Science and Art Converge in Concert Hall Acoustics

by Jennifer Ouellette

The 19th century saw the full flowering of large public performance halls for orchestral concerts, some of which still stand as exemplary models of acoustical design. However, many modern halls for musical performance have failed to achieve the same sound quality as those earlier structures. Today, acoustical consultants and researchers specializing in concert hall design are relearning the lessons of the past and combining them with innovative modern features, inspired by the latest discoveries in psychoacoustical research that are achieving a delicate balance between science and art.

Sophisticated new architectural and electro-acoustical features compete to maximize the listener's experience

Most acoustical consultants, engineers, and architects consider performing arts centers among the most complicated structures one can build, according to Ashley Goodall, a consultant with Artec, an acoustical and theater design firm based in New York City. Acoustical consulting for concert halls is an increasingly select field, with only a handful of firms worldwide competing for the major projects. These include, to name a few, Artec, Jaffe Holden Scarbrough (JHS) Acoustics, Inc. (Norwalk, CT), Kierkegaard and Associates (Downers Grove, IL), George Izenour Associates (Stony Creek, CT), and Arup Acoustics, a division of the European-based Arup Engineering (London).

The design process is further complicated by the fact that single-purpose concert halls are increasingly rare, and different types of performances have different acoustical requirements. "In these times of economic inflation-induced building costs and consequent escalating operational and maintenance costs, the overspecialized, single-purpose facility is becoming ever more economically unrealistic," said George Izenour, who heads Izenour Associates. Hence, designers have responded to the need for flexibility by developing adjustable features to rapidly convert a single structure into a space that has a sufficiently wide range of acoustical environments.

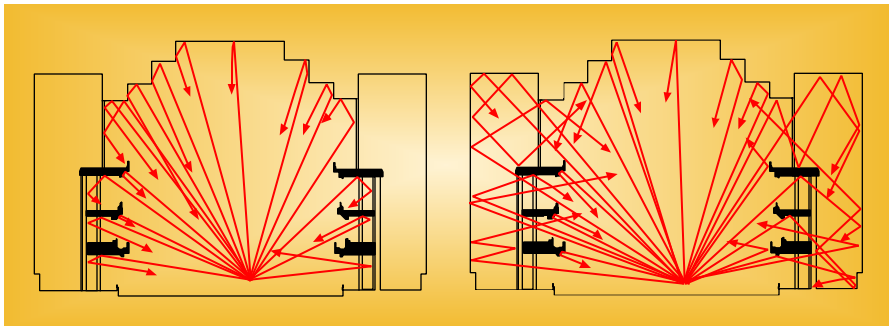

Figure 1. Reverberation chambers up to one third the size of the main hall, may be closed (left) or opened (right) through a series of pneumatically controlled concrete doors.

Reflections

According to John Bradley of the Institute for Research in Construction at the National Research Council (NRC) in Ottawa, Ontario, Canada, studies in the 1950s and 1970s demonstrated that early-arriving reflections from the sound source were highly significant for sound quality, especially "lateral" reflections arriving from the sides of the listener. These early lateral reflections, along with the right balance of late-arriving reflections (reverberance), create a sense of being enveloped within the sound. In the 1990s, beginning with studies by researchers at Kobe University in Japan, it was discovered that lateral reflections arriving a little bit later could be more important than early reflections from overhead for determining spatial impression in concert halls. Furthermore, recent tests by Bradley and his colleagues demonstrated that the perception of listener envelopment increased as more energy was contained in late-arriving reflections.

The direction and time of arrival of specific reflections are traditionally determined by the geometry and architectural features of the room. Most early concert halls, including the first"scientifically" designed Boston Symphony Hall built in 1900, tended to be narrow and rectangular shaped, much like a shoebox, which naturally generates strong early lateral reflections with optimal late-arriving acoustical energy. Bradley explained that more modern designs, typically large-capacity, fan-shaped halls, which often have large overhead reflecting surfaces to boost early-arriving reflections, may not produce as good a sound, because the late-arriving reflections are too weak to provide an adequate sense of listener envelopment.

Artec has embraced the traditional shoebox shape as the cornerstone for its acoustical designs and refined it with sophisticated new features. "If you look at the chain of evolution of the rooms this firm has designed, you can see it as a rediscovery of this form, along with a critical augmentation that responds to the needs of music at the end of this century," said Goodall. "We take the basic shoebox form and add to it certain adjustable acoustical features, so that you actually have

Figure 2. Symphony Hall Birmingham, U.K., which has a reverberation chamber and large adjustable-height canopy, is recognized as having world class acoustics.

a room that is itself, in a dynamic way, part of the musical performance."

Christopher Jaffe, founder and president of JHS, adheres to a somewhat different philosophical approach. He believes that the latest psychoacoustical research undertaken by Bradley and others in the field has provided sufficient understanding of the patterns of reflected sound to enable designers to reproduce those patterns using modern, innovative electroacoustical features, regardless of the shape of the room. "If the process is related to the relationship between the direct sound and the reflected sound, then the ability to design a good concert hall would depend on those relationships, and not on the geometry of the room itself," said Jaffe. "Reflections are the key to developing the sound quality we are familiar with. If we can simulate those same patterns of reflections and relations, we would have the traditional sound."

Innovations

One recent innovation is Artec's use of large reverberance chambers—large empty spaces enveloping and coupled to the main hall (Figure 1). In the case of the Symphony Hall in Birmingham, England (Figure 2), completed in 1991 and already recognized by classical performers as having world-class acoustics, this chamber constitutes one-third the cubic volume of the hall's main body. Such a chamber is linked to the hall through a series of pneumatically controlled concrete doors, which can be opened or closed in a variety of combinations to control the amount of sound energy entering and leaving the chamber. Along with large, adjustable-height canopies, this essentially creates a two-volume hall: an inner volume to enhance clarity (early reflections) and an outer volume to enhance reverberance (late reflections). The chamber doors enable optimization of these two qualities for different types of music, so that the audience can hear clarity and reverberances simultaneously.

The balance achieved between these early- and late-arriving reflections is the key. "In order to create great clarity in the acoustics, you have to make sure that enough energy arrives at people's ears within the first 80 milliseconds or so," said Goodall. "In order to create a feeling of reverberance or acoustical spaciousness, you have to make sure that sufficient energy is arriving after 80 milliseconds." A reverberance chamber was incorporated into the design for the Meyerson Symphony Center in Dallas, Texas (Figure 3), which opened in 1989 and was followed shortly thereafter by the Birmingham Symphony Hall.

While the concept worked well, Artec's design team decided that the location for reverberance chambers should be nearer to the audience's ears so that late-arriving reflections would reach more listeners from the side,

Figure 3. McDermott Hall, Morton H. Meyerson Symphony Center, Dallas, Texas, opened in 1989, incorporated a reverberance chamber.

thereby creating a stronger sense of envelopment.

Thus, the reverberance chamber designed for the Cultural and Congress Centre in Lucerne, Switzerland (which will open next year) extends down the side of the room to a level slightly above those seated in the first balcony. For the concert hall in the Singapore Arts Center scheduled for completion in 2002, the chamber extends further down to the first balcony. And for the Metro-Dade Performing Arts Center in Miami, Florida (Figure 4), Artec has designed a reverberance chamber that extends all the way down to the floor, so that even those audience members seated on the main floor will receive some sound energy from the side. To enable the audience to enter and exit the hall, it was necessary to design bridges through the reverberance chambers for access to audience seating.

Another innovation for achieving flexibility in multi-use halls is Jaffe's incorporation of a "concert hall shaper," which is a unique orchestra shell or "false ceiling" that creates a single-room concert hall by cutting off the upper reaches of the traditional opera scenery stagehouse. Within the shaper itself, other reflector panels are hung from winches to create the more familiar acoustical shell, providing the added "liveness" required for symphonic performance. "Essentially, you create this chamber around the orchestra to compensate for the fact that you are not in a single room," said Jaffe. His firm used this approach for the first time in their design of the Tokyo International Forum, which opened last year, and later in the Bass Performance Hall in Fort Worth, Texas (opening next spring) and the Novo Teatro opera house in Sao Paulo, Brazil.

Energy system

Jaffe is best known for his pioneering development of what he terms an "electronic reflected energy system," which is intended to improve the acoustical qualities of existing spaces where physical solutions alone cannot meet the required acoustical criteria due to budget constraints, building landmark restrictions, or operational flexibility. The system also allows a single hall to be tuned for different kinds of performances ranging from a chamber group to an opera. For the ongoing renovation of Uihlein Hall in Milwaukee, Wisconsin, Jaffe designed a system of 60 small speakers concealed throughout the house, a battery of amplifiers, two microphones suspended 24 feet above the orchestra, and a computer to control and monitor the system.

Jaffe admits that this approach has met with some resistance from musical purists who favor naturally generated acoustics. He points out that there was initially considerable resistance to the concept of surround halls in which at least one-third of the audience is seated to the rear and sides of the orchestra when the Berlin Philharmonie was first built in the 1960s, yet these designs have now become quite popular. "The human ear doesn't know whether a reflection is coming from a wall or from a loudspeaker. It's still a pressure wave," he said, adding that the Nashville, Indianapolis, Anchorage, San Diego, and San Antonio symphonies all perform in halls using electronic reinforcement. "In the end we're still creating the same traditional sound, only through nontraditional means."

Other acoustical features

Surround halls are designed to create an intimate, less formal musical experience with easier access between the performers and the audience by achieving more even distribution of direct and reflected sound, according to Jaffe. His firm designed the first surround hall in the Western hemisphere, the Sala Nezahualcoyotl Hall in Mexico City, as well as the Boettcher Hall in Denver, Colorado, the first surround hall in the United States. Both were modeled after the Berlin Philharmonie.

One important factor in Jaffe's surround hall designs is the inclusion of a series of terraces. These break up the seating pattern to achieve the same reflecting patterns of the classic shoebox-shaped hall. Both the Mexico and Denver halls also feature an acoustical moat under the orchestra platform extending to the first five rows of seats. This design increases the ratio of low-energy reflections for audience members seated nearest the stage, where the reflected energy field is weakest. "The reason people love the balcony, even though the sound pressure levels are lower, is because it's rich in reflecting patterns relative to the levels of direct sound that reach you," said Jaffe.

Canopy control

Overhead reflectors and canopies, principally over the performance platform, have also become common in modern concert hall designs. Artec favors a massive acoustical canopy hung from the ceiling, weighing about 40 tons and adjustable in height by means of winches. The canopy controls the time required for the sound of the music to reflect back to the performers. "The first rule of acoustics is that, however good the room, you're only going to hear as good a performance as is given," said Goodall. "The ability to adjust the acoustical environment on the platform is key to that." Since it extends over the first several rows of seating, the canopy also controls the sound directed to the main floor of the room as well as to the upper volume of the room, which is critical to developing reverberance.

Artec used such a canopy a decade ago in its design of the Calgary Center for the Performing Arts in Alberta, Canada, and has used them in all of its concert halls since then. Most recently, the firm designed an adjustable ceiling in eight pieces for its conversion of a courtyard in a former rail station into a concert hall in Brazil. The pieces can be arranged so that there are gaps between them, allowing sound to reach the space above the ceiling and essentially creating a mini-reverberance chamber. Artec also used a reflecting canopy to improve on-stage acoustical quality in its renovation of the concert platform in New York City's Avery Fisher Hall, along with a set of spherical sound-reflecting panels fixed to the side walls around the platform.

The $7 million renovation of Uihlein Hall includes the removal of the existing plastic acoustical "clouds" above the orchestra pit. Jaffe is replacing them with new movable banks of acoustical panels, angled to allow visibility from the balconies and adjustable in height to accommodate different kinds of performances. He used a similar canopy of multiple panels in the recent $10 million renovation of the Kennedy Center for the Performing Arts in Washington to better reflect sound back to the musicians, as well as out into the audience.

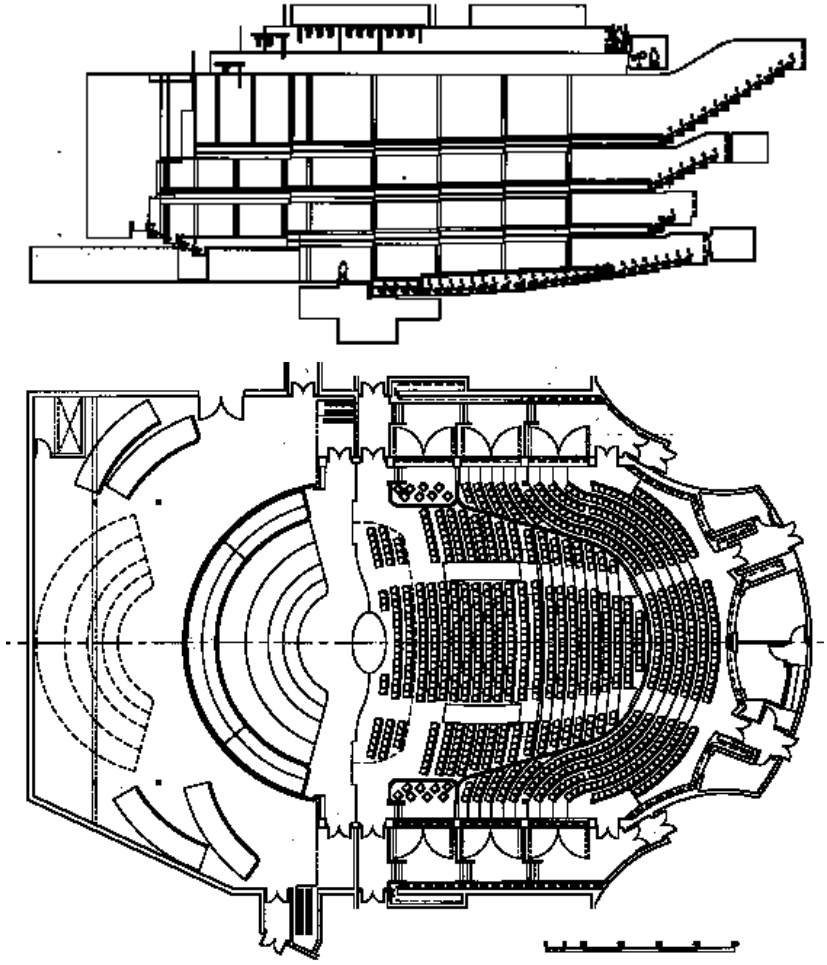

Figure 4. In the Metro-Dade Performing Arts Center in Miami, Florida, bridges have been designed for the audience to reach their seats through the reverberance chambers that reach to the floor.

Even nominally single-use concert halls are occasionally used for amplified popular music, comedians, commercial presentations, graduations, or other events, all of which require significantly less reverberance. Because of this, Artec's design for the Birmingham hall incorporates the use of moveable sound-absorbing panels, which are lowered mechanically from ceiling pockets or manually slid into place from storage bins along the sides of the hall, as well as a large curtain that can be suspended around the rear of the concert platform from ceiling to stage floor to further dampen amplified music. According to Goodall, this minimizes the reflection of sound from the front of the hall, providing sound technicians with an acoustical environment that is compatible with touring performance sound systems.

The pursuit of perfection in concert hall acoustics will no doubt continue, building on the great strides already made by today's acoustical consulting firms and researchers. To paraphrase Izenour in a recent lecture, "Science without art is nothing, and art without science is nothing."