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Virtual Auditorium Concepts For Exhibition Halls

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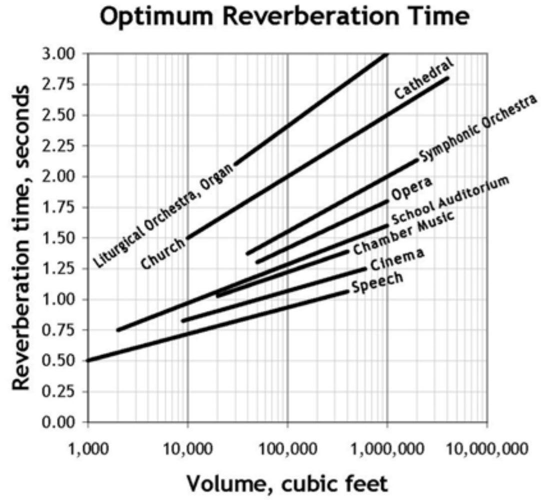
Abstract: Many communities lack good performance facilities for symphonic music, opera, dramatic and musical arts, but have basic convention, exhibition or assembly spaces. It should be possible to develop performance space environments within large multi-purpose facilities that will accommodate production and presentation of dramatic arts. Concepts for moderate-cost, temporary enhancements that transform boxy spaces into more intimate, acoustically articulated venues will be presented. Acoustical criteria and design parameters will be discussed in the context of creating a virtual auditorium within the building envelope. Physical, economic and logistical limitations affect implementation. Sound reinforcement system augmentation can supplement the room conversion. Acceptable control of reflection patterns, reverberation, and to some extent, ambient noise, may be achieved with an array of non-permanent reflector and absorber elements. These elements can sculpture an enclosure to approach the shape and acoustic characteristics of an auditorium. Plan and section illustrations will be included.

Introduction

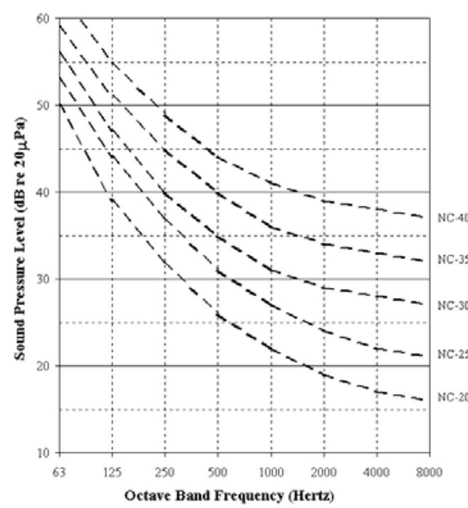
Many communities have basic convention, exhibition or assembly spaces with original programming including a variety of uses, ranging from indoor sports, to exhibition hall, to banquet and ballroom. But what about the use of the space as an artistic performance venue? Can the acoustics in the space be modified to support temporary use for traveling presentations of dramatic arts, symphonic orchestra, ballet or opera? This evaluation will compare acoustical criteria for dramatic arts with the effects of moderate-cost, portable, temporary enhancements of room acoustics and background noise control that can be purchased and installed in an existing venue.

Discussion of Acoustical Parameters



Functions that present mostly speech, such as dramatic plays and banquets, require short reverberation decay time and moderately low background noise to provide speech intelligibility. Short reverberation, approximately one second, is also appropriate for pre-recorded audio-visual or cinema sound tracks and live amplified music to avoid adding to or coloring the sound track. On the other hand, functions with music and singing, such as musical plays and dance performances, benefit from the warmth and fullness of slightly longer reverberation. Orchestral and opera music require even longer reverberation time, up to two seconds[1,2] (see chart, right).

Any multi-purpose room involves some compromise. Room volume and proportion of surface absorption are the primary factors that control reverberation decay. In a given room, effective volume changes can be a challenge. Some temporary surface finish changes are possible, but cannot be expected to double or halve the natural reverberation time of the original space. Electronic augmentation of reverberation time is possible through sophisticated sound systems, but these systems are still limited by the natural reverberation of a space. Thus, staying within the realm of moderate-cost solutions, the design goal for a multi-purpose room's reverberation time must be a compromise, somewhere between the shorter time for speech and longer time for music.



Permissible continuous background noise from building systems also varies with function. Speech interference increases as background noise becomes louder. In addition, background noise can color music and pre-recorded audio tracks. The design goal for any public assembly hall is a non-obtrusive, smooth spectrum, continuous background sound that is free of tonal and temporal characteristics. With amplification of speech or music, the signal to noise ratio can improve, allowing some tolerance of background noise. However, with the introduction of unamplified symphonic music, musical plays, or opera, there will be less tolerance of background noise, and noise from building systems will need to be reduced to extraordinarily quiet levels. The acceptable loudness varies from about Noise Criterion[3] NC-40 (50 dBA) for a sport or exhibition venue with public address, to NC-30 (40 dBA) for banquet speech and ballroom music, to NC-20 (30 dBA) for dramatic and unamplified music performance (see Noise Criterion curves, right[3]). Buildings designed specifically as concert halls and opera houses, without trying to accommodate other uses, are often designed and constructed for even lower background noise levels. Since ambient noise levels are due mainly to building systems, they cannot likely be altered significantly to accommodate various uses. Therefore, the lowest noise criterion for a range of functions in a multi-purpose facility should control design efforts. Achieving the lowest noise criterion may require a compromise between what is possible and what is economically feasible.

Sound isolation to prevent intrusive noise includes interior demising partitions between the assembly or performance space and surrounding pre-function, service, corridor and other spaces. Sound isolation from exterior noise is also required through the building envelope. Intrusive noise can be tolerated up to a few dB above ambient for sports or exhibition venues, but should not exceed the ambient for banquet speech or ballroom functions. For dramatic and music performances, intrusive noise should be rendered essentially inaudible, since it could occur during the quietest dialog or music passages. Since the permissible intrusive noise has been related here to the ambient noise level, it should be obvious to the reader that the threshold for allowable intrusive noise varies with the allowable continuous background noise (re: building systems, above).

Likewise, the sound isolation requirements of a multi-purpose room must be compromised between what is possible and what is economically feasible.

Acoustical Parameters for a Basic Boxy Space

Acoustical design concerns for the typical exhibition hall include the control of a) room reverberation, b) reflection patterns, c) background noise, and d) sound isolation. Under the initial functional programming for a typical exhibition hall, which might include indoor sports, exhibition, live amplified music, banquet (speech), and ballroom (music), the reverberation decay time might be designed for approximately 1.25 seconds in the 500 - 2000 Hz frequency range. Acoustically absorptive surface finishes in the space might be distributed on walls, floors, and ceilings to reduce flutter echo patterns between large parallel surfaces.

In addition to reverberation control, some exhibition halls are designed to limit acoustical reflections between walls or between the floor and ceiling. This combination of reverberation and reflection control might be based on multiple seating configurations, accommodating the fact that sound sources and sound receivers may be almost anywhere in the building, depending on venue requirements. Background noise might be designed for NC-30 (40 dBA). The reverberation decay time and control of reflections and continuous background noise described above, designed primarily to accommodate banquet and ballroom use, would be better than necessary for sports, exhibition, and amplified music functions.

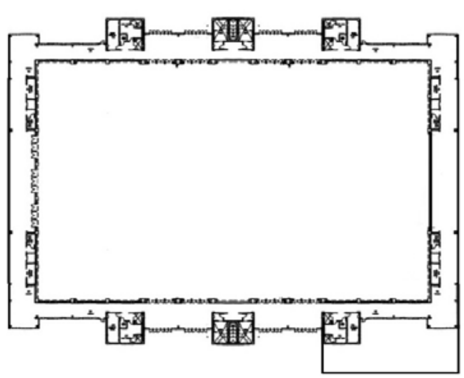
Sound isolation from adjacent interior spaces would be adequate to prevent annoying disturbance or speech interruption in the banquet / ballroom mode. Exterior noise from ancillary truck dock operations might be audible near loading dock doors, such as metal overhead doors, but it would not be expected to significantly exceed allowable background noise (although tonality of low frequency truck engine noise and transient impacts can be perceptible to humans even when equal to the continuous ambient noise level).

Acoustically, the typical exhibition hall is likely to be appropriate for amplified music, indoor sports, and exhibition. Some halls might be appropriate for banquet / ballroom function, and possibly "cabaret" or pops symphony. In most cases, design criteria for background noise, sound isolation and reverberation decay would have to change, and additional acoustical and noise control treatments would need to be implemented in the building to accommodate symphonic orchestra, ballet, musical plays, and/or opera.

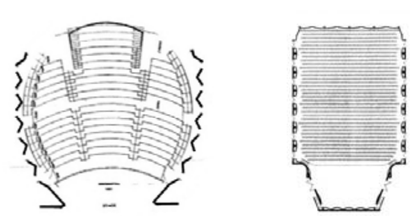
Imagining the Virtual Auditorium

Let us assume our community has an existing exhibit hall designed to accommodate banquet / ballroom functions, and now we want to use it for dramatic and performing arts. The dramatic and performing arts place special demands on the facility that are not yet incorporated into the building design. It is possible to present ballet, symphony, and opera in a modified exhibition hall, but if you will pardon the mangling of a popular idiom, it is necessary to do some thinking *inside the box*.

In addition to the background noise and reverberation control required for the venues described above, the room volume, shape, and surface finishes need to be modified to achieve specific aims. Intimacy, clarity, fullness, and other acoustical conditions should also be created by use of reflections, diffusion, and absorption on various



Typical Exhibition Hall



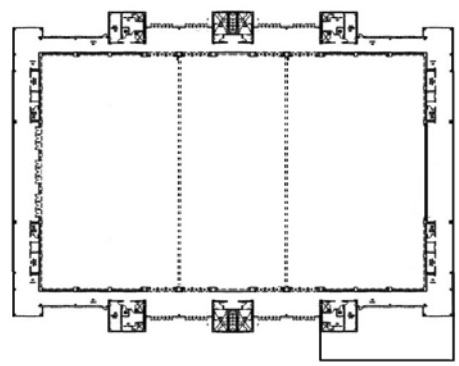
”Fan” and “Shoebox” Concert Hall Shapes

surfaces. Dramatic and musical performances benefit from acoustic reinforcement of source sound by directing reflections into the audience in a controlled diffuse manner, for the purpose of achieving even sound coverage of the entire audience seating area. The relative weakness of a human voice or unamplified musical instruments in a large volume room requires that the volume be reduced to optimum ratios. The location of the stage should be determined and fixed. The ceiling and side walls should reflect stage sounds into the audience and spread them evenly over areas that otherwise would suffer from weak direct sound from the stage.

Taken altogether, this means that the big rectangular box must be transformed from a collection of large parallel surfaces and 90° corners, into a sculptured enclosure that moves sound from front to back but does not return reflections to the source. All of this must be achieved within the context of the architecture, and coordinated with the other facility elements, including lighting, rigging, sound systems, set construction and installation, seating, sight lines and patron comfort.

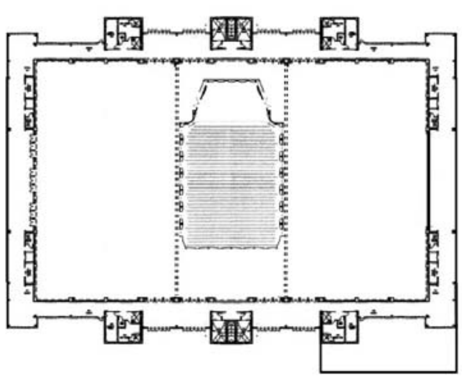
Creating the Virtual Auditorium

In order to implement design features to support higher dramatic and performing arts within a multi-use facility, those special features may need to be provisional. It is possible to create a room within a room using portable, temporary enclosing elements. Pros and cons of various concepts are discussed below.

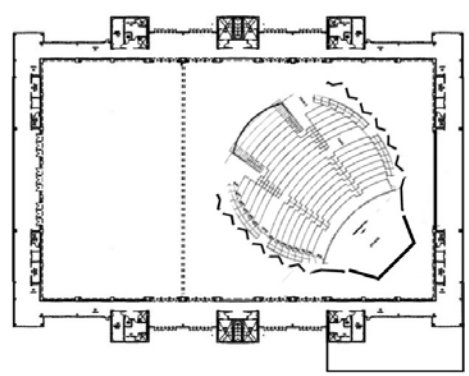


Operable Partitions: can be used to divide the enormous scale of the big box to create the intimacy necessary for appreciation of higher dramatic arts (right). An exhibition hall may enclose a volume up to 3,000,000 ft^3 (85,000 m^3)[4,5], while the optimum volume for a symphony hall will be 1,000,000 ft^3 (30,000 m^3) or less[6,7]. Operable partitions can squeeze the dimensions of the enclosure to a more appropriate volume and better length-width-height ratios (e.g., 2.0-1.5-1.0). Operable partitions can also be arranged to achieve beneficial sidewall reflections.

Room Orientation: can be arranged to achieve beneficial sidewall reflections of the building walls and/or operable partitions. Consider a rectangular room with the stage at one end, in typical "Shoebox" fashion (below, left). In lieu of a rectangular room, the room could be laid out on a diagonal axis, so that the stage backs up to a room corner. When configured on a diagonal axis, the room begins to approach the shape of a fan-like auditorium (below, right). In this configuration the side and rear 90° corners present some special reflection problems. Also, given a rectilinear building structure, a diagonal layout may pose reflector and curtain deployment problems, acoustical distribution problems, and the ratio of seating capacity to floor area of the room may be reduced.

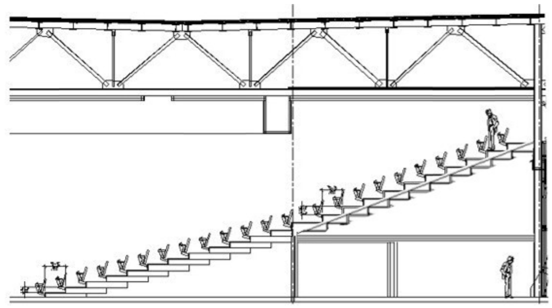


Rectangular arrangement with "Shoebox"

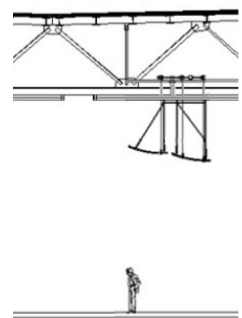


Diagonal arrangement with "Fan"

Seating: can be used in conjunction with room design to interrupt and prevent "backslap" reflections from the rear wall, whether the room is configured diagonally or on the building axis. By setting up seating on risers steep enough that upper rows are at least 8' to 10' above stage elevation, patrons occupying the seats receive the direct sound from the stage, and prevent those sounds from reaching and reflecting back off of rear walls (see retractable bleacher seating, right). Box seats, side seats, and balcony seats pose a challenge. Using risers or bleachers for side seats can dictate a wide, fan-shaped seating area. A seating area wider than 100 ft (30 m), in conjunction with a clear height from floor to trusses of approximately 25 to 35 ft (10 m), may compromise the quality of early sound[7], which is the combination of direct sounds and first reflections reaching the audience. The rectilinear arrangement (above, left) might prove to be better for the development of early sound, but without additional side seats, the venue may not be able to sell enough tickets to make shows economically feasible.



Reflector Panels: can be suspended on cables from the ceiling/roof structure and/or supported on floor stands (see illustration of moveable, adjustable panels suspended from secondary structure between existing roof trusses, below). Panel shapes can be selected to provide diffusion, or flat surfaces can be installed at specific angles to direct reflections to desired locations. Additional reflecting surface areas added to the room would tend to enhance reverberant and reflective energy, and restore more brilliance and intimacy to the room. Controlled reflections can provide ceiling and sidewall reinforcement of direct sound from the stage, so that the sound system, if used, will support, but not dominate natural sounds. Reflector panels, especially those that are suspended as ceiling clouds, require a support infrastructure, such as cables, winches and pulleys, "flying" space frame trusses or beams, and time for installation/removal. Since the objective is to move sound from front to back, reflector panels are principally effective in the front half of the room. The rear walls and rear ceiling need more absorption than reflection. Given a high roof, moveable ceiling reflectors can be used over the seating to raise and lower the effective ceiling height, to achieve optimum width-to-height ratios for various uses and audience sizes. Moveable reflectors can also be used over the stage to adjust the absorptive effects of the fly loft for various uses. Without a high roof, reflectors may as well remain at a fixed height, as high as possible to maintain a lower width-to-height ratio.



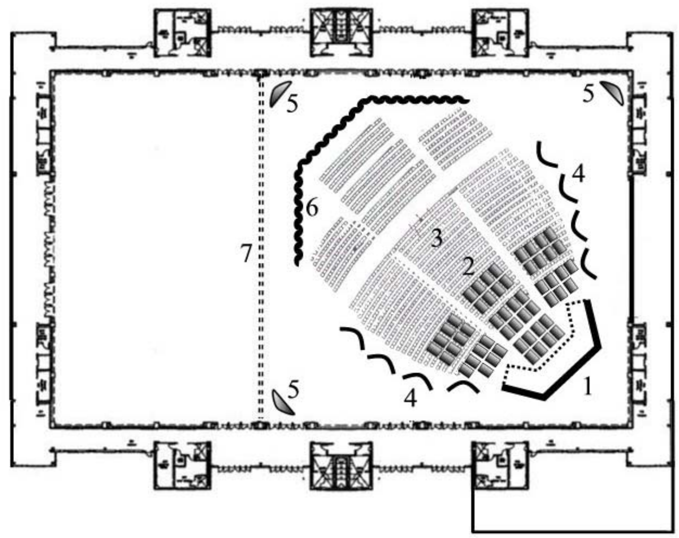
Curved reflector installation (Courtesy of Acoustical Resources, Inc.)

Curtains: can be hung above and around the stage to create a faux proscenium and mask the wings. Other curtains can be arranged to form diagonal, curved or shaped sidewalls, and to provide non-reflective rear walls, behind audience seating. While curtains may be less expensive than reflector panels, problems arise with the excessive use of curtains to create an auditorium appearance, leaving the space acoustically dull. With an exhibition hall designed for speech and amplified music, the reverberation time will be shorter than desirable for musical comedy or symphonic music. Complete enclosure with curtains would tend to reduce reverberation time, when the opposite is needed. Curtains would also attenuate sidewall reflections, when reflective reinforcement is desired. Intimacy and fullness would be lost. The sound system would have to compensate.

Electronic Sound Reinforcement: When good (or mediocre) acoustical reinforcement conditions are achieved with various surfaces, the natural sound can be supplemented by an electronic sound reinforcement system. Without good acoustical reinforcement from room surfaces, the sound system must dominate the room, which can result in an unnatural sound or acoustic images displaced from the sound sources.

Ensemble: Combinations of these concepts can be implemented. Since each of the concepts involves use of temporary, portable elements, including reflector panels, seating risers, audience members, and curtains, many arrangements can conceivably be devised to work in the various room sizes (with or without some combination of operable partitions deployed).

1. Stage shell and platform
2. Suspended reflector panels above stage and front seating
3. Audience seating
4. Vertical side reflector panel arrays
5. Corner absorption (bass traps)
6. Heavy curtains behind seating
7. Operable partitions

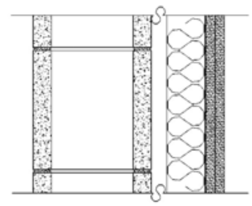


At a minimum, use a stage shell and platform to define the stage and project stage sounds. Apply reflector panels suspended above and in front of the stage as ceiling clouds to reflect stage sounds back down into the audience, in combination with drapes above the stage to create a proscenium. Shaped vertical reflector panels can be arrayed more or less diagonally on either side of the stage, either suspended or floor supported, to form close sidewalls, which provide reinforcing reflections into the audience. Additional panels can be placed along the room's sidewalls to provide diffusion to the room. Heavy drapes can be suspended in front of rear walls to act as rear wall acoustical absorption, and prevent backslap to the front of the room.

Modifying Permanent Building Systems and Designs to Accommodate Performing Arts
Auditorium, concert hall and opera house noise criteria for air conditioning systems may be 5 to 20 points lower than exhibition hall criteria. To achieve the lower ambient sound levels, noise control concepts might include:

- Review air handler and fan selections to determine whether quieter selections are possible while meeting other aerodynamic parameters.
- Enlarge air handler plenum cabinets to achieve more fan noise attenuation, particularly lower frequency noise, at the source (before it enters return and supply duct systems).
- Add duct attenuators to supply and return truck ducts, or increase sizes of attenuators where they are already incorporated into design.
- Change supply trunk (main) ducts from rectangular to round duct for better containment of low frequency "breakout" noise in the hall (outside of equipment room), or provide noise barrier lagging (enclosure) of trunk ducts if they remain rectangular.
- Increase branch duct sizing and enlarge diffusers and grilles to pass air at slower velocities, to minimize duct, fitting and diffuser noise.
- Review equipment room floors and wall sound transmission loss, relative to lower criteria. Heavier construction or decoupling techniques may be required for AHU noise.

The building shell design may accommodate railway or aviation noise at some distance from the building in addition to trucks driving by and idling at the loading dock. However, exterior or environmental noise sources might require additional sound isolation in the building shell to assure that transient intrusive noise is no louder than the reduced ambient noise permissible for dramatic and performing arts. To achieve improved environmental noise transmission loss through the building shell, design concepts might include:



- Increase roof mass and/or decouple upper roof mass from structural roof deck (i.e., a sandwich assembly with a concrete or high density layer over a low density, resilient layer, such as insulation, on top of structural roof deck).
- Increase mass of building walls and/or add or increase thickness of cavities with insulation. Additional sheathing board layers might be added, or the walls near truck docks might be changed to masonry with furred interior frame and sheathing finish (right).
- Use sound rated doors or apply higher-performance acoustical seals at building openings near truck docks.
- Review potential plumbing noise transmission from toilet blocks into performance hall. The reduced ambient sound level required for performance venues could result in audible noise.

Conclusion

A multi-purpose hall can support venues that carry different performance parameters and criteria, but compromises are often necessary. The building and building systems should be designed to accommodate the most stringent criteria, since those elements are permanent, and not subject to temporary or short term adjustments. Other portable or non-permanent elements can be introduced into the space to create a virtual room within a room that changes the large hall into a performance space shaped with more desirable length-width-height ratios. Flexibility and adaptability of the space, therefore, depends on the creativity and resources of the designers and operators to extend the functional limits of the exhibition hall.

Acknowledgements

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