VERSION 2.0

planning guide

FOR PERFORMANCE SPACES

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A NEW CONSTRUCTION, RENOVATION AND EXISTING FACILITY RESOURCE FOR MUSIC EDUCATORS, FACILITY PLANNERS, ADMINISTRATORS AND ARCHITECTS

E D U C A T I O N   A N D
P E R F O R M A N C E   G U I D E S

At Wenger Corporation we have over 60 years of experience studying music education and music performance spaces. On staff, we have some of the industry's leading experts in the fields of music education and performance facilities, acoustics, storage and equipment. To create a series of resource guides, we pooled all of our experience and then consulted the real experts - music educators.
After more than 6,000 surveys, hundreds of interviews and site visits, we focused our attention on topics and problems educators and musicians face every day.

The topics we cover in our free Wenger resource guides are a joint effort - a combination of our knowledge, input and writings from leading acousticians, architects and facility planners, and of course, the creative solutions of individual music educators. There are as many variations of these topics as there are schools and facilities in North America. Although every facility and every situation is unique, Wenger guides will provide a starting point for addressing many of the questions you have and the problems you face in your facility. We are always working on updated versions and new topics - see below for a current list of Wenger guides for music educators and the spaces in which they teach and perform.

A L S O   F R O M   W E N G E R

Acoustic Primer
Explains the fundamental acoustical concepts that affect music areas.

Acoustic Problems & Solutions for Rehearsal & Practice Spaces
Addresses the most common acoustic problems music educators face in their rehearsal and practice areas, and suggests solutions to fix or minimize these problems.

Planning Guide for Secondary School Music Facilities
Focuses on critical elements to consider when designing an effective Music Suite.

Elementary Music Planning Guide
Details how to put together the perfect music facility from ground up.

Athletic Facility Planning Guide
Provides consultation on the critical requirements of the space for athletic programs which requires some of, if not the most, specialized storage in the school.

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PERFORMANCE SPACES

overview

All music educators recognize that supportive acoustical environments are critical to a successful performance. Performance spaces range from concert halls to large lobbies, from multi-use gymnasiums and cafetoriums to the outdoors. Whether you are fortunate enough to have an auditorium, or are rounding up stray basketballs before your rehearsal, chances are you have to perform in spaces that are less than ideal. Wenger has developed this guide to show you options that will make these spaces more musically supportive.

This guide is organized into sections corresponding to performance environments:

Auditoriums **Orchestra Pits** **Gymnasiums** **Cafetoriums** **Outdoors**

Each section addresses both the acoustics of the stage area (or "sending end") and the acoustics of the audience area (or "receiving end"). Problems or weaknesses in either area can compromise the success of any performance (see Figure 1).

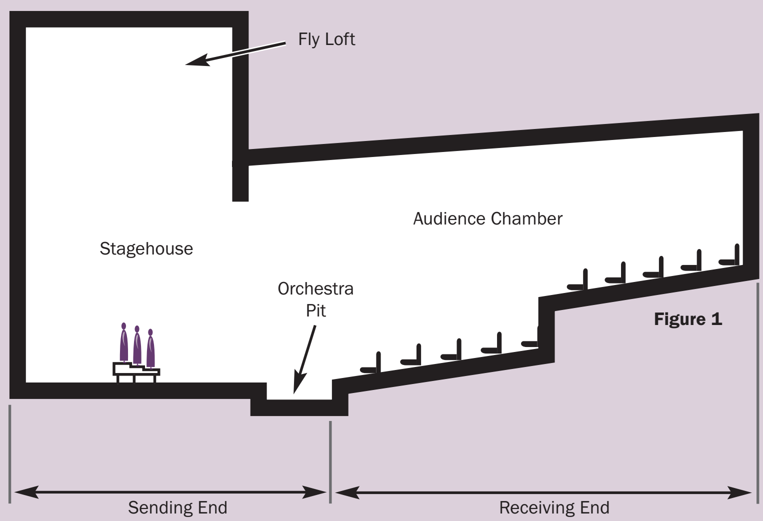


Figure 1

STAGEHOUSE — "SENDING END"

The primary focus must be on where the sound is produced, helping the musicians hear themselves and each other. In each section, we first address the "sending end", showcasing some typical on-stage acoustical challenges and suggesting solutions. When musicians can hear themselves and each other, they can master the musical skills of timing, phrasing and intonation with confidence, resulting in a better performance.

AUDIENCE CHAMBER — "RECEIVING END"

We recommend hiring an acoustician to improve the receiving-end acoustics for musical performance in an auditorium. A performance, by definition, requires an audience. The audience chamber represents the "receiving end" of the sound produced by the performers. Each audience space presents special challenges which are addressed in this guide.

PERFORMANCE SPACES

auditoriums

While dedicated concert or music halls are typically the best spaces for music performances, they are rarely built in school facilities. Multi-purpose halls that support everything from theater to music are the most common auditorium in schools. These spaces typically follow a proscenium theater design but can change as the requirements of the performance changes. Typical features include a fly loft and rigging system for lights, acoustical panels, curtains and stage scenery. A thrust stage and orchestra pit are also common features. Today we also see a number of creative designs for multi-purpose areas that vary from the traditional proscenium theater.

Successful multi-purpose auditoriums have the following characteristics:

- Acoustical shells used to enhance acoustics in stagehouse and audience chamber.
- Acoustical clouds and panels used to support acoustics in audience chamber.
- Ceiling height that provides sufficient cubic volume for desired reverberance.
- Side walls shaped to reflect sound toward side of audience.
- Incorporate ways to vary strength and reverberance onstage and in audience chamber (such as adjustable absorption and coupled volumes).
- Quiet so intruding noise does not interfere with performances. Enclosing constructions that isolate unwanted sound of adjacent spaces and outdoors. HVAC systems serving auditorium do not produce disruptive noise.

STAGE AREA

In most auditoriums, the stage area is separated from the audience area by a proscenium opening. This is ideal for drama, but poses several acoustic challenges for music performance. The fly loft space, where curtains, lighting and scenery are hung, absorbs too much sound, compromising acoustics. (see Figure 2)

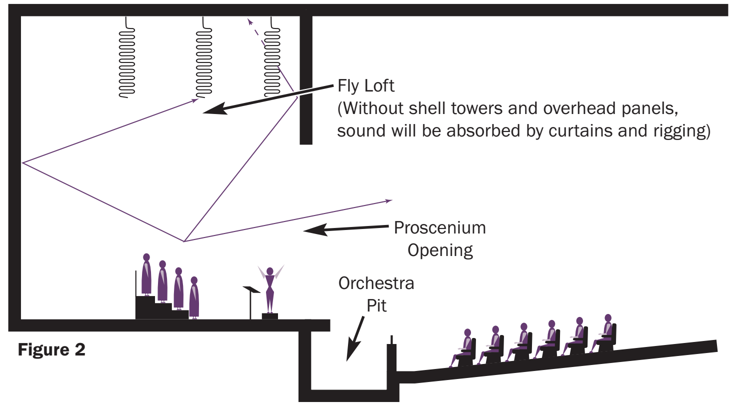


Figure 2

ACOUSTICAL SHELLS

In auditoriums, acoustical shells connect the stagehouse to the audience chamber. The ability of performers to hear their own and distant instruments will be enhanced. Shells can be arranged onstage to best support the style of music to be performed. Use acoustical shells to:

- Improve reverberation and conserve sound energy by shielding onstage sound absorption (such as curtains, scenery, or props) and acoustically connecting the stage area to the audience chamber.
- Increase strength of sound by more than 3 decibels at many seat locations (approximately equal to doubling the size of the performing group). Onstage effects are even greater, more than 5 decibels, according to findings published by the Journal of the Acoustical Society of America.
- Enhance warmth by providing heavyweight boundary surfaces around the performers and overhead reflections toward the audience.
- Scatter sound among performers to facilitate onstage intercommunication (ensemble).
- Contribute to musical presence by providing early reflections to the performers (within a 30-millisecond delay).
- Provide an impressive aesthetic background for performances.

Sound-reflective shell towers and overhead panels surrounding the performers are critical to achieving proper acoustics. Overhead panels, or clouds, are suspended above the stage using the rigging system. Shell towers rest on the stage floor, forming back and side walls that enclose the performers (see Figure 3).

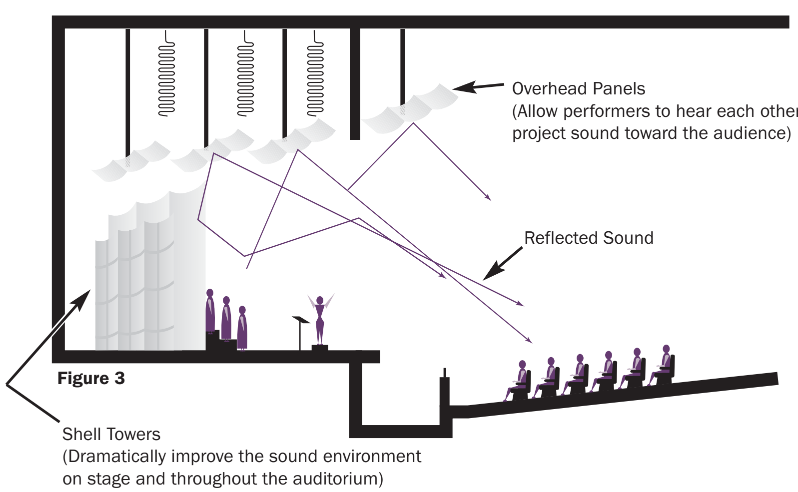


Figure 3

Use of overhead panels, which provide reflections, enables you to position performers at the back of the stage. This also takes advantage of the reflective benefits of the hard floor surface in front of the performers (see Figure 4).

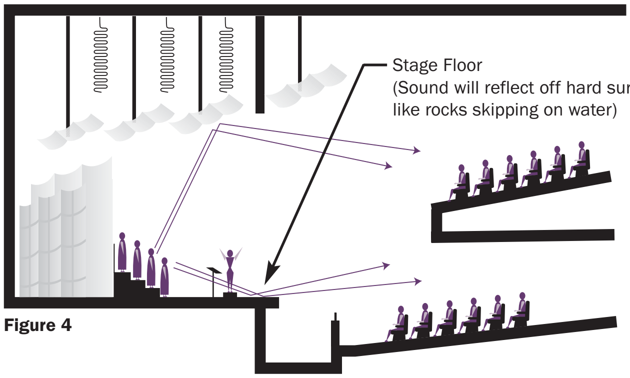


Figure 4

Without overhead panels to provide reflections, use a stage extension and move the performers in front of the proscenium (see Figure 5).

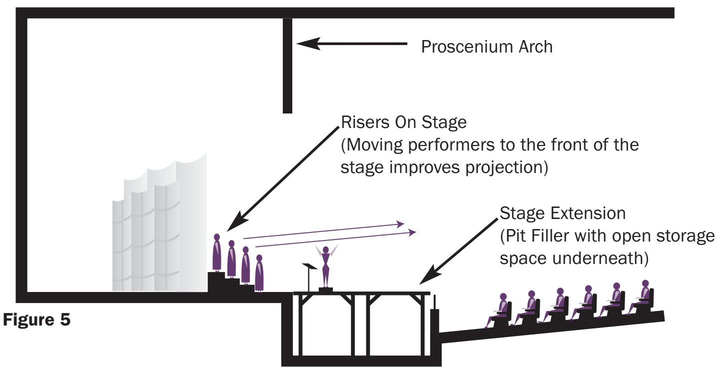


Figure 5

Pay careful attention to how you arrange your performers underneath a proscenium arch. Do not place some of the group in front of the arch (without overhead reflecting panels) and some behind the arch because this will result in very diverse and skewed acoustics.

When a band or orchestra is onstage surrounded by a shell, some instruments may be too loud. To improve acoustics, move the shell towers slightly apart from each other, allowing some of the sound to escape behind the shell (see Figure 6).

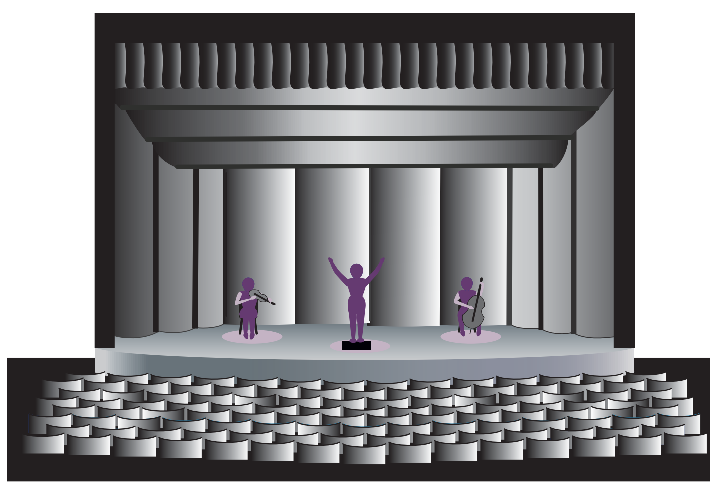


Figure 6

A full-stage acoustical shell with towers and overhead panels is the ideal solution for music performance on a proscenium stage. Together, these two elements create a "blending chamber" for sound on stage, and help to reflect sound toward the audience.

RECOMMENDATIONS - ENSEMBLE

Ensemble

To most people, the word "ensemble" only means a group of musicians performing together. However, music educators use the word to describe a balanced, blended sound that unifies a group. The result is like the Latin saying found on U.S. coins, E pluribus unum — "Out of many, one." Achieving true ensemble is the result of more than just effective rehearsals and individual practice. Musicians must be able to hear themselves and each other.

Acoustical environments should support the musicians' need to hear by providing useful, multi-directional reflection and blending of the broad spectrum of musical sound. In most school performance spaces, the acoustical qualities must be enhanced with appropriate equipment and acoustical treatments. No amount of practice or talent can overcome poor acoustical environments.

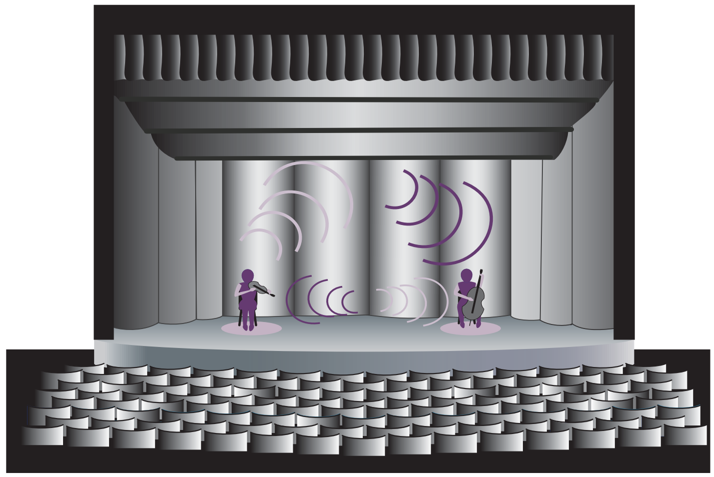


Figure 7

AUDIENCE AREA

If your budget limits your ability to install a full stage solution (including overhead panels and towers), we recommend you start with the overhead panels. By closing off the fly loft area, you will achieve the greatest acoustical benefits. When future budgets permit, add the towers.

ACOUSTICAL CLOUDS

Just as sound onstage gets lost in the fly loft, high ceiling in the audience area can be a similar sound trap. With large ventilation ducts, lighting and catwalks, much of the sound that gets into this overhead volume, especially higher frequencies, will not be reflected to the audience.

Reflective panels or “acoustical clouds” suspended above the audience chamber will reflect some sound down toward the audience. Yet, unlike the more solid enclosures on the stage, the panels are spaced apart to allow sound to enter the volume above the panels. The later reflections from this volume enhance reverberance and give the audience a sense of space and acoustical envelopment (see Figure 8).

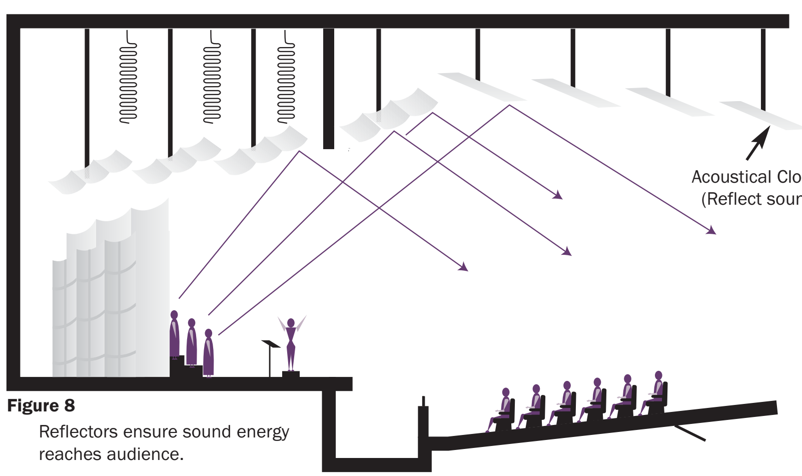


Figure 8

Reflectors ensure sound energy reaches audience.

ACOUSTICAL PANELS

Acoustical design professionals often will position diffuser panels on the walls in the front one-third of the auditorium and suspend panels over the audience. These panels will project sound toward the entire audience.

On the middle one-third of each side wall a combination of diffuser and absorber panels is often recommended.

The rear one-third of the side walls should be covered primarily with absorber panels (depending on the reverberance desired).

Depending on reverberance goals, the back wall should be treated with absorption to eliminate any strong reflections or oriented to reflect sound upward or downward. If the room is very "live," all panels can be absorptive. If the room is very "dead," all panels should diffuse sound. Otherwise, use a combination of absorber and diffuser panels (see Figure 9).

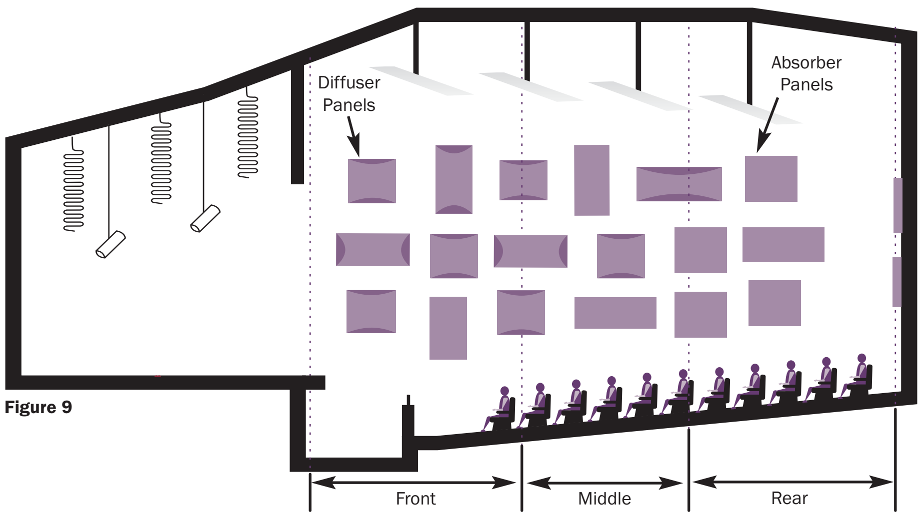


Figure 9

If the balcony face is a large flat or concave surface, tilt the surface or apply diffusion or absorber panels (depending on acoustics in the audience chamber). Without proper treatment, the balcony face can focus sound and create annoying "slap-back" echoes (see Figure 10).

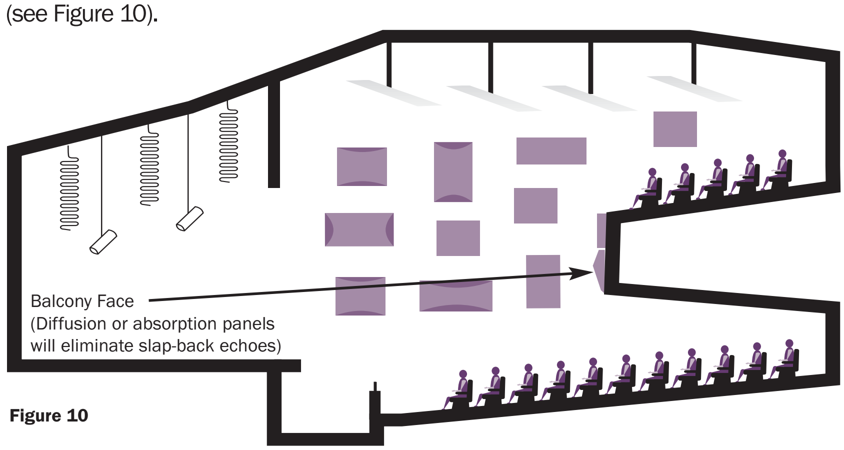


Figure 10

Slap-back echo is a discrete, high frequency echo off flat or concave surfaces. You can test for slap echo by sharply clapping your hands and listening for an echo.

RECOMMENDATIONS

As you evaluate the uses of your auditorium, there are some acoustical requirements you should consider. If the auditorium will be used for speech and film as well as music performance, you may have to add more absorption than is ideal for music. For example, where speech is important, reverberation times at mid-frequencies should be below one second to not adversely affect sound intelligibility. To be heard clearly, an A/V or film soundtrack usually requires even lower reverberation. Both of these situations require considerable absorption, but too much absorption will diminish the strength of music performances, which require longer reverberation. Your acoustical consultant can recommend ways to vary acoustics so conflicting requirements will be resolved.

Use of Sound Reflectors and Diffusers

The following are some recommendations regarding the use of sound reflectors and diffusers:

- For vocal enhancement, use sound reflectors with flat surfaces or moderately convex surfaces (radius of curvature about 20 feet) that are tilted to reflect sound toward listeners at the middle to rear of the seating areas (an acoustical consultant should use scale models or ray diagrams on section drawings to determine optimum position and orientation for reflectors).
- Be sure the surface of the reflector is smooth. Depth of ribs or other surface relief should not exceed one-half inch.
- For music enhancement, be sure the surface of the reflector has sound-diffusing elements or other significant surface modulations.
- Sound-diffusing shapes include: convex, gull-wing, pyramidal, and array of wells of varying depths.
- Avoid concave shapes because they focus rather than evenly distribute sound.
- Sound reflectors and diffusers should be constructed from hard-surfaced materials (such as wood, gypsum board, or acrylic plastic) that have sound absorption coefficients less than 0.10 at 2000Hz. Panels should be well braced to be rigid.

SOUND ISOLATION

Intruding sound can interfere with rehearsals and performances. You should eliminate all sound leaks. In existing performance spaces, carefully examine all doors and windows. Check the seals around doors, especially in the backstage area. If there are none, or if the seals are worn, replace them so doors will be airtight when closed. Sound isolation is particularly difficult if your performance space has windows or doors to the outside. If necessary, replace them with high sound-isolation rated units.

Sound Isolation Principles

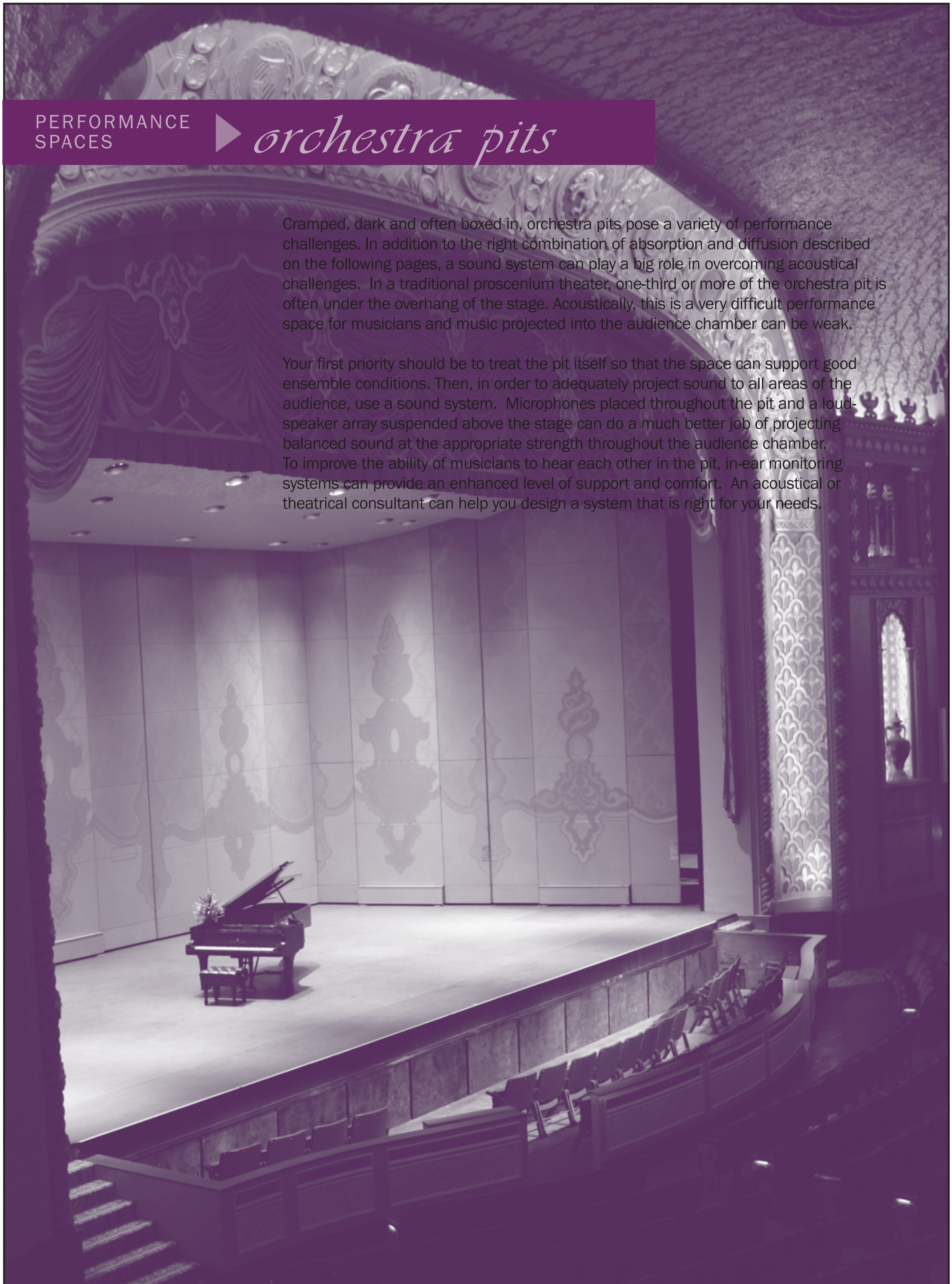
- Monolithic construction, such as masonry walls or gypsum board attached to steel studs, can isolate sound if they are “heavy.” Use heavyweight block rather than lightweight block, multiple layers of gypsum board rather than a single layer.
- Improve isolation by “decoupling” opposite layers of wall. Use independant rows of studs, or resilient connections to support gypsum board.
- Sound-absorbing fibrous materials, placed in cavity airspaces in walls and ceilings, can increase isolation by reducing buildup of sound within cavity.

PERFORMANCE SPACES

orchestra pits

Cramped, dark and often boxed in, orchestra pits pose a variety of performance challenges. In addition to the right combination of absorption and diffusion described on the following pages, a sound system can play a big role in overcoming acoustical challenges. In a traditional proscenium theater, one-third or more of the orchestra pit is often under the overhang of the stage. Acoustically, this is a very difficult performance space for musicians and music projected into the audience chamber can be weak.

Your first priority should be to treat the pit itself so that the space can support good ensemble conditions. Then, in order to adequately project sound to all areas of the audience, use a sound system. Microphones placed throughout the pit and a loud-speaker array suspended above the stage can do a much better job of projecting balanced sound at the appropriate strength throughout the audience chamber.
To improve the ability of musicians to hear each other in the pit, in-ear monitoring systems can provide an enhanced level of support and comfort. An acoustical or theatrical consultant can help you design a system that is right for your needs.



CONSIDERATIONS

Orchestra pits are challenging performance spaces. Where there is insufficient stage overhang, the closeness of the pit walls can make proper ensemble very difficult. In an untreated orchestra pit, sound will be trapped and built up within the cramped volume. Be sure the pit is sufficiently large. Consider also using adjustable features in the pit, such as removable panels or curtains hung on a track, according to the guidance of an acoustician.

In addition, sound is often directed up and out over the heads of audience members. Without proper ceiling treatment, much of this sound will be lost, creating an imbalance between the sound levels on stage and in the pit (see Figure 11).

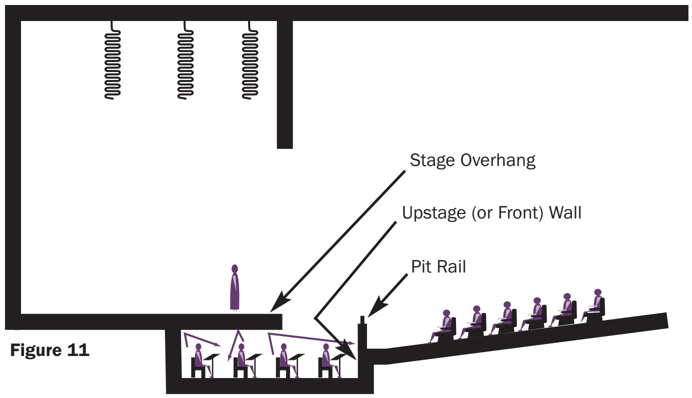


Figure 11

RECOMMENDATIONS

A well-planned combination of absorber and diffuser panels can improve the acoustics in an orchestra pit. The absorber panels are best placed on the back wall and portions of the side walls. The diffusers should be placed on the front wall and remaining portions of the side walls (see Figure 12).

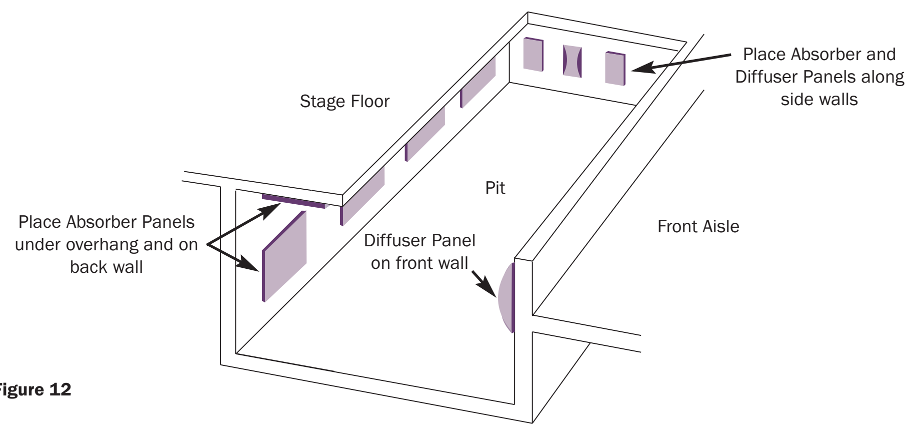


Figure 12

Careful placement of Absorber and Diffuser Panels enhances pit acoustics.

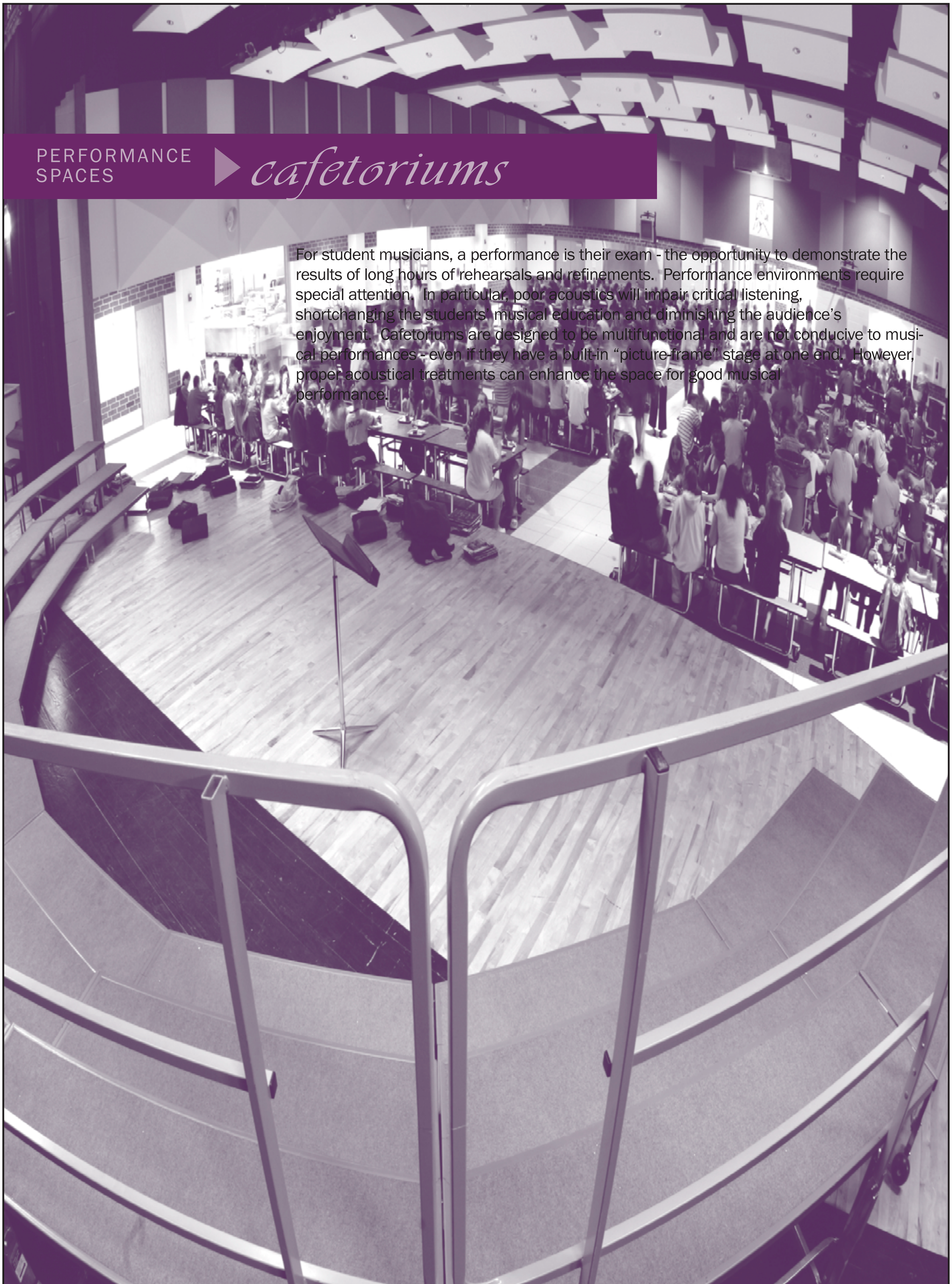
If you are using an electronic monitoring system, most of the pit wall should be lined with absorber panels. Newer in-ear monitoring systems are a good way to reduce amplified sound levels in the pit area. If necessary, instruments in the pit area can be mic'd and then amplified through the auditorium sound system to compensate for inadequate sound projection to the audience.

The following are recommendations regarding the acoustical treatment of orchestra pits:

- Provide sufficient space per musician in the orchestra pit (>18 square feet per musician is preferred).
- Use area under stage overhang to provide cubic volume to control loudness in the orchestra pit (>8 foot overhang).
- Reversible panels can be used to vary absorption in the orchestra pit. One side should be sound absorbing (such as one-half inch thick glass-fiberboard) and the other side sound reflecting (such as hardboard or thick plywood). Use absorptive side to control level of sound near loud instruments without diminishing sound from other instruments.
- Upstage wall of the orchestra pit could be sloped to reflect sound back toward the stage.
- Removable pit rail should be solid to reflect sound back toward the stage.
- Deck components of pit fillers should be sufficiently stiff and damped.

PERFORMANCE SPACES

cafetoriums



For student musicians, a performance is their exam - the opportunity to demonstrate the results of long hours of rehearsals and refinements. Performance environments require special attention. In particular, poor acoustics will impair critical listening, shortchanging the students' musical education and diminishing the audience's enjoyment. Cafetoriums are designed to be multifunctional and are not conducive to musical performances - even if they have a built-in "picture-frame" stage at one end. However, proper acoustical treatments can enhance the space for good musical performance.

STAGE AREA

The multi-use cafetorium, designed with a "picture-frame" stage at one end, is found in many schools. While very convenient for a variety of functions, these cafetorium spaces are not conducive to musical performances, unless the walls and ceiling are treated throughout the room (see Figure 13).

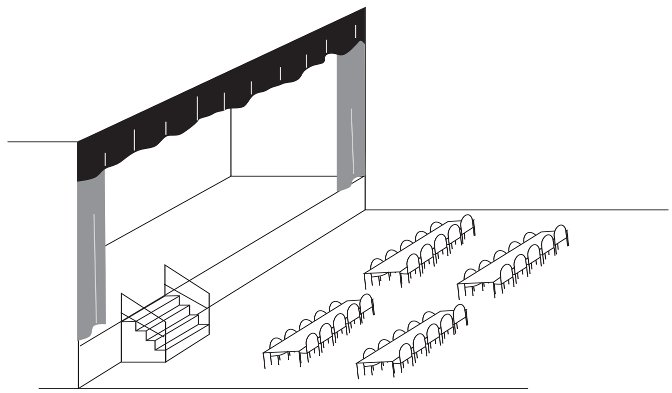


Figure 13 Built-In Stage

RECOMMENDATIONS - PORTABLE SHELL

If your cafetorium has a built-in stage, proper acoustical treatments on stage are essential to provide the necessary reflections for ensemble. Otherwise this stage will be more of a hindrance than a help. A portable shell around the group and reflective ceiling overhead will best achieve proper acoustics (see Figure 14).

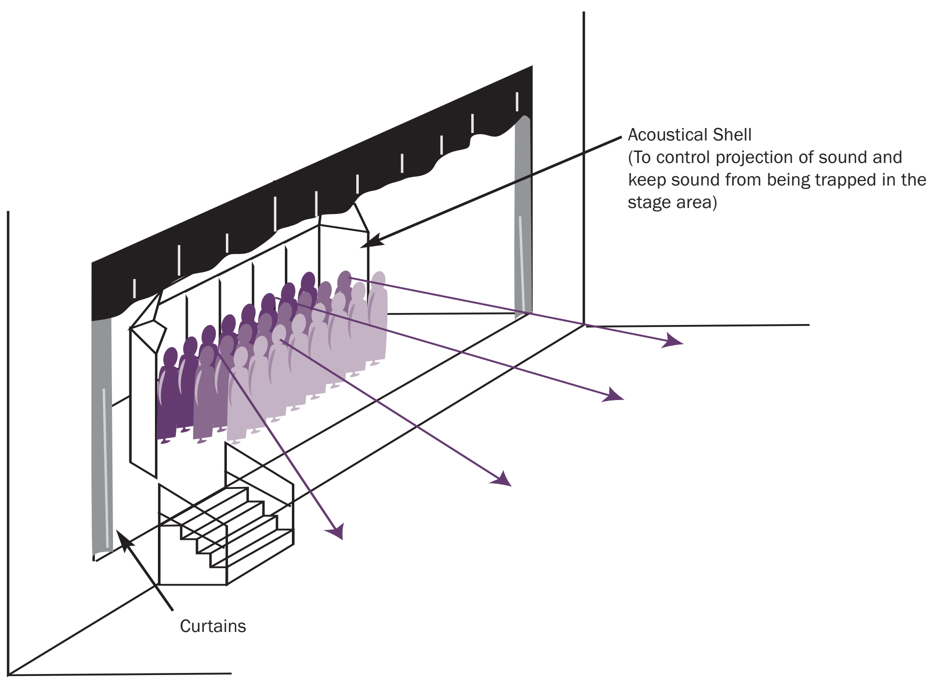


Figure 14 Portable Shell

RECOMMENDATIONS - PANELS

If you do not have a shell, treat the wall and ceiling with reflecting and diffusing panels. Without any reflective surfaces, such as acoustical shells or overhead panels, your musicians will find it difficult to hear each other and will not have a sense of ensemble. In addition, the undirected sound energy may be dissipated or absorbed before reaching the audience. For these fundamental reasons, it is critical to have reflective surfaces behind and over your performers (see Figure 15).

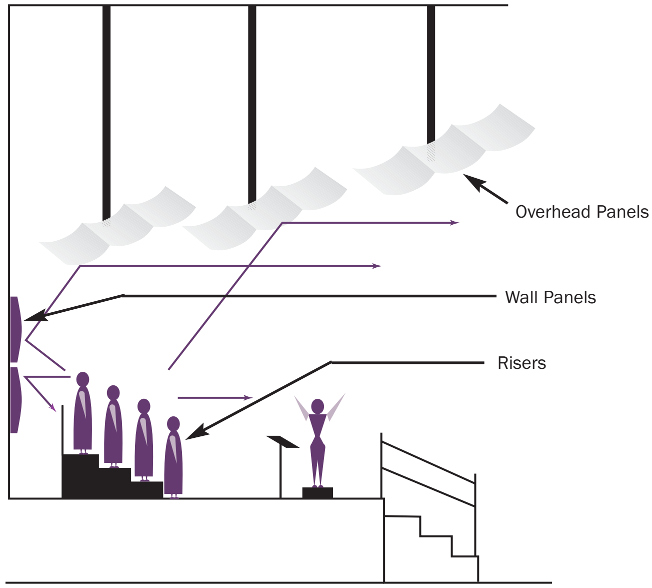


Figure 15 Overhead and wall panels reflect sound toward audience

RECOMMENDATIONS - TIERED RISERS

A tiered performance configuration is essential also for the projection of sound. When performers are all on one level, without risers or staging, a portion of their sound will always be directed at the backs of other performers, interfering with projection to the audience. Avoid performing on an untreated stage. The proscenium opening and curtains will muffle the sound. While a stage may provide visual benefits, the resulting poor acoustics will seriously compromise the quality of the performance, both for the performers and the audience (see Figure 16).

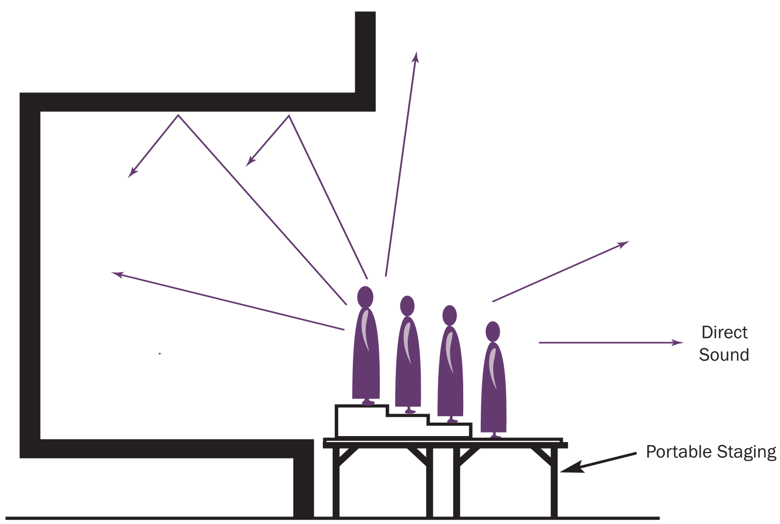


Figure 16 Performers on tiered platform, close to audience

RECOMMENDATIONS - TIERED RISERS

If you are unable to make any of these recommended corrections, position your performers on the floor against a large wall (see Figure 17). The solid wall behind your performers will provide some degree of reflection and focus for sound.

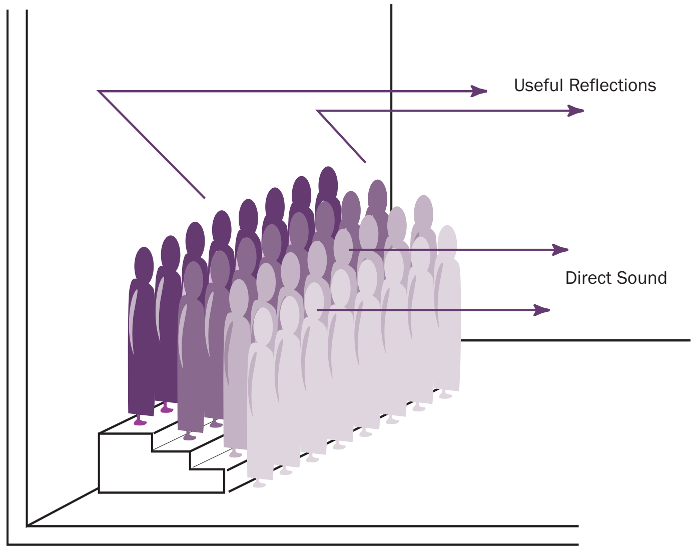


Figure 17 Performers on tiered platform placed against wall

AUDIENCE AREA - ROOM ACOUSTICS

Depending on the floor and ceiling surfaces, a space can be either very "live" or "dead". A "dead" room absorbs too much sound energy, usually as a result of excessive porous materials like carpet and heavy drapes. These materials act like sponges that selectively absorb higher-frequency sounds. The result is muffled, indistinct sound (see Figure 18).

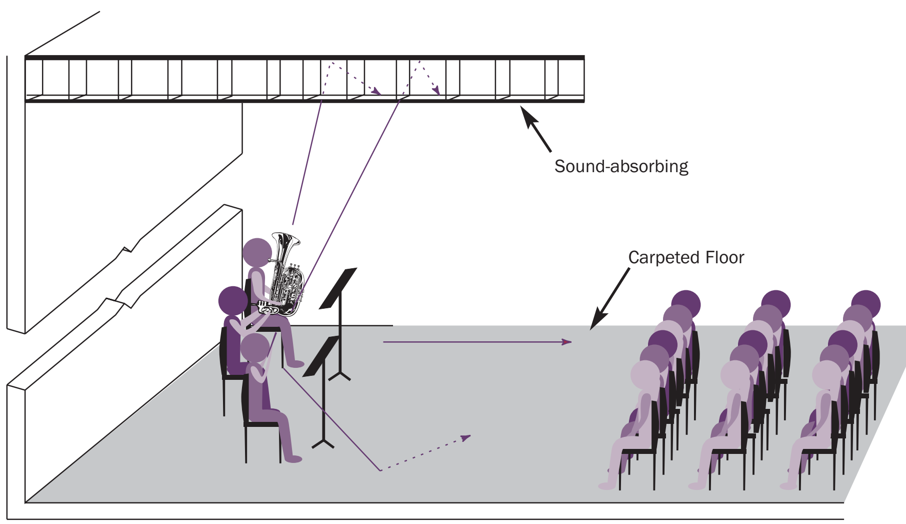


Figure 18 A suspended sound-absorbing ceiling and carpeted floor can overly absorb sound making listening difficult for both performers and audience

On the other hand, a "live" room reflects too much sound energy, due to hard reflective surfaces on the floor, walls and ceiling. Live rooms are stressful for both performers and the audience - in some cases, over time the high levels of sound energy in a live room may cause permanent hearing loss.

RECOMMENDATIONS - PANELS & SEATED RISERS

If cafetorium has a carpeted floor and a low ceiling of suspended acoustical tile, it likely will be acoustically "dead." To improve acoustics for music, you could remove the carpet and replace the sound-absorbing tile over the performance area with sound-diffuser panels (see Figure 19).

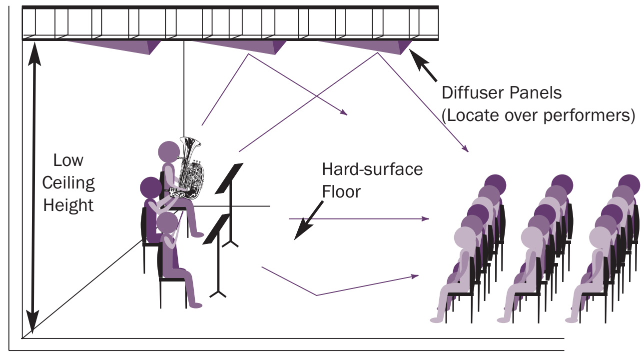


Figure 19

To improve sightlines and hearing for the audience, portable tiered audience seating may be a solution. In a tiered configuration, audience members also would be in a better position to help absorb sound in a "live" room (see Figure 20).

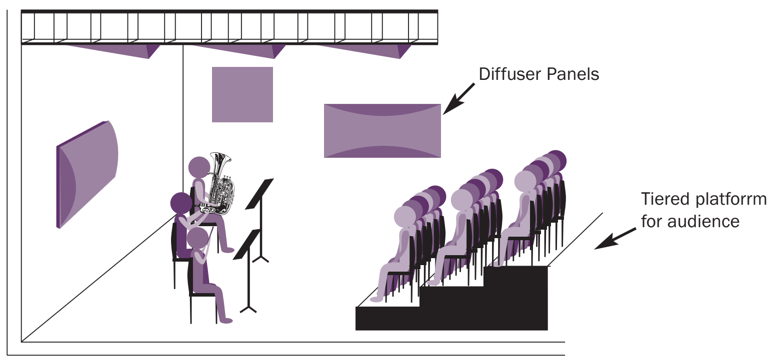


Figure 20

If your cafetorium space is more on the "live" side, rear wall and ceiling treatments with absorber and diffuser panels will improve the acoustics. If your cafetorium is also used for physical education, be sure the panels are impact resistant.

PERFORMANCE SPACES

gymnasiums

A gymnasium is a challenging acoustical environment for musical performance. Although a gymnasium has some physical benefits, such as ample cubic volume and space for performers, equipment and audience members, it presents a variety of acoustical challenges. Hard-surface walls, floors and bleachers that are separated by large distances create distinct echoes and excessive reverberation. A gym usually is too large and too reverberant for most musical performance. Achieving an intimate performance environment is very difficult due to the following effects that occur when performing in an untreated gymnasium:

Reverberation

Reverberation is the persistence of sound that affects the character and quality of music. The sound of a band in a gymnasium is reverberant because it is reflected many times before it dies away. The same music played outdoors does not reverberate because there are no walls or ceiling to contain it. Strategically placed absorbers are required to control excessive reverberation and noise buildup in a gymnasium.

Echoes

Echoes are produced when hard surfaces reflect sound to a listener long after the direct sound from the original source has been heard. Although absorbers and diffusers can be used to control echoes, diffusers are generally preferred when longer reverberance is desired.

Flutter

Flutter occurs when a sound source is between parallel, sound-reflecting surfaces. A rim shot played on a snare drum inside an untreated rectangular space will produce the prolonged, buzzing sound of flutter. Diffusers are generally the best cure for flutter.

STAGE AREA

Hard-surface walls, floors and bleachers that are separated by large distances create distinct echoes and excessive reverberation. Normally a gym is too large and too reverberant for most musical performances (see Figure 21).

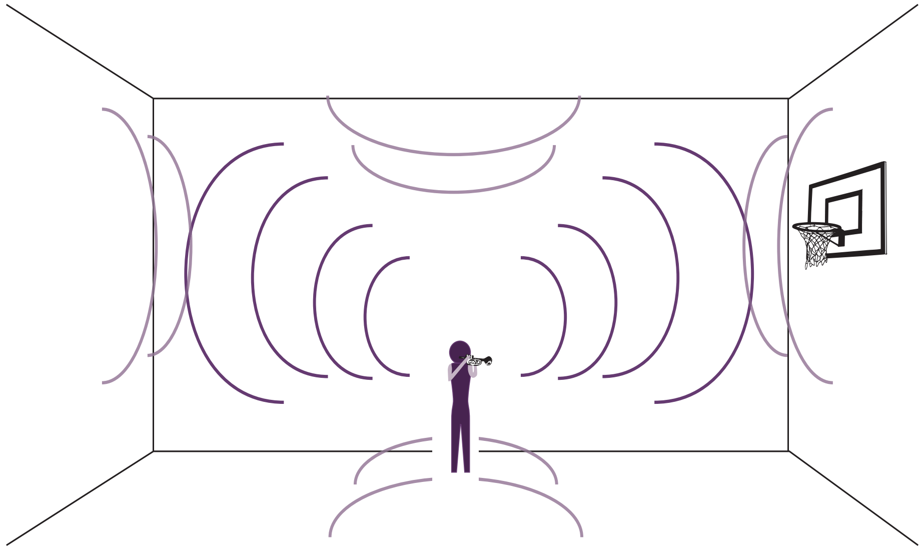


Figure 21 Sound buildup in a gymnasium

RECOMMENDATIONS - PORTABLE SHELL

Because gymnasiums are so large, most reflections are too delayed to be musically supportive. Reflective surfaces are needed near the musicians. Since backing up the musicians against a wall may not be possible, you will need to surround the back of your performers with acoustically reflective surfaces. For example, an acoustical shell behind your performers will return early reflections to musicians so they can hear themselves better. Musicians will be better able to focus on phrasing, timing and intonation, and to perform as a cohesive group (see Figure 22).

The more massive and rigid the shell material, the more a shell will be able to reflect low frequency sound. Heavier shells are essential for bands and orchestras, which generate a broad range of frequencies and high levels of sound energy. Because choral groups typically produce sound at higher frequencies and lower levels of sound energy, they can perform in shells that are less heavy.

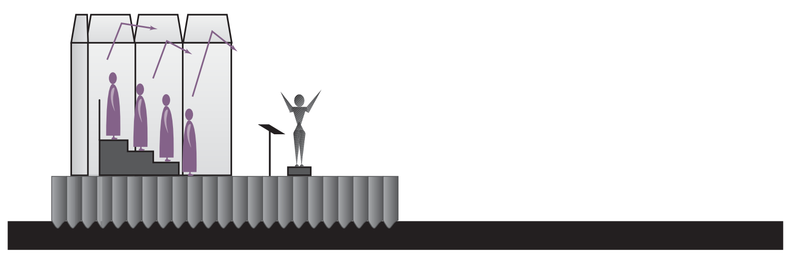


Figure 22 Early sound reflections from portable acoustical shells are essential to good ensemble

RECOMMENDATIONS - STANDING RISERS

If possible, utilize risers or staging so performers will project sound out into the audience, not onto the backs of other performers or toward bottom rows of bleachers. When the performers and audience are on a flat surface, sound will be absorbed as it grazes across performers and rows of the audience. Only a portion of the audience will clearly hear the performance. By elevating the performers, you will improve projection into the audience. Risers also greatly improve sightlines to the director and audience (see Figures 23 and 24).

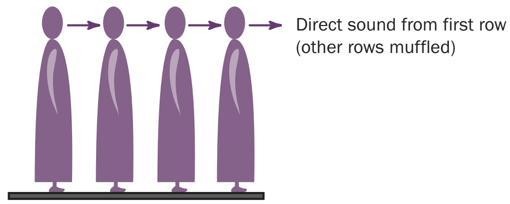


Figure 23 Lack of risers or staging significantly reduces projection

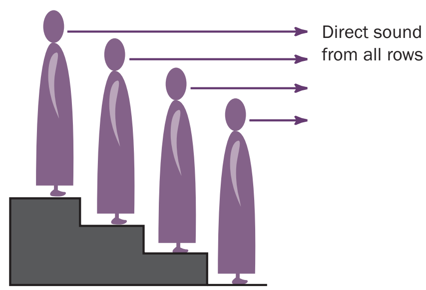


Figure 24 Risers improve sightlines and projection

AUDIENCE AREA - REVERBERATION

In a gymnasium, a variety of acoustical challenges can compromise the ability of your audience to hear and enjoy music performances. Most gymnasiums create excessive reverberation. The large volume of the space, along with dense, hard surfaces on the floor, walls and ceiling result in a significant lack of clarity.

Reverberation refers to the persistence of sound in an enclosed space and is measured in the time it takes sound to decay to inaudibility. As sound reflects off of the hard surfaces in a gym, very little sound is absorbed, which lengthens the decay time of every sound produced. This “sound-cycle” is repeated many times per second causing sounds to overlap.

AUDIENCE AREA - REVERBERATION

Compounding the problem is the large size of the space. Powerful distant reflections (echoes) off far walls and ceiling surfaces will return to the audience and musicians long after the early reflections from sounds just produced. The result is a muddy indistinct confusion of sound that makes ensemble among the performers difficult and compromises the audience's enjoyment (see Figure 25).

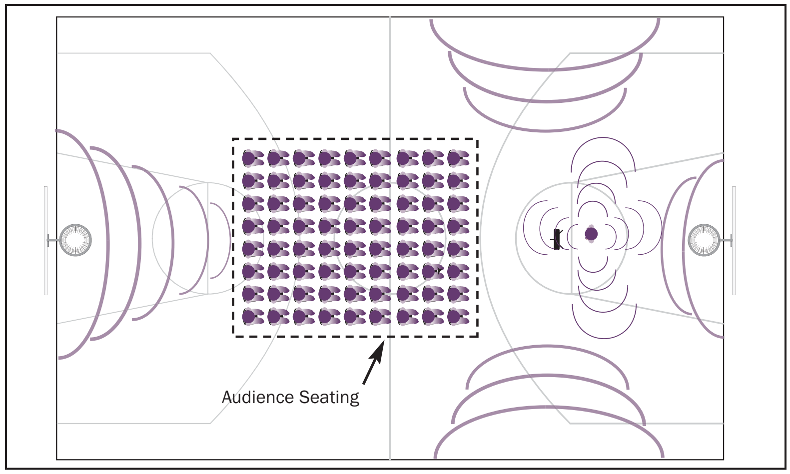


Figure 25 Hard, sound-reflecting surfaces and large cubic volume create excessive reverberation

If the performance is in a multi-purpose gymnasium with retractable walls, use only the space that is needed for the performance. By closing walls, excess reverberation is reduced (see Figure 26).

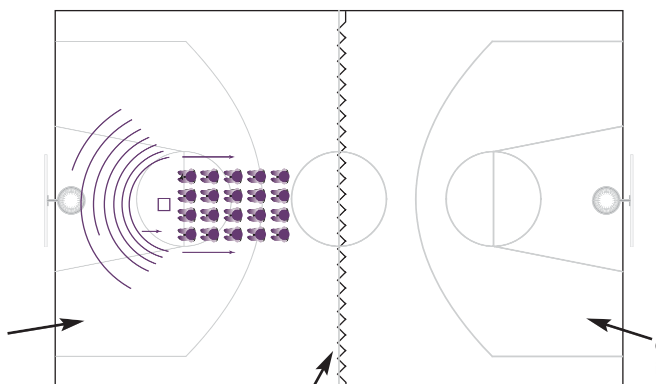


Figure 26

Of course, no other activities should be going on in the unused space, or the performance could be jeopardized with unwanted noise. Make sure that sources of noise such as telephones and intercoms are turned off prior tothe performance. Be careful not to turn off fire alarms or other required warning systems.

RECOMMENDATIONS

If your gymnasium has stackable bleachers on the walls, pull these out slightly to add diffusion to the room. The multi-level, broken surface will help to better scatter and redirect sound throughout the space (see Figure 27).

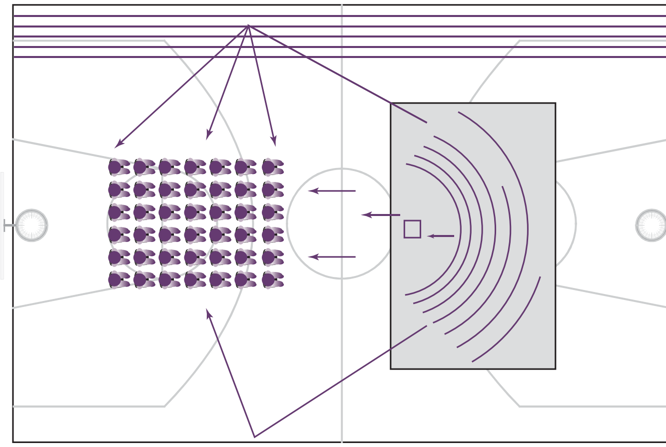


Figure 27 Pulling out retractable bleachers provides some diffusion

In contrast, with the bleachers folded against the wall, the flat reflective space will increase the likelihood of flutter or slap echoes in the gym (see Figure 28).

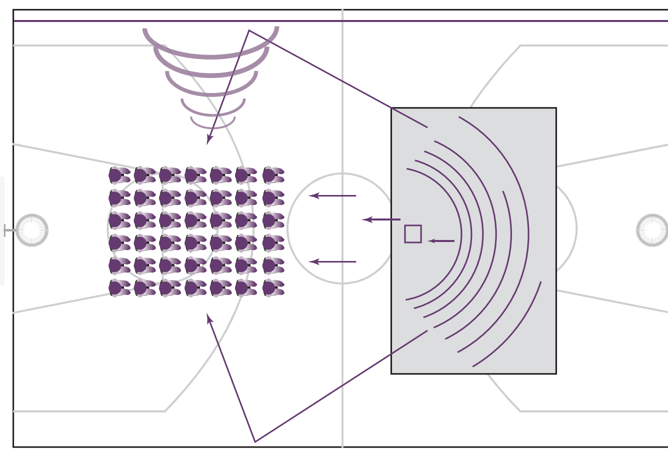


Figure 28 Bleachers in the flat storage position will not diffuse sound across an audience. In addition the facing parallel surfaces create distracting flutter echoes

Controlling Noise Buildup

Large gymnasiums and cafetoriums can be extremely noisy. Guidelines to control noise buildup follow.

- Use sound-absorbing materials to control noise buildup and excessive reverberance. Place sound-absorbing materials on the ceiling and upper wall surfaces. Evenly distribute sound absorption on all walls.
- Do not use sound-absorbing materials on surfaces that should reflect sound, such as area of ceiling over stage platforms.
- Architect should be sure installation method will provide desired absorption. For example, an airspace behind a sound-absorbing panel will increase absorption of low-frequency sound. Actual mountings in rooms should be the same as ASTM standard mounting used to determine absorption coefficients in laboratory testing.
- Be careful, the noise reduction coefficient (NRC) is an average number, rounded to the nearest 0.05 increment. It does not account for absorption at low frequencies (below 250 Hz) or high frequencies (above 2000 Hz).
- Before specifying a material, architect should evaluate the absorption coefficients across the frequency spectrum. Always specify absorption performance of a material along with the corresponding mounting method.

RECOMMENDATIONS

The audience will play a significant role in the absorption of sound in the room. The more people there are, the more absorption there will be. People tend to absorb mostly high frequency sound; they will not affect the low and mid-frequencies as much. As a result,low notes might persist longer than high notes.

If your space is flexible, it is best to arrange audience seating in a long, narrow configuration (see Figure 29). Performing in the "wide mode" does not allow for the best acoustic experience for the audience. The side walls provide important lateral (side) reflections to the audience, which increase the feeling of envelopment.

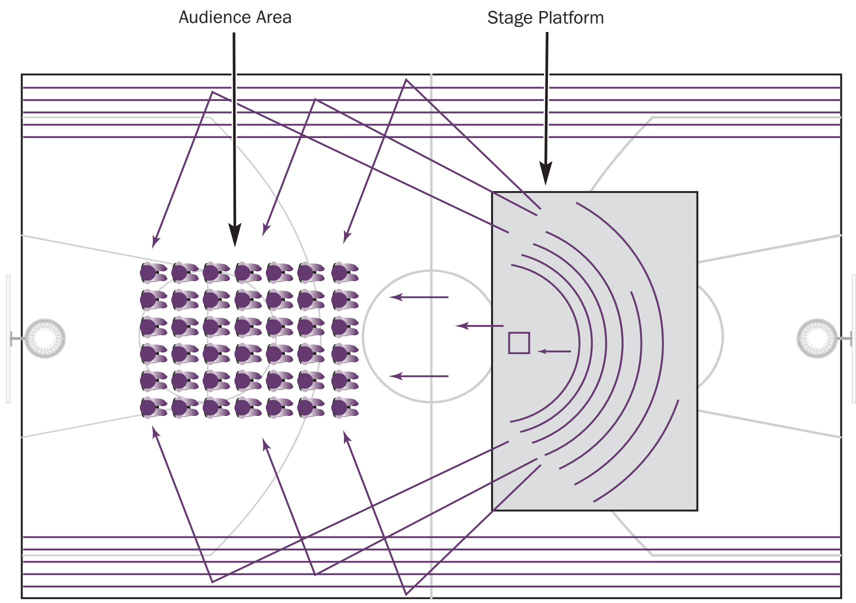


Figure 29 Long, narrow seating provides the best listening experience for audience. Elevating performance group using a portable stage will improve sightlines as well.

MECHANICAL NOISE - LIGHTING

Gymnasium lighting systems often have electromechanical ballasts that produce a loud, buzzing sound (see Figure 30).

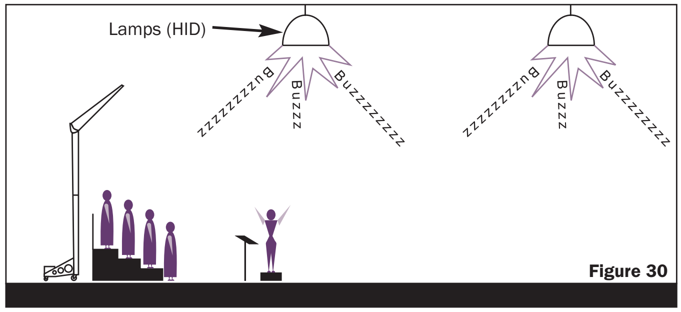


Figure 30

If possible, turn these lights off during your performance, and use temporary theatrical lighting. An added benefit of theatrical lighting is the creation of an appropriate mood that differs from sporting events. Some suggestions follow:

- Make sure that you have enough electrical power or separate circuits. Theatrical lighting typically requires a significant amount of power.
- Incandescent lamps are the quietest sources of electric light.
- Fluorescent ballasts are rated from A to F (A-rating is the quietest under test conditions). Refer to National Electrical Manufacturers Association (NEMA) reports for noise rating of HID lamps.
- Be careful not to set-up your lighting on a dimmer circuit. Many inexpensive dimmers cause filaments to “sing” or “buzz”.
- For lighting system, use modern low-noise dimming components specifically designed for performance environments.
- Work with your building maintenance staff and an electrical engineer to determine the best way to reduce noise from the lighting system.

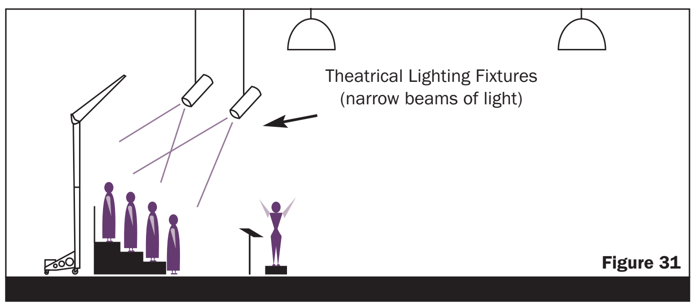


Figure 31

MECHANICAL NOISE - HVAC SYSTEMS

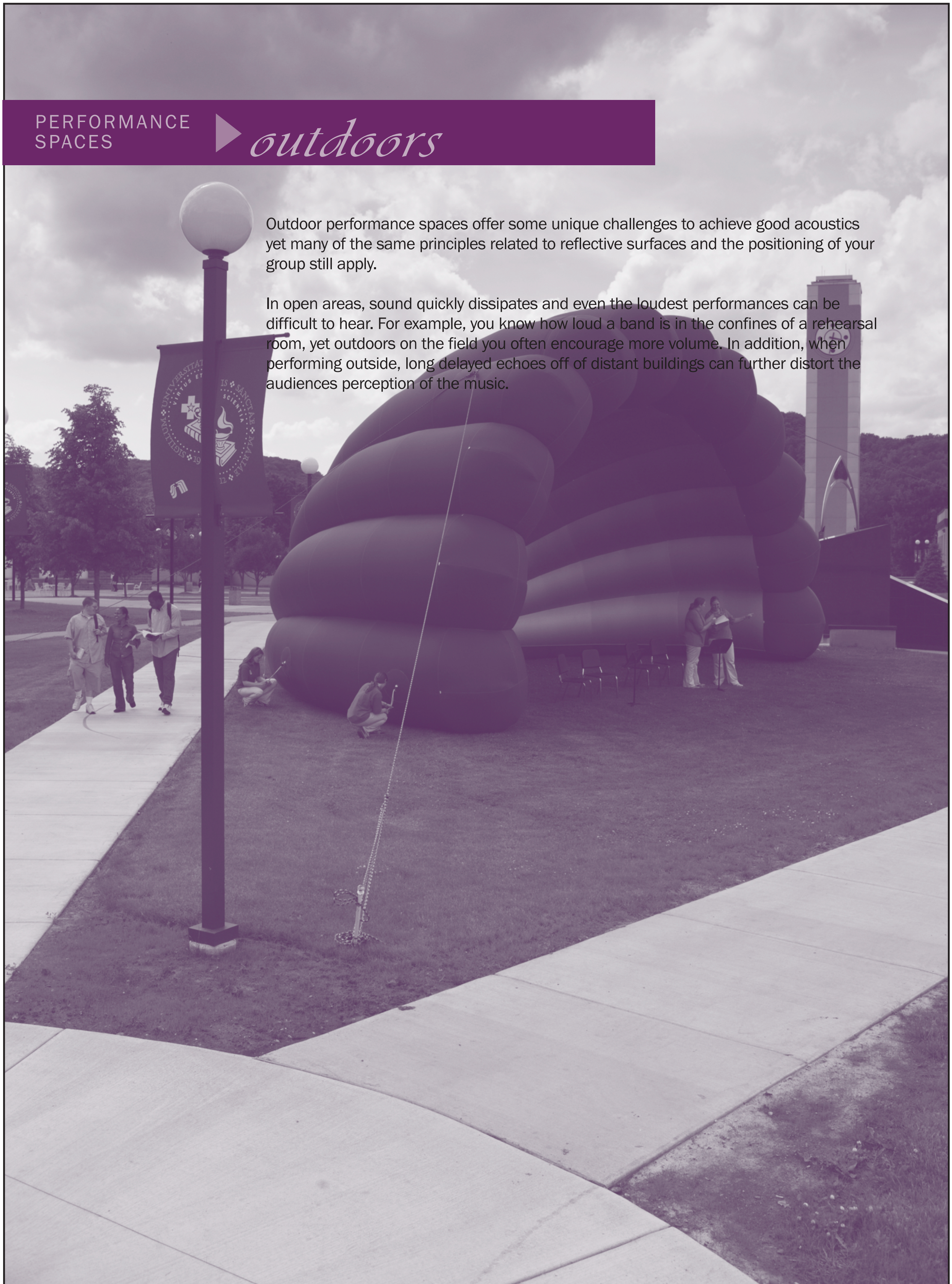
HVAC systems in gyms can be very noisy and distract from your performance. Adjustments to reduce noise, while maintaining adequate ventilation, include using larger size ducts and changing the air outlets (called diffusers or registers) to a more open design (producing less of a "whooshing" sound).

Disruptive sounds (hisses, hums, roars) from mechanical systems must be isolated from performance spaces. The following guidelines should be passed along to your project’s mechanical engineer.

- Use buffer spaces (such as storage areas, toilet rooms, corridors) to isolate loud mechanical rooms from noise sensitive spaces. Enclosing constructions should be designed and built to achieve high levels of sound isolation.
- Support mechanical equipment on thick slabs. Use unhoused steel springs and/or resilient pad isolators to break the path of vibrations.
- All pipe and duct penetrations through walls, floors, and ceilings of mechanical rooms must be sealed airtight. Leave continuous gap around perimeters of pipes and ducts. Fill gap with low-density fibrous insulation and caulk both sides with non-hardening sealant.
- The mechanical engineer should design air-distribution systems to have low air velocities at both supply outlets and return inlets and not to have abrupt turns and transitions. Layout air ducts so sound cannot be transferred between rooms.
- Round or flat oval duct cross-sections radiate less low-frequency rumble than square or rectangular cross-section ducts.
- In most systems, duct silencers and/or sound-absorbing duct linerboard will be required in the main supply and return air ducts.

PERFORMANCE SPACES

outdoors



Outdoor performance spaces offer some unique challenges to achieve good acoustics yet many of the same principles related to reflective surfaces and the positioning of your group still apply.

In open areas, sound quickly dissipates and even the loudest performances can be difficult to hear. For example, you know how loud a band is in the confines of a rehearsal room, yet outdoors on the field you often encourage more volume. In addition, when performing outside, long delayed echoes off of distant buildings can further distort the audiences perception of the music.

RECOMMENDATIONS - PORTABLE SHELL

A shell structure is essential to provide the early reflections needed for ensemble and controlled acoustical support. When using a portable shell outside, make sure that it is designed for outdoor use. An outdoor shell requires additional anchor treatments to secure the panels against wind and other forces (see Figure 32).

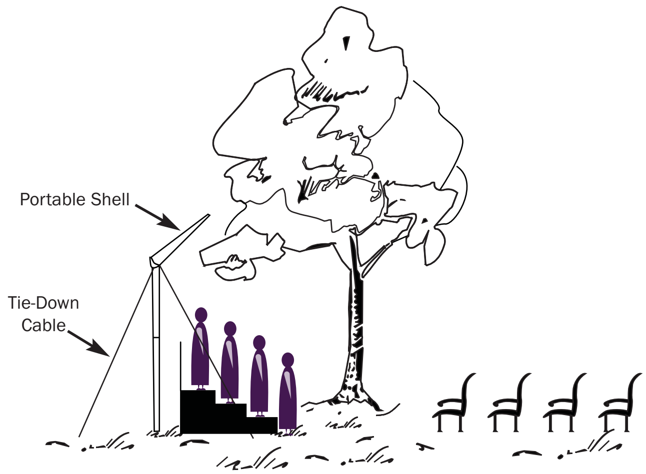


Figure 32 Multiple tie-downs ensure the safety of the performers

RECOMMENDATIONS - INFLATABLE SHELL

Inflatable shells provide all the acoustical benefits associated with a portable shell systems and will create an impressive outdoor setting. Make sure that you follow all the manufacturer's setup guidelines (see Figure 33).

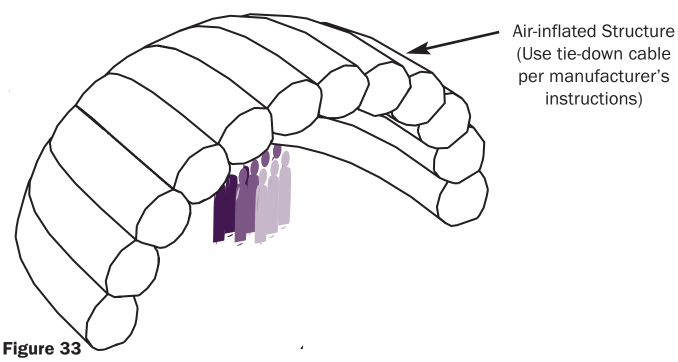


Figure 33

RECOMMENDATIONS - WITHOUT A SHELL

If a shell is not available, position the group in front of a large, solid wall that can provide adequate reflection. Recognize that achieving optimal acoustics is most difficult when you perform out in the open, without any reflective surfaces (see Figure 34).

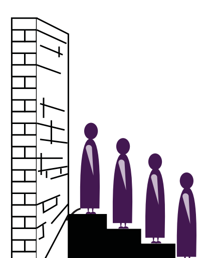


Figure 34 Solid wall, preferably no openings at windows

RECOMMENDATIONS - WITHOUT A SHELL

Trees and shrubbery absorb high-frequency sound and do not act as good reflectors. If possible, place your performers on a sidewalk, paved parking lot, or other hard surface to improve acoustical support. Some guidelines follow.

- Avoid shrubs, grass, or other soft groundcover in front of performers.
- Use vinyl-coated canvas tents to create good outdoor performance venues.
- If tent surfaces are taut, the roof and side curtains can provide adequate reflection of high-frequency sound.
- Make sure the sides surrounding the performers are closed and secured in place.

RECOMMENDATIONS - CONTROLLING OUTDOOR NOISE

Outdoor Noise Controls

Select a quiet site far away from noisy streets and highways. If this is *not* possible, use the following strategies to control outdoor noise.

- Take advantage of natural shape of terrain and location of nearby buildings to shield audience from noise. The "line-of-sight" from noise sources to the audience must be blocked.
- Consider constructing physical barriers such as high walls or earth berms to reduce noise. Reduction can be up to 15 decibels (dB), depending on sound frequency, barrier height, continuity and mass. Sometimes barrier walls can be used in combination with earth berms.
- Place barrier as close as possible to either the noise source or audience (least effective location is mid-way).
- Use dense vegetation to reduce noise. Some plantings of trees and shrubs can reduce noise by 0.12 dB per meter. Extending depth of planting beyond 150 feet may not greatly increase reduction of noise.
- Driveway and walkway surfaces should be smooth asphalt, *not* rough concrete which can *roar* or gravel which can *crackle* when driven on.
- Asphalt rubber and polymer asphalt surfaces can be 5 dB quieter than conventional asphalt surfaces.

RECOMMENDATIONS - SOUND REINFORCEMENT

Even if you have the luxury of a band shell, getting your sound out to a large audience will still require sound reinforcement. One of the best ways to overcome the acoustical problems of outdoor musical performances is to use a sound system designed to boost volume and project sound. An underpowered system or amateur sound technician can destroy all of the planning and expectations for these events if the speakers and musicians cannot be heard. Not only will an underpowered system fail in projecting adequate volume, the sound will also lack clarity. The best results will come from a well-powered system mixed by an experienced sound technician at a control board located in the audience area.

sound systems

Sound systems may be used in conjunction with music performances to enhance the projection of a soloist or other special part of a performance. It is important to use a qualified sound technician so that the enhanced sound does not become overbearing. The technical staff should understand the philosophy of "sound reinforcement" rather than "sound creation”.

Use of Electronic Sound Systems

- Maintain the correct acoustical balance during performances. The goal is to amplify enough sound to help reinforce the music, not to “over-enhance” or alter the performance.
- For rock concerts and other musical styles, the sound system is a key element of the performance, often over-enhancing the natural sound. Loud outdoor events must comply with local noise ordinances.
- Be sure sound system is turned off when not in use, especially if it produces excess noise, such as a “buzz” or “hiss”.
- Ensure that sound system is designed for music (reinforcing the range of sound from low frequencies to high frequencies) and not just for voice amplification.

FIXED POSITION SYSTEMS

Sometimes the acoustical limitations in an existing facility cannot be resolved using acoustical shells, overhead panels and wall panels. For example, some older halls have intricate architectural and decorative features that you would not want to cover with acoustical treatments. In newer facilities, the acoustical treatments that are necessary for musical performance are not the types of treatments that improve the hall for lectures or theater. An in-house sound system used in conjunction with on-stage acoustical towers is often a feasible solution. Good electronic sound-reinforcement systems can improve performance sound quality, but can not overcome inadequate acoustical treatment in your performance space.

A “central” loudspeaker system, where a loudspeaker cluster is located above the source of sound, is preferred because it can provide optimum realism and intelligibility. A “distributed” system, with several loudspeakers supplying low-level amplified sound from different locations, should be used in auditoriums that have low ceiling height. To avoid feedback, microphones must be positioned out of the coverage of loudspeakers (see Figure 35). Sound systems should be designed and specified by a sound system engineer. Refer to “Finding Acoustical Professionals” at the end of this guide.

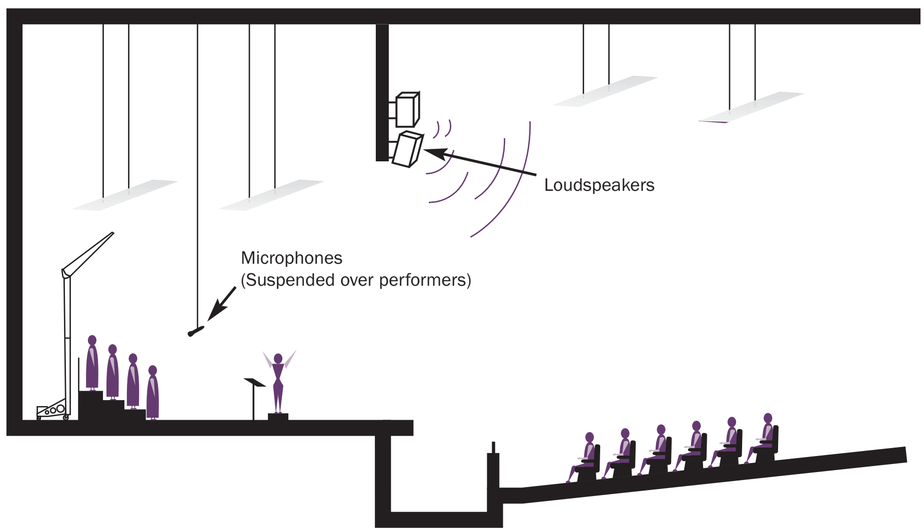


Figure 35 Loudspeaker array best positioned slightly ahead of performers to enhance “realism” of sound. Pick up microphones can be hung overhead

PORTABLE P.A. SYSTEMS

Many times, portable P.A. systems will be used in gyms and cafetoriums (see Figure 36).

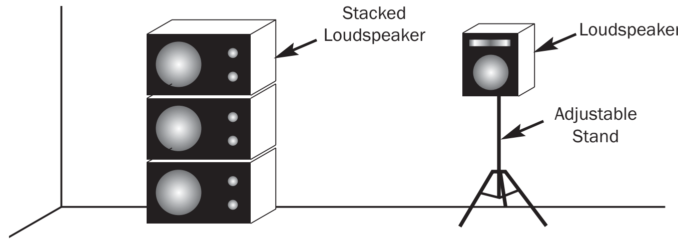


Figure 36

The same operating principles apply to those systems. However, there are some key differences from a fixed, house system. Here are some suggestions:

Use of Portable Sound Systems

- To avoid feedback, loudspeakers always must be in front of microphones.
- Proper use of microphones is essential. Most modern microphones require "close micing," which means the vocalist and instruments must be within one inch of the microphone. [For fixed house systems, use "shotgun" type microphones for large ensembles.]
- Make sure the height of the speakers is at, or slightly above, the heads of the audience, even when standing.
- Angle loudspeakers to point toward the audience area, not toward the side walls (see Figure 37).

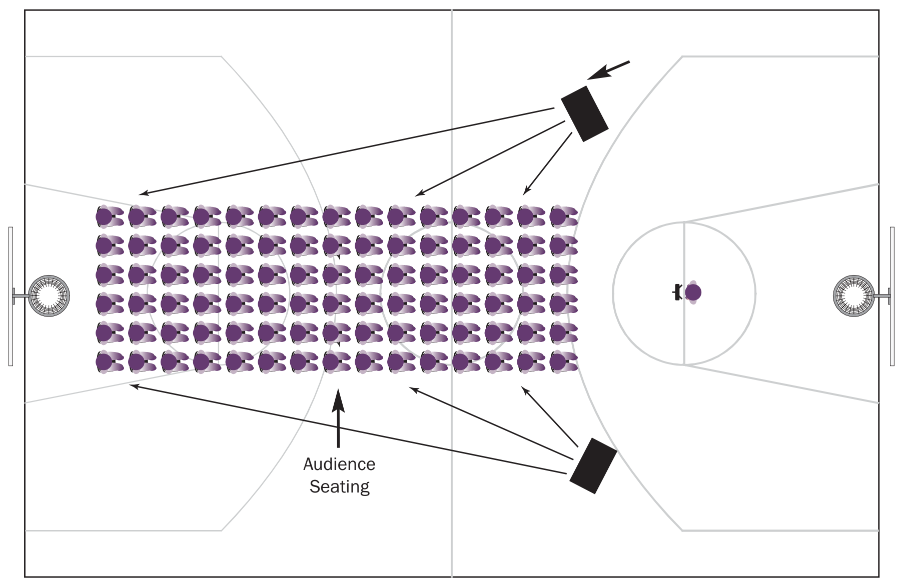


Figure 37 Loudspeakers aimed toward audience

There are many helpful books on the general operation of electronic sound systems. Please refer to "Recommended Reading" at the end of this guide.

NOTES

TABLES

The following are recommended guidelines for preferred reverberation times.

PREFERRED REVERBERATION TIMES*	
Room	Reverberation Time (seconds)
Choral Rehearsal	<1.3
Band/Orchestra Rehearsal	0.8 - 1.0
Performance Area (occupied)	1.3 - 2.2

*Wenger, Planning Guide (1998), p. 13.

The following are recommended guidelines for stage & pit area layout.

STAGE & PIT AREA LAYOUT GUIDELINES*	
Performance	Floor Area (sq ft per person)
Orchestra and Band on Stage	20 to 30
Orchestra in Pit	14 to 20
Choir, Standing	3 to 4
Choir, Sitting	7 to 9

*Wenger, Planning Guide (1998), p. 37.

The following are recommended guidelines for rehearsal room planning.

REHEARSAL ROOMS PLANNING GUIDELINES*			
Room	Size (students)	Floor Area (sq ft per musician)	Ceiling Height (ft)
Choral Rehearsal	60 to 80	20 to 25	16 to 20
Band/Orchestra Rehearsal	60 to 75	30 to 35	18 to 22

*Wenger, Planning Guide (1998), p. 50.

The following are recommended guidelines for auditorium planning.

AUDITORIUM PLANNING GUIDELINES*	
Dimension	Criterion
Width	<80
Height to Width ratio (H/W)	>0.6
Volume to Seat ratio (V/N)	300 to 400 cu ft per seat

*Beranek, Concert and Opera Halls (1996) and Egan, Architectural Acoustics Workbook (2000), p.4.21.

CREDITS

Technical content of the Guide was reviewed by Dr. M. David Egan, Distinguished Professor of the Association of Collegiate Schools of Architecture (ACSA) and Emeritus Fellow of the Acoustical Society of America (ASA).

GLOSSARY

Active Acoustics
Also referred to as electronic architecture or "virtual acoustics." Electronic devices (such as microphones, loudspeakers, digital signal processors) are used to enhance the natural acoustics of a space. Effective active acoustics are also dependent on the correct room treatment with passive acoustics.

ASTM
American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

Brightness
The relative loudness of the higher frequencies (treble pitches) to the mid-frequencies.

Clarity
The ability to hear detail and definition in the music.

Decibel (dB)
The unit used to express the level or "strength" of sound. Sound levels can range from threshold of hearing at 0 dB to threshold of pain at 130 dB. Unamplified music is between these extremes.

Echoes
Echoes are produced when hard surfaces reflect sound to the listener after the direct sound from the source has been heard. For example, horn sections on stage may create a distracting echo off the back wall of an auditorium. Although both absorbers and diffusers can help correct this type of echo, diffusers are generally preferred because more sound energy will be conserved.

Ensemble
To most people, the word "ensemble" only means a group of musicians performing together. However, music educators use the word to describe a balanced, blended sound that unifies a group. The result is like the Latin saying found on U.S. coins, E pluribus unum — "Out of many, one." Achieving true ensemble is the result of more than just effective rehearsals and individual practice. To get the desired ensemble result, musicians must be able to hear themselves and each other.

Envelopment
The feeling of being immersed in the sound and surrounded by the music.

Flutter
Flutter echoes occur when a sound source is situated between parallel, sound-reflecting surfaces. The effect is a prolonged buzzing sound. For example, a rim shot off a snare drum in an untreated room will produce a distinct flutter echo.

HVAC
Heating, ventilating, and air-conditioning.

Intimacy
The auditory impression of the apparent closeness of the performers. For example, does the music sound "close" or "distant"?

Loudness
How strong the sound is. Do the performers sound normal, or is the sound weak or "small" for the space?

Masking
Masking occurs when an unwanted noise conflicts with or masks a musician's ability to hear musical sounds of a similar or higher pitch. For example, the whooshing noise of air coming out of an air supply duct can mask musical sound.

NEMA
National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1752, Rosslyn, VA 22209.

Noise Criteria (NC)
A single number rating to quantify the level of background noise. The lower the NC, the quieter the space.

Noise Isolation Class (NIC)
Similar to STC, but takes into account all parts of a structure enclosing a room. The higher the NIC, the greater the sound isolation between rooms.

Noise Reduction Coefficient (NRC)
A single number describing the average amount of absorption (measured in percent of perfect absorption) at octave band frequencies of 250Hz, 500Hz, 1kHz and 2kHz. It provides a good estimate of absorption when used for the speech range, but has limited value when used for music applications since it ignores frequencies below 250Hz and above 2kHz.

Passive Acoustics
This term refers to the use of architectural (non-electronic) design and acoustical surface treatments to create a musical space. Primarily broken down into absorptive and diffusive properties, elements such as geometric wall and ceiling shape and acoustical panels on walls and ceilings are examples of passive acoustics.

Reflection
Sound reflection off a hard surface can be compared to the reflection of light off a mirror. Without reflective surfaces such as acoustical shells and overheads on a proscenium stage, for example, sound energy may be dissipated or absorbed without ever reaching the audience.

Reverberance
The perception of the "liveness" of the sound, or the sound's persistence.

Reverberation
The persistence of sound in an enclosed space measured in time from the instant the sound is generated to inaudibility.
As sound reflects off of the hard surfaces in a gym, very little sound is absorbed, which lengthens the decay time of every sound produced. This “sound-cycle” is repeated many times per second causing sounds to overlap, thus losing clarity.

Sound Isolation
Sound Isolation measures a room's effectiveness at keeping desired sound in, and preventing unwanted outside noise from intruding. Inadequate sound isolation can seriously compromise your performance's acoustic environment. Ideally, you should eliminate all potential sound leaks, both into and out of your performance space. This should apply to areas as small as the electrical outlet on the wall.

Sound Transmission Path
Air borne: Sound that is transmitted through the air than strikes a barrier and is retransmitted on the other side.
Structure borne: See definition of “Structural Flanking.”

Sound Transmission Class (STC)
Sound Transmission Class is a single number rating system used to describe the amount of sound isolation provided by a construction element (i.e. wall, door, window). Typically the STC rating best represents ability of a construction to isolate speech. The higher the STC number, measured in the lab, the greater the sound isolation by the construction element.

Structural Flanking
Sound that is transmitted by direct contact with the sound source, such as vibrating HVAC equipment attached to a building surface or the legs of a ground piano in contact with the floor.

Warmth
Also referred to as bass warmth, the relative loudness of low frequencies (bass pitches) to mid-frequencies.

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FINDING ACOUSTICAL PROFESSIONALS

Contact: Acoustical Society of America (ASA)
2 Huntington Quadrangle, Suite 1N01
Melville, NY 11747-4502
(516) 576-2360 Fax: (516) 576-2377
Website: www.asa.aip.org

Contact: National Council of Acoustical Consultants (NCAC)
7150 Winton Drive, Suite 300
Indianapolis, IN 46268
(317) 328-0642 Fax: (317) 328-4629
Website: www.ncac.com

Contact: Wenger Corporation
555 Park Drive
P.O. Box 448
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