3 to 5 dB improvement in the critical 2,000 Hz octave being fairly typical.

A 3 to 5 dB improvement appears to be small until it is compared with the improvements that typically can be achieved in the 500 to 2,500 Hz range by other methods. For example, air space depth and cavity insulation thickness must be doubled or the number of layers of gypsum board increased by 50% to achieve 2 to 6 dB improvements in the 500 to 2,500 Hz frequency range. It should be noted, however, that increasing cavity depth, insulation thickness and the number of gypsum board layers can provide much greater improvement than this below 250 Hz so these techniques play a critical role in the design of high−performance partitions. One of the advantages of the improvement due to insulation density is that it is additive to the improvements that can be achieved with other methods.

Density And Isolating Music

Music contains substantial energy in the whole audible frequency range and is generally much louder than speech. The top curve in Fig. 1 is a typical design spectrum for 90 dB orchestra music. Most people would judge this as "loud" orchestra music.

The graph shows that the privacy achieved with a single layer partition with THERMAFIBER SAFB’s (B curve) need not be increased very much in the 500 to 1,000 Hz frequencies to start isolating the music source, but it must be improved significantly above 1,000 Hz and below 250 Hz. The greatest needs are in the 63 Hz and 2,000 Hz octave bands. Creating the equivalent of two separate walls, and increasing the number of layers of gypsum board, the cavity depth and the insulation thickness are some techniques that can be used to improve acoustic performance. However, above 1,000 Hz, a performance plateau is quickly reached that is difficult to exceed with simple techniques. This is where the density of the insulation is one of the keys to success in isolating music with gypsum partitions. One partition tested at Riverbank Acoustical Laboratories consisted of 60SJ20 USG Studs, two layers of 5/8−in. SHEETROCK® Brand FIRECODE "C" Gypsum Panels on one side, RC−1 Resilient Channels and 2 layers of the same type panels on the other side and 5−in. SAFB’s in the cavity. This high−performance system provided 2 dB more isolation in the 250 and 500 Hz octaves and almost 6dB more isolation above 1,600 Hz than when 6−in, low−density glass fiber was used. The optimum density for cavity insulation in the 31 to 125 Hz frequencies appears to be in the 0.7 to 3.0 lb/cu.ft. range. Within this frequency zone, insulation at 0.7 lb/cu.ft. may sometimes be 1 or 2 dB better in certain 1/3 octaves while a 3 lb/cu.ft. insulation may be 1 or 2 dB better at other 1/3 octaves. This varies with insulation thickness and the partition design.

Comparative listening tests on the receiving side of test partitions emphasized the importance of isolating the upper frequencies when the source is music, If high−frequency isolation is substantially out of balance with mid−frequency isolation, the mid−frequency harmonics can be heard, along with the high−frequency fundamentals, as an unnatural (telephone quality), highly intelligible sound. However, if the partition can attenuate the sound so that the intrusive music sounds natural and unfiltered (similar to a stereo played at low volume), the intrusion is not nearly as objectionable. This result can be created by a partition with a sound transmission loss curve that, starting at about 31 Hz, rises at a nominal rate of about 12 dB per octave to 400 or 500 Hz, gradually flattens out in the next octave and then remains relatively flat above 1,000 Hz. Except for special facilities such as recording studios and music buildings, it is seldom economically feasible to totally isolate loud music, especially when the background noise level is very low in the adjacent spaces. Therefore, a partition with these general characteristics is the best choice when isolating music. Insulation density is an important resource to use in achieving this goal.

The sound isolation of unamplified speech is discussed in the previous section. However, the isolation requirements for amplified speech can approach those of music. The low−frequency component of speech can be boosted significantly through amplification. This low−frequency component does not contribute to speech intelligibility, but it can be heard through a partition that provides little isolation in the low frequencies. A partition designed to isolate music is also an excellent design for isolating amplified speech.

Density And Electrical Outlets

Another sound−isolation problem is the transmission of sound through electrical outlets on opposite sides of a partition. High−frequency sound is easily transmitted through small openings in the outlet boxes themselves or in joints between the boxes and the gypsum board. The joint between the outlet boxes and the gypsum board should always be sealed with an appropriate caulking material, such as USG Acoustical Sealant. In high−performance sound−isolating partitions, it is usually necessary to seal the back of outlet boxes as well. It takes vigilant inspection during partition construction to assure that the back sides of all outlet boxes are well sealed, and it is difficult to verify or correct after the partition is built.

The problem created by inadequate sealing can be minimized by offsetting the outlets and using the cavity insulation as a sound attenuation medium. (Underwriters’ Laboratories, Inc. requires a minimum 24−in, offset to maintain the fire rating.) The greater the offset, the farther sound must travel through the cavity insulation in order for it to be transmitted through inadequately sealed outlet boxes.

Fig. 2 shows that sound transmission loss through a porous material increases significantly as density increases. Low−density glass fiber must be nearly twice as thick as the standard THERMAFIBER SAFB’s to provide the same attenuation (curves C and D, Fig. 2). The way to handle the acoustics of outlets should always be decided by the project acoustician since so many variables are involved.

Summary

Drywall partition systems with cavity insulation in the 2.5 to 4.0 lb/cu.ft. density range consistently outperform those with lower density glass−fiber insulation. The 2.5 lb/cu.ft. insulation provides better results when isolating either speech or music and provides a distinct advantage in minimizing the negative effects of the sound leaks associated with electrical outlets.

If THERMAFIBER SAFB’s (standard 2.5 lb/cu.ft. density) are substituted in a partition tested with the commonly−used 0.7 to 0.8 lb/cu.ft. glass−fiber insulation, the sound transmission loss will always be superior or at least equal to the tested partition. The THERMAFIBER SAFB’s have the added advantage of a higher melt−point than glass fiber, so they offer superior fire endurance. Consequently, it cannot be assumed that low−density glass fiber can be substituted for THERMAFIBER SAFB’s in a rated partition without significantly reducing the acoustic or fire performance.