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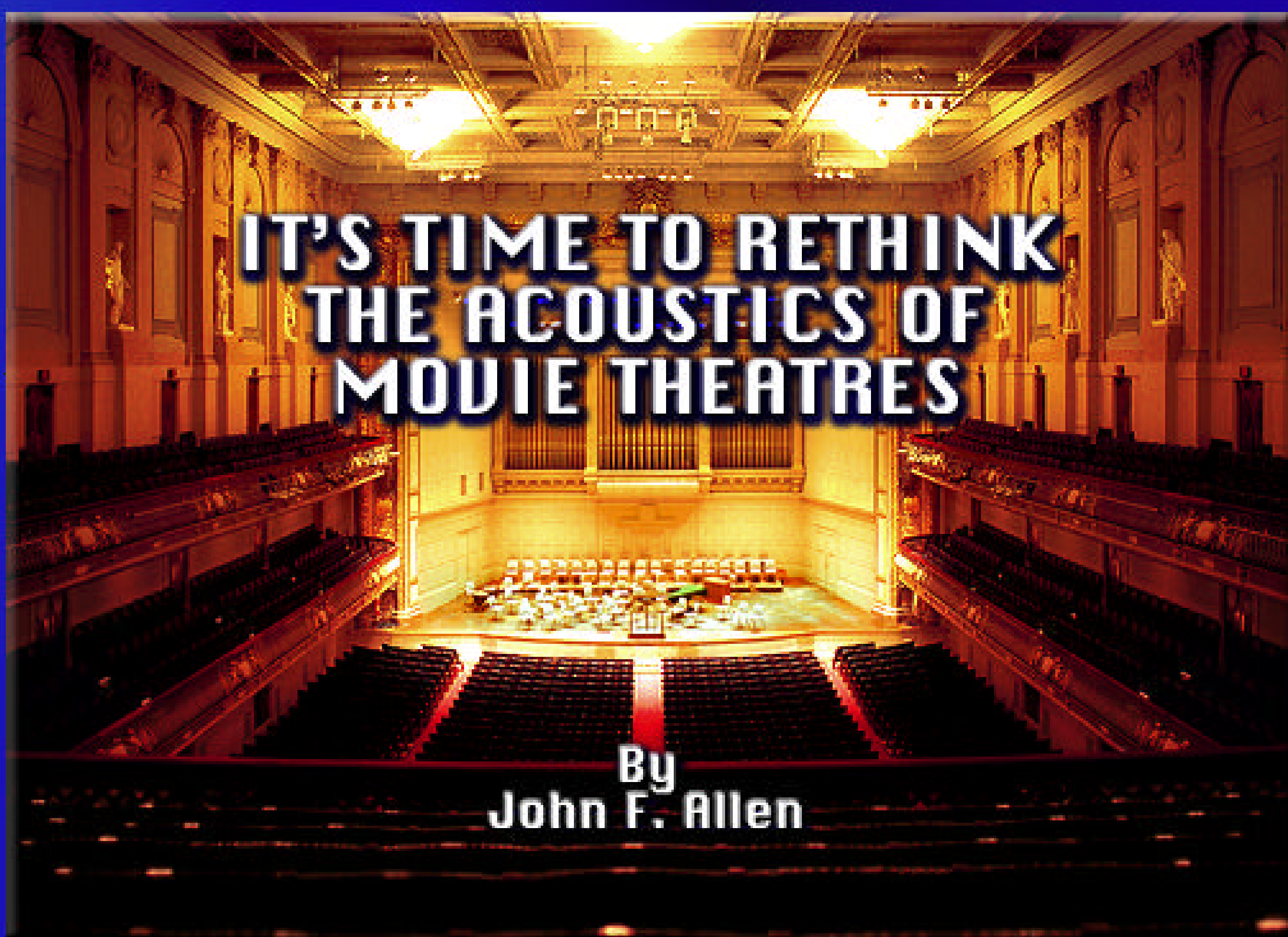

IT'S TIME TO RETHINK THE ACOUSTICS OF MOVIE THEATRES

By
John F. Allen

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IT'S TIME TO RETHINK THE ACOUSTICS OF MOVIE THEATRES

BY
JOHN F. ALLEN

What defines good acoustics? Who invented the concept? Are the acoustics of modern motion picture theatres as good as they could be? In this special article prepared exclusively for BOXOFFICE, contributing writer John F. Allen doesn't think so. He goes on to explain why and suggests ways to make improvements.

In the past two decades, several aspects that contribute to the acoustics of motion picture theatres have been modernized. For one thing, the amount of sound absorbing materials installed in new movie theatres has increased significantly. Other acoustic changes we have seen include reduced noise levels from air handling systems and increased isolation from adjacent auditoriums. Most of these needed changes have been welcome and have improved the moviegoing experience. However, in my opinion, the use of sound absorbing materials has gone too far and needs to be reexamined. To understand why, we need to go back a few hundred years and take a quick look at how the enjoyment of music and sound in rooms has evolved.

Composers have had a major influence on what has become known to us as good acoustic environments. Consider Bach and Beethoven. Bach wrote music to be performed in churches. Some of these rooms tended to have fairly short reverberation times, perhaps 1.5 seconds. His organ music was intended for a room with a reverberation time in excess of 2 seconds. Even though the term reverberation time had not been defined as it is today, Bach understood the nature of the acoustics in the places his music would be performed and wrote to take full advantage of what he had.

The same is true of Beethoven. By the time he began writing symphonies, concert halls and opera houses had evolved to a remarkable degree. As still happens today, rooms would be selected for musical performances for the simple reason that music sounded good when played in these spaces. The science of why these rooms sounded good would not be invented for over hundred years. But musicians, composers and listeners at least could tell what they liked.

When Beethoven wrote his third symphony, everything changed. Not only was this symphony twice as long as any other, the scope of the composition was unprecedented. Indeed, nothing has been the same since. In addition to the demands his Eroica Symphony placed on the musicians as well as listeners, this work plus those that followed helped define and shape the concert halls that followed. Today, many of these halls are considered the best in the world.

The First Acousticians

Until the end of the 19th century, musicians served in the roll of acoustical consultants. By both performing or listening to music in various places, they developed an understanding of what enhanced the sound of the music and what didn't. They would then work the details considered important into the designs of new halls and opera houses. In fact, as one studies the best concert halls built during this period, one immediately sees they are all shaped like shoeboxes, just as most movie theatres are today.

There is perhaps no better example of a musician/acoustician than Richard Wagner. In 1876, he had the luxury of designing and building his own opera house, the Festspielhaus in Bayreuth, Germany, for the sole purpose of performing his own works, particularly the Ring Cycle and Parsifal.

Dr. Leo L. Beranek, today's preeminent acoustician and prolific author, has detailed in his many lectures and books on concert halls how the science of acoustics began here in Boston in the last years of the 19th century when the Boston Symphony Orchestra needed to build a new concert hall. At the time, Major Henry Lee Higginson owned the orchestra that he had founded following the Civil War. He hired McKim, Mead and White, the country's leading architectural firm of the day, to design his new hall. He had two directives; that the room sound as good as the best European halls and that it seat 2600 people.

The first design submitted was a wedged shaped room modeled after a Greek amphitheater. Because no concert hall in the world had ever been built this way, Higginson sought opinions from several people he knew in Europe, including conductors.

When they all said not to build such a hall, he asked them what hall they liked the best. Several people suggested that the Gewandhaus in Leipzig, Germany had great sound and that Boston's new hall should be modeled after that one. The Gewandhaus (later destroyed in World War Two) sat about 1560. In order to accommodate 2600, it was thought that all that was needed would be to multiply the dimensions of the German hall by a factor of 1.3. Higginson was still not convinced and as it was his money on the line, not to mention the survival of his orchestra, he began to look for help.

By a lucky coincidence, nearby Harvard University had built a lecture hall that had such bad acoustics that it was unusable. By chance, a young assistant physics professor by the name of Wallace C. Sabine was willing to take on the assignment of fixing the room so that lecturers could be understood when they spoke. Sabine devised a way of measuring reverberation time by playing an organ pipe in the room and measuring how long it took the reverberation to die out after he stopped. He then enlisted the help of a paid assistant to borrow the heavily padded seat cushions from Harvard's Sanders Theatre and trot them across Harvard Yard to this lecture hall.

During the night he would conduct his experiments. With his organ pipe and a stopwatch, he noted how much the addition of various numbers of cushions to the room would reduce the reverberation time in the troubled lecture hall. Then, before morning classes began, the seat cushions would be returned to Sanders Theatre. This went on for several years and became something of a joke around the campus with these seat cushions being marched back and forth from building to building night after night. But in the end, Sabine had found the first mathematical formula for predicting reverberation time based on the volume of a room and the amount of acoustical absorption within the room. Reverberation time was defined as the length of time it takes a sound level to drop 60 decibels once the source is turned off.

The Dawn of Modern Acoustic Science

In conversations with Higginson, Harvard's president learned of Higginson's concern about the proposed design for his new concert hall. He told Higginson of Sabine's experiments and suggested that Sabine might be able to offer some advice. Indeed, this set in motion a series of events that resulted in what many, including myself, regard as the finest concert hall in the world, Boston Symphony Hall -- the first hall designed with the use of a scientific formula for reverberation time. For starters, Sabine used his new formula and found that a hall designed simply by multiplying the Gewandhaus' dimensions by 1.3 would result in a reverberation time of around 3 seconds -- way too much for orchestral music. That put an end to the second design for Higginson's new hall. Still there was the absolute requirement that the new hall have 2600 seats.

Sabine pointed out that the old Boston Music Hall, the Boston Symphony's original home, sounded wonderful. This was a European style shoebox shaped hall of some 2200 seats and an open stage at one end of the main floor for the orchestra. He suggested a new hall design that would essentially duplicate the footprint of the Music Hall but with a new stage house extension. This would free up enough floor area to bring the seat count up to 2625. Sabine then used his new formula to calculate the volume of the hall required for the desired reverberation time. It was then simply a matter setting the ceiling height to create the needed volume.

It is a testament to Sabine's genius that he was able to design a stage house that would work so well. But in retrospect, we now understand the workings of concert halls well enough to realize that he made many extremely critical choices and somehow managed to get them right, even though he had never designed a concert hall before.

Charles McKim, still the architect of record, wrote a letter to Higginson disavowing any responsibility for the acoustics of Symphony Hall. McKim's papers make no mention of this commission even though it is at least as famous as some of his other buildings, such as the Boston Public Library. It appears that with the birth of acoustical science also began the often difficult relationship between architects and acousticians -- something we still see today.

A lifetime of interest and intense research done by Leo Beranek has given the world of architecture, music and the science of acoustics tremendous insights into the different qualities of not only concert halls, but auditoriums of all kinds, and how these qualities contribute to their success or failure. Beranek has studied and reported on halls all over the world. His latest book, CONCERT HALLS and OPERA HOUSES, 2nd Edition, lists the top 100 concert halls and ranks them according to their reputation for good acoustics. Through interviews with conductors and others, we learn why these halls are regarded as well -- or not so well -- as they are. He also gives their technical specifications and then compiles this information into a set of comparative specifications that the top halls have in common.

So how does a good concert hall like Boston Symphony Hall work? Referring to the pictures of the hall in Figures 1 and 2, let's assume a listener is seated in my seat, left of center in the 14th row. When the orchestra plays, the first thing the listener will hear is the direct sound. This is the sound as it travels straight from the musician(s) to the listener's ears -- without reflections. The next thing the listener will hear is nothing -- at least for a short period of time. This time period has been defined by Beranek as the

Figure 1. Boston Symphony Hall

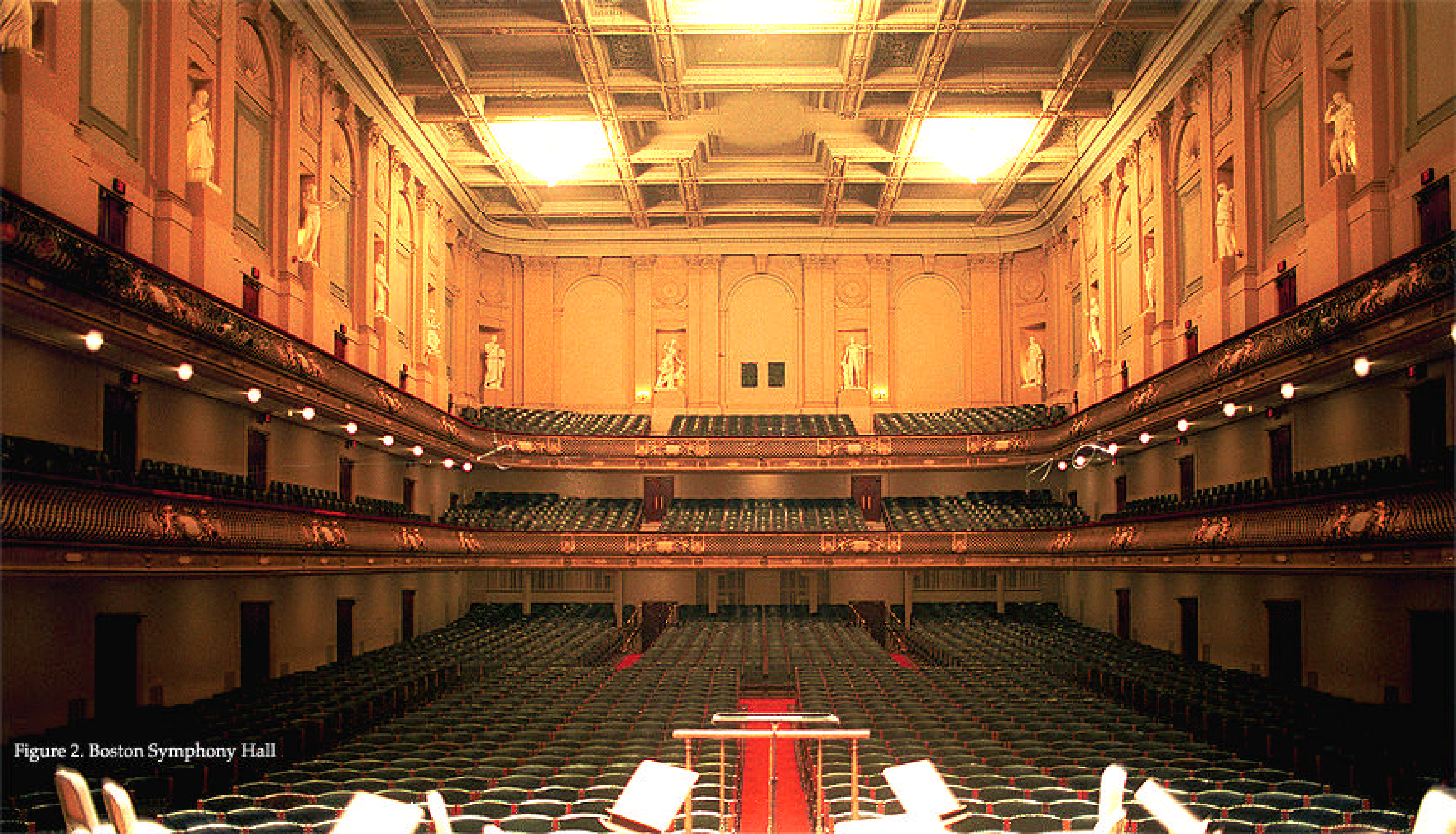

Figure 2. Boston Symphony Hall

Initial-Time-Delay Gap. Then the listener hears the arrival of the first significant reflection. In Symphony Hall, this will be a reflection off the front of the first balcony. The length of the initial time delay gap is critical to the clarity of the music. If it's too short, the music will not sound clear. If it's too long, the reflection will begin to sound like an echo and intimacy will be reduced. The first reflection is, of course, followed by many others, also from the boundaries at the sides of the room and ultimately from the ceiling. An important attribute of the lateral reflections from the sides is that they arrive at our two ears not only from different directions, but at different times. Lateral reflections are critical for the sense of spaciousness and envelopment.

As time progresses, the listener will hear the reverberation of the music as it travels and decays throughout the room while blending with the orchestra. In a very real sense the hall is an instrument of the orchestra *and* the composer. In the best halls, this reverberation time in the middle frequencies with an audience present is about 1.6 to 2 seconds. Symphony Hall is 75 feet wide, with an initial-time-delay gap of 15 milliseconds and a volume of 662,000 cubic feet (18,750 cubic meters). It has a reverberation time of about 1.9 seconds in the mid frequencies and somewhat longer in the low frequencies as is typical of the better halls. Since its opening in 1900, the acoustics of the hall have not been changed.

Two of the important acoustical attributes for a good hall are hard surfaces and lots of irregularities. The principal sound absorber will be the audience. But when the sound from the stage strikes the walls of the room, over and over again, it is important to disperse the sound rather than reflect it to a specific area. The walls of Symphony Hall are mostly 3/4 inch plaster. These hard, parallel and irregular surfaces -- including the statues -- are critical for good dispersion as well as good bass. Perhaps it would be more accurate to say good preservation of the bass. The bass is produced by the instruments on the stage and enhanced by the acoustics of the stage house as well as the vibrations of the stage floor. It is the properties of the hard surfaces in the hall that, among other things, help the bass to be delivered to the entire audience. If there is a 2600 seat concert hall in this world with better bass than Boston Symphony Hall, I have yet to hear it.

Movie Theatres

What has any of this got to do with movie theatres? A lot, actually. In order to fully appreciate the acoustic potential of a movie theatre, it helps to have a basic understanding of the acoustic properties that audiences seem to like and that ultimately allow good concert halls to last, while bad ones are torn down or abandoned. In fact, as we move into the 20th century, we begin to see the introduction of movie theatres -- movie palaces to be more specific. These auditoriums were built for essentially two conflicting purposes,

music and, after a time, speech. If music sounds best when played in an environment with a relatively long reverberation time, speech is the most intelligible when there is no reverberation at all. Fortunately, we don't require anechoic conditions to hear and understand spoken words. In fact, we can understand speech with reverberation times as long as 1 second or more, assuming there are no other problems such as lots of discrete echoes.

The movie palaces were designed to have reverberation times of about 3/4ths of a second. Like opera houses that also have reverberation times that are less than concert halls, these shorter times allow for intelligible speech while still providing a relatively nice space for listening to music. From an acoustic point of view, some of these theatres are quite remarkable. See Figures 3 and 4. However, with reverberation times as high as one second or more, some of them are not really optimum for speech.

In the past twenty years, reverberation times in many new movie theatres have been in the range of 1/4 second or less -- sometimes much less. This has been accomplished by a combination of smaller room volumes and the number of acoustic panels employed as well as their placement. In recognition of his seminal work, the unit of acoustic absorption was named after Wallace Sabine. Covering all the walls and ceiling with sound absorbing materials, and thus lots of sabines, will accomplish the goal of a short reverberation time. However, the large areas of soft surfaces, including padded chairs with or without seated patrons, will also have a negative effect on the quality of the music (and sound effects), heard in the room. This is especially true of the bass. This is true even though artificial reverberation is added to the music recordings. If you imagine the extreme example of listening to recorded music outdoors, you understand what I mean. It sounds dead.

It should be also understood that such low reverberation times in movie theatres were driven in part by sound system designers that were promoting the use of horns behind the screen with constant coverage angles for all the frequencies they deliver. Working the formulas, as well as practical experience, showed that speech intelligibility with these horns was improved when reverberation times were kept short.

As I have described in previous articles, constant directivity horns were not designed to go behind movie screens. They were intended for large arrays of multiple horns as used in stadiums and other large venues. Movie screens actually render the coverage angles of these horns anything but constant. When used behind a screen, the coverage angles of the highest frequencies are considerably widened in all directions, spraying higher frequency sounds all over the floor, walls and ceiling. Therefore it is quite understandable that we

Figure 3. Classic Cinemas' Tivoli Theatre in Downers Grove, Illinois

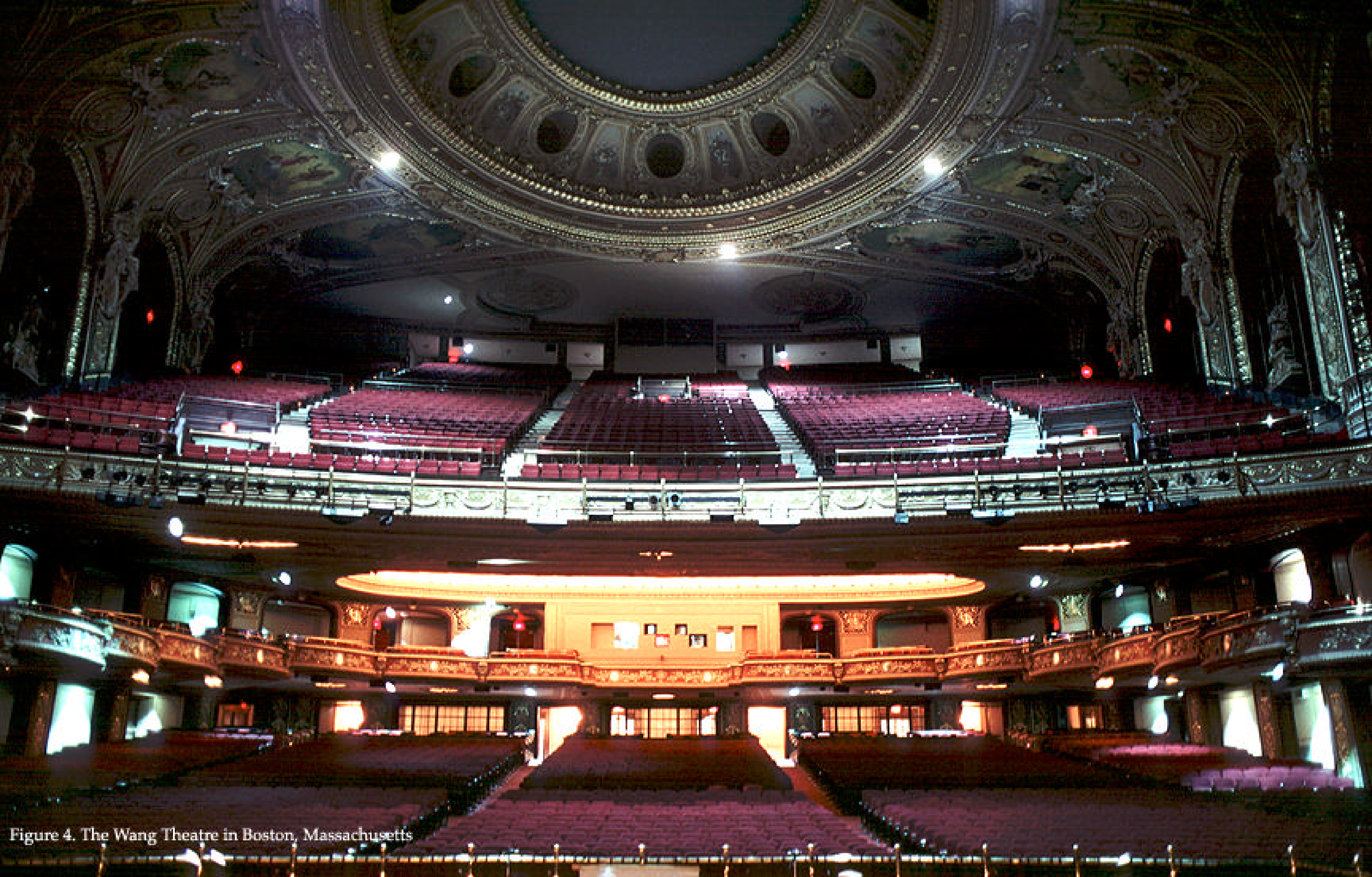

Figure 4. The Wang Theatre in Boston, Massachusetts

would see recommendations for full coverage of the side walls when it comes to sound absorbing panels in modern motion picture theatres. But is this really the best way to design a movie theatre?

Rethinking the Acoustics of Movie Theatres

Recalling the importance of the early lateral reflections in a concert hall, the question becomes whether movie theatre acoustics could be enhanced by better optimizing the balance between allowing some lateral reflections and the need for dialogue intelligibility? I believe that the answer is yes. I have, in fact, been recommending minimal acoustic treatment on the side walls of most of the theatres I have done for the past 24 years. When using loudspeakers that are actually designed for placement behind movie screens, and therefore do not spray excessive unwanted sound all over the place, I have consistently found that the minimal side wall treatment such screen speakers allow, results in a warmer more spacious sound, with much better bass.

We still need sound absorption and quite a lot of it. However, it needs to be more strategically concentrated on the ceiling as well as the wall behind the audience, as that wall is where the screen speakers are aimed and we don't want echoes. We want the ceiling to be absorptive because ceilings in movie theatre are much lower than they are in concert halls. The reflections from the screen speakers are, therefore, very early and potentially quite strong. In addition, any reflections from above are by definition not lateral in nature. If they arrive at both our ears at the same time, they are essentially monophonic. We don't have ears on the tops of our heads, so this is the last thing we need as it reduces the stereo effect. So, in addition to the rear wall, the other important place to concentrate sound absorption in movie theatres is the ceiling.

The side walls generally need little more than the equivalent of a simple layer of pleated fabric with nothing behind it but the hard surface of the wall. The walls themselves should consist of at least one inch of plaster or sheetrock. Obviously, concrete would also serve quite well. There are exceptions to this approach, such as in very narrow theatres. Allowing some lateral reflections becomes deleterious in theatres that are less than about 35 to 40 feet wide. This is because reflections from the side walls in such narrow spaces will be too early and too loud. This will have a negative impact on dialogue intelligibility. Therefore, the side walls of narrow theatres should be treated with 3/4 to 1 inch of sound absorbing material. In addition, theatres above around 60 feet in width, are best treated with heavier materials on the side walls. This is helpful in preventing the reverberation time from becoming excessive. In all cases, the ceilings and rear walls of movie theatres should be absorptive, or "fuzzy" as some like to say.

Figure 5. AMC's Framingham 16 Theatre #6 in Framingham, Massachusetts

Figure 6. Consolidated's Kahala 8 Theatre #1 in Honolulu, Hawaii

Figure 5 shows a 50 feet wide by 90 feet long auditorium with acoustics designed to not only allow for optimized lateral reflections, but increased dispersion from the side walls as well. This 1994 design has been a complete success in all the auditoriums in the complex and cost about 1/3rd *less* than standard acoustic treatments as applied to modern movie theatres. Music sounds warm and spectacular in this room. The bass is incredible, not to mention far more natural than one experiences in dry dead theatres. The careful control of the loudspeaker's coverage patterns through a perforated screen allows all this while maintaining excellent dialogue intelligibility. The sound can just about lift you out of your seat. Indeed, the exceptional quality of the sound in these theatres propelled the complex to the front page of the Boston Sunday Globe in an extensive story about the sound of movies.

Figure 6 shows another example. The walls of this theatre are 18 inch thick solid concrete, finished with epoxy paint. With the exception of the absorptive horizontal bands midway up to hide the lighting fixtures, there is no other acoustic treatment on the side walls of this auditorium, and none at ear level. The rear wall is padded with three inches of sound absorbing material behind a pleated fabric. The ceiling is acoustically absorptive as well. The room is 54 feet 6 inches wide and about 65 feet long. If I had to select one movie theatre I have done as having the best acoustics, this would probably be it. For my ears, this room achieves a perfect balance between the needs for full dialogue intelligibility with appropriate use of lateral reflections and an optimum amount of reverberation. Standing in the middle of this theatre and clapping one's hands produces slap echoes from the side walls, as one can imagine. However, it is important to understand that this is not a bad thing in a room this wide, as there is no sound source between these walls when a film is playing.

The science of auditorium acoustics remains imprecise. It is not a science that determines what people will like and what sounds good. Rather it is the study to *discover* what people like, to learn and understand the traits that contribute to what we like as well as how to achieve a desirable balance of these things in a given space.

Anyone who puts towels in an empty bathroom immediately notices that they have reduced or eliminated the sound reflections in the room. Blanketing an entire movie theatre with "towels" or sound absorbing materials will do the same thing, but goes too far when we want to provide the most in entertainment and audience satisfaction. Moviegoers are not deaf. Composers, musicians, concert lovers and film makers all take their sound very seriously. Designers of auditoriums of any size, for any purpose, but most especially movie theatres, should do so as well.

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John F. Allen is the founder and president of High Performance Stereo in Newton, Mass. In addition, he serves as the sound director of the Boston Ballet. He is also the inventor of the HPS-4000® motion picture sound system and in 1984 was the first to bring digital sound to the cinema. John Allen can be reached by E-mail at johnfallen@hps4000.com. Mr. Allen's 24 year series of articles written for BOXOFFICE are available for download at http://www.hps4000.com.

For further reading, Leo Beranek's latest book, **CONCERT HALLS and OPERA HOUSES, 2nd Edition,** ***is published by Springer, ISBN 0-387-95524-0. It can be ordered directly from the publisher at www.springer-ny.com.***

An Enlightened Approach to Better Sound

Discussions about the issue of acoustics in movie theatres over the past few years have often focused on whether the room should have some reverberation, or if it should be dry and depend solely on the reverberation artificially contained within the soundtracks. It is said by some that mixers can only know how their films will sound if they control the reverberation.

Personally, I agree with the late John A. Bonner of Warner Hollywood Studios who used to say that "nothing sounds right in a dead room." Beyond that, I think suggestions about hearing "what the producer heard," are full of wishful thinking. The idea that we should all hear a film EXACTLY as the producer heard it in the rerecording stage is not only unrealistic, but may not even be such a great idea. After all, the only way audiences will hear exactly what the creators of a film heard is to listen to it in the same room that the soundtrack was made -- not very likely. No two rooms will sound the same. Some will be better than others for any number of reasons, starting simply with the size of the room.

Are we to build only 200 seat theatres? To restrict audiences to hearing exactly what the mixers heard also rejects any possibility that, in the right theatres, audiences might even hear it better than the producer did. No producer or director I have spoken to has ever objected to superior presentations. Why would they? No one seems to oppose screens larger than the one the producer used. Are exhibitors to be restrained from using better lenses or upgrading their equipment if it should be superior to that found in a particular studio?

Auditorium acoustics is an applied art. I have not specified an "ideal" or "perfect" reverberation time for movie theatres because the recommended values are well known and because I believe that there should be room for creativity and growth. While there are those who will argue that acoustically dead rooms are best for motion picture sound, I have advocated that, while not rising to the levels impairing dialogue intelligibility, there be enough reverberation for the room to respond to the sound of the films and not to seem to fight it by absorbing it all. I have also recommended that lateral reflections be judiciously allowed as this will improve the listening experience.

The application of standards and practices to the presentation of motion pictures is necessary for many of the technical aspects to work. However, when it comes to the

designs, architecture and acoustics of the theatres themselves, a certain amout of latitude and even experimentation needs to be allowed. To prevent this is a form of artistic censorship and effectively freezes the state of the art in place, when the place it is in could be a lot better.