THE INFLUENCES OF THEATRICAL SETS ON ACOUSTICS

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Successful and cohesive theatercraft must engage and accommodate the needs of multiple disciplines, not the least of which is carefully considered set design. The way that sound interacts with a set influences the life of the performance.

This paper is an exploratory article aimed at encouraging the design team to consider how best to avoid often-repeated acoustical mis-steps and optimize set design elements to help ensure acoustical success for every production, especially in acoustic (unamplified) environments.

The author will draw on his recollection of various performances, and commenting on the experiences of others regarding set shaping, reverberation, and performer blocking.

GENERAL ACOUSTIC CONCERNS IN THE THEATRE

The three main concerns that an acoustician generally has regarding acoustics in the theatre are surface shaping for specific reflections, overall room reverberance (the duration of sound once it's stopped), and background noise. Unless each of these key elements are correctly addressed, risk looms large that speech intelligibility will suffer and poor reviews could result.

Reflections help sound propagate throughout a space, and if handled correctly, will naturally reinforce a performer's voice. Acousticians pay close attention to reflections from wall surfaces in both the house and on stage (when possible) to enhance the overall listening experience in an unamplified environment.

If such reflections are too focused or not redirecting reasonably strong energy to the audience, no one receives the potential benefit. In general, surfaces of the order if 16 ft^2 or more are better for generating a wider "spread[1]" than small surfaces, convex surfaces create an even wider "spread" than flat surfaces. On the contrary, concave surfaces should be avoided, as they foster focusing toward their arc's center, thereby "starving" reflected energy from reaching some audience members.

In the case that set shaping is problematic (i.e. concave surfaces), sound absorptive material is often desirable to deaden reflections.

Reverberation can help or hurt the audience's perception of a performance. Excessive reverberation can hinder intelligibility, however in moderate quantities, reverberation can add a beneficial "lift" to a performer's voice, and can be quite a lovely addition.

[1] Spread refers to the coverage area of reflected energy.

Noise, which is a topic beyond this article, is very important to intelligibility. HVAC systems, mechanical equipment, and even noisy lighting and AV equipment contribute to a noise-floor which can decrease an audience member's ability to understand words.

EFFECTS OF REFLECTIONS

A reflection is sound energy that is redirected off a surface. This energy is redirected in a path that mirrors the direct sound energy's angle of incidence. Based on the surface's Noise Reduction Coefficient (NRC), the reflected energy will be decreased in intensity accordingly. NRC values range from near zero (highly reflective) to 1.00 (highly absorptive)

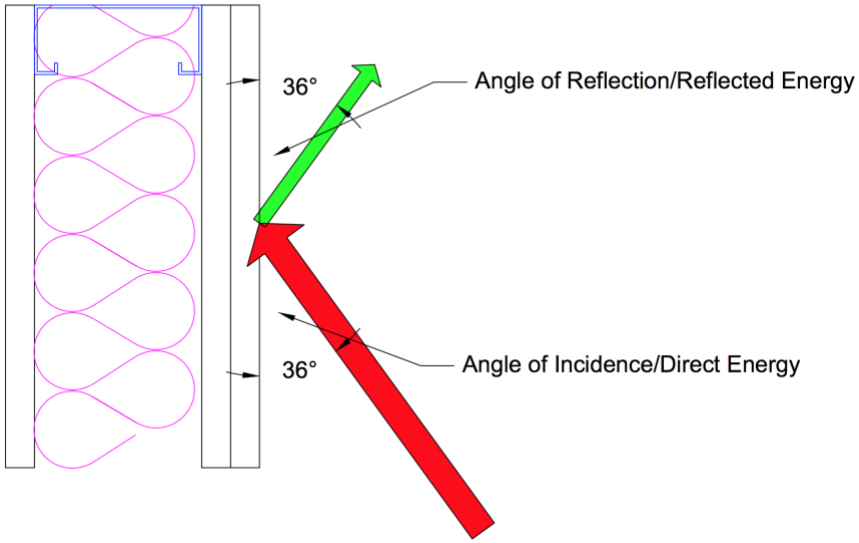
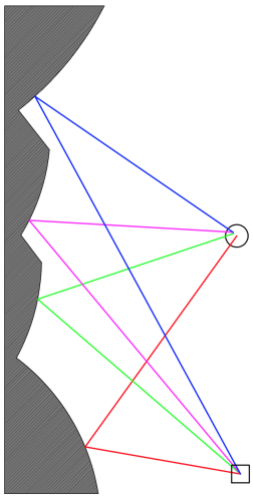


Figure 1: Graphic Example of Reflected Sound Energy off a Wall



In acoustic design, key surfaces are generally analyzed to maximize coverage of an audience. As shown by the image to the left, it is also helpful for audiences to receive reflections from multiple locations. This is possible by carefully angling surfaces to reflect sound energy in overlapping paths. While a complete analysis is not a practical approach in the realm of theatre, some guidelines may be beneficial to those whose first concern is not acoustics.

The image to the left shows a source (square), and a receiver (circle). By carefully angling and curving the shape of the wall to the left of the source and receiver, it can be ensured that the receiver will hear multiple reflections that originate from the source.

1. Shaping

Shaping is the act of maximizing coverage of reflected energy to promote clarity, intimacy, and envelopment. If a theatre is designed without considering shaping, the tendency is for reflections to not be directed in a useful manner. For instance, if the walls in the theatre are angled in a "fan" shape, or even a shoe-box rectangular shape, most of the sound energy will likely be directed along the sidewalls toward the back of the house instead of into the audience. Conversely, if the walls are carefully designed to incorporate greater spread, the space has a greater chance of promoting clarity, intimacy, and envelopment.

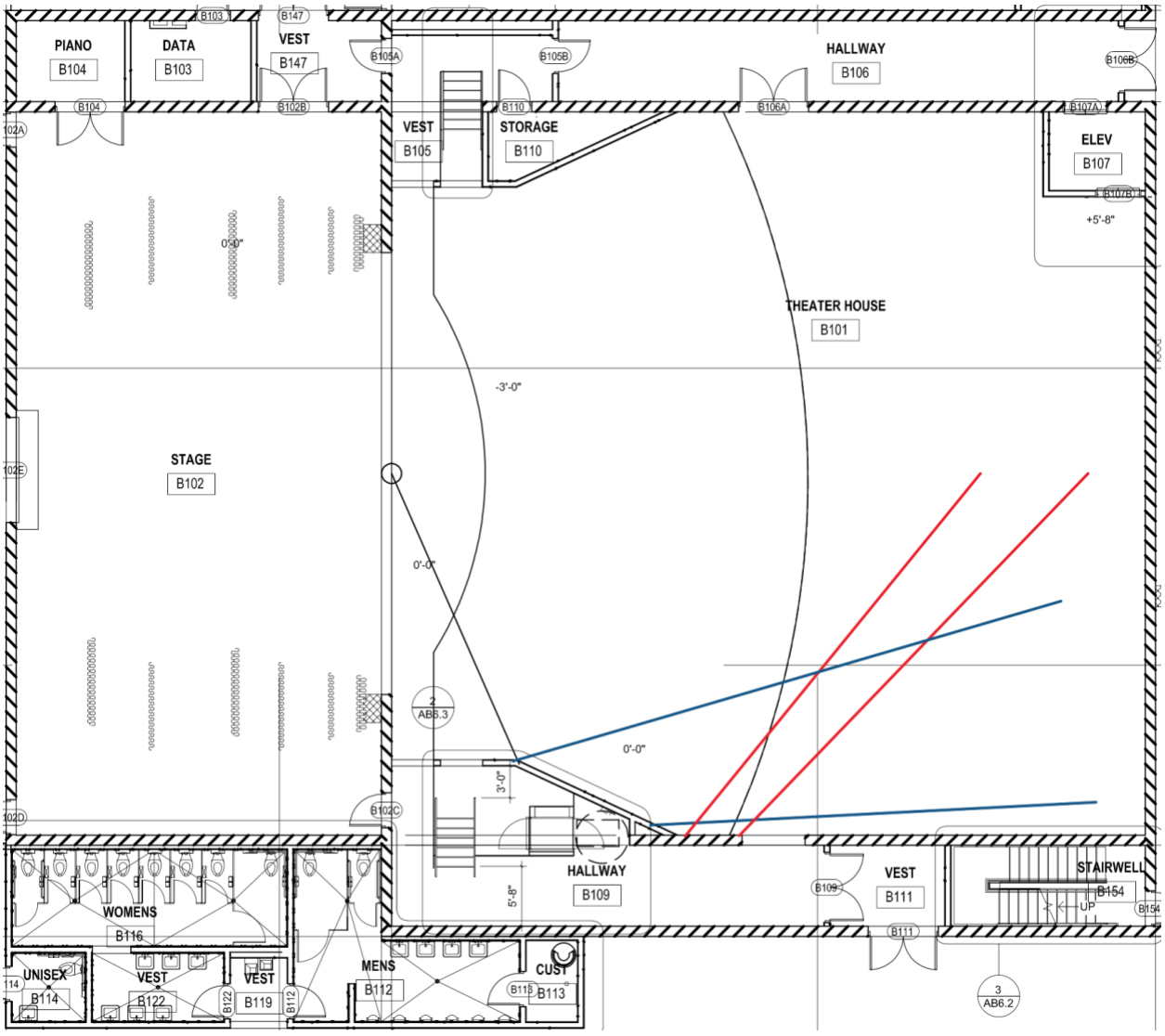


Figure 2: High School Auditorium with No Wall Shaping

As shown in Figure 2, the walls do not allow for great spread throughout the space, and generally push the sound in narrow patterns toward the back wall. In addition, there is very

limited overlap of reflections, meaning that most audience members will only receive one or two reflections.

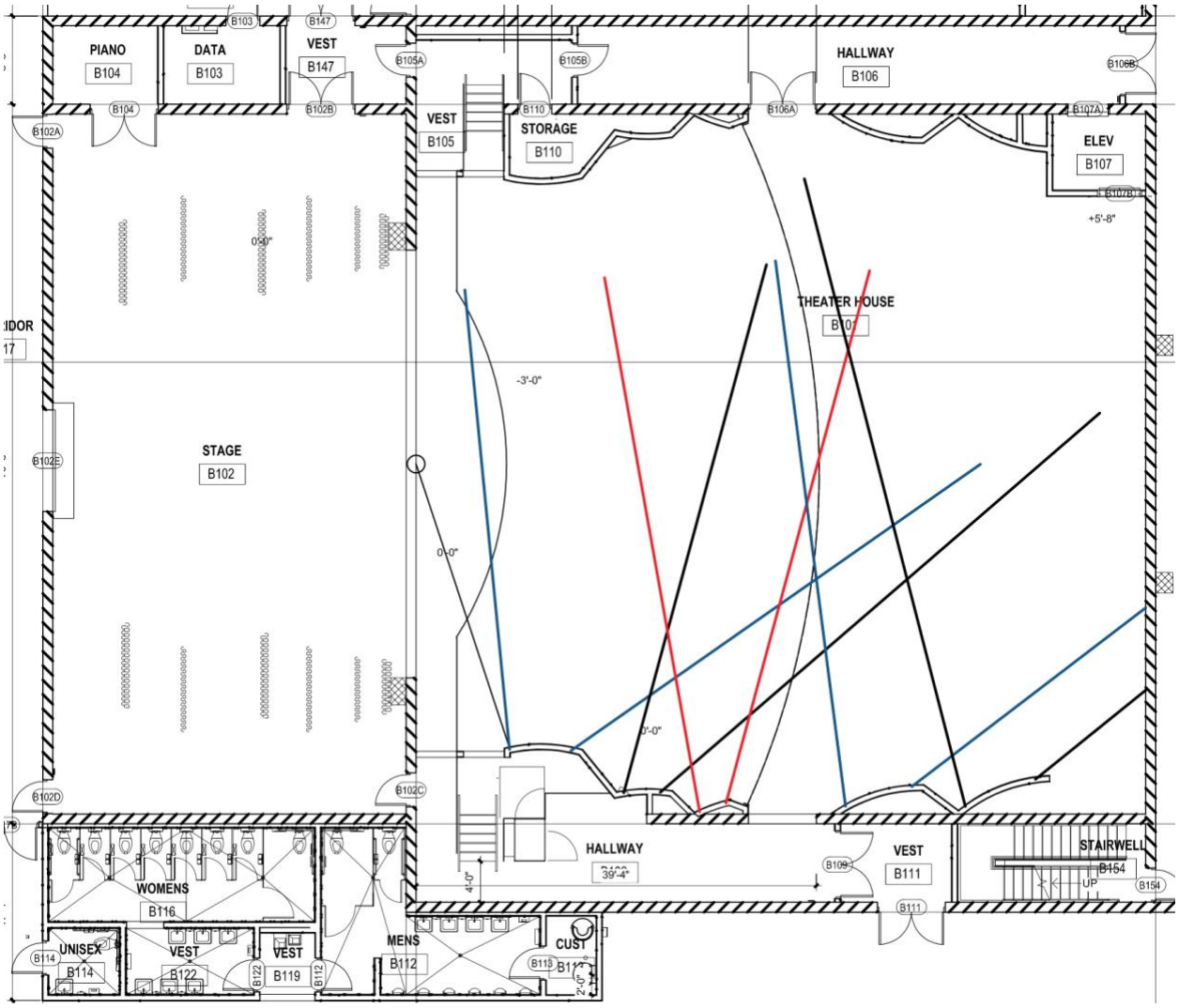


Figure 3: High School Auditorium with Wall Shaping

As shown in Figure 3, the convex wall shaping, and variety in angle allows for the spread of the reflected energy to cover greater area, and have greater overlap meaning that the audience will receive numerous reflections, which is desirable.

These same concepts of wall shaping in a theatre can be applied to the design of a set in order to push sound toward the audience.

Flat Walls vs. Convex Walls

Set designers have decisions to make based on their research, interactions with the design team, as well as prior experience. There are a lot of decisions to be made, and while there are many elements to set design, walls normally provide the most significant (whether for good or bad) impact on the acoustics of a space.

Surfaces close to actors, (i.e. the set, cheek walls, and eyebrows) should typically be angled in a fan-like shape. By angling the surfaces as such, they push the sound downstage toward the audience. As seen above, spread can be maximized by convexly curving walls, and this applies equally to set walls. When appropriate in a design, modestly convex surfaces (e.g. radius 12-20ft) work best acoustically to both spread sound reflections and avoid focusing.

To imagine how convex surfaces are ideal, one can imagine light pointed at a mirror. If the mirror is then bent, the reflected light will be more greatly spread.

Flat walls can be beneficial for directing sound toward the audience when angled outward, however flat walls will not produce even coverage. There will be less variance in the angles of incidence with direct sound energy on flat surfaces.

Concave Surfaces

Broadly concave surfaces are simply to be avoided whenever possible. This is because reflected sound energy is focused to a very specific point, the "hotspot", and has the possibility of coloring the sound and decreasing intelligibility.

If the focal center is aimed toward the audience, there is great potential that a few specific seats in the audience to receive a lot of excess sound energy. This will improve intelligibility for those few audience members. However, other audience members who are out of the arc's focal center would not receive enough reflected sound energy. This can lead to large sections of an audience finding it difficult to understand subtleties in dialogue.

Additionally, concave surfaces have the potential to create onstage reverberation which contributes to poor intelligibility.

Our firm was once called upon to discover why some key seats at Los Angeles' Geffen Playhouse had been receiving multiple patron complaints about unamplified intelligibility at specific seat regions for *Boston Marriage*, while the same seats had been perfectly fine for a raft of other productions. As it turned out, concave surfaces were abundant in the set design and it became readily apparent that these were the culprits. As actors moved about the set they were in and out of these regions that fostered the resultant complaints and the quick changes in intelligibility were stark.

Set retrofits were suggested, including application of highly absorptive materials (high NRC) in specific set regions, of up to 2" thick coated glass fiber, some of which materials could accommodate compound-curvature. Other areas were candidates for coated glass fiber duct liner board, but would be within the line-of-sight of the actors yet out of sight of audience. Additionally, we proposed introducing plush/thick rugs that fit the overall design.

According to a September 2002 issue of *Entertainment Design Magazine*, some shows have incorporated sound absorptive material to reduce onstage noise caused by reverberation.

While direct application of duct liner board to an entire concave surface itself may present a problematic visual aesthetic, if it fits the design, the set can usually benefit from added absorption as long as it's not placed on otherwise beneficially-reflective surfaces.

To maintain integrity of the set designer's intent, alternative options can be explored. For instance, if a "breathable" (highly sound transmissive) fabric can be stretched on a frame to create a desired visually-concave shape, an additional convex surface could be constructed directly behind the fabric to help direct the sound toward the audience. If the geometry of this surface can provide no benefit as a reflector to audience, a highly absorptive flat wall (or panel) could substitute for the convex shape. Finally, in addition to placing rugs on the set floor, hanging thick tapestries can also be beneficial to helping on stage reverberation and reflection issues. Thin, breathable tapestries with 2" of coated duct liner board immediately behind can serve equally well.

2. Enclosed Spaces

Enclosed spaces are defined here as being any space that even partially surrounds the actor by walls or similar surfaces. This could be a hallway, or a smaller onstage room.

Such spaces can be problematic because if hard (sound reflective), they excite localized reverberation which may be excessive and detected as an anomaly by audience, as well as have the potential to generate flutter[2] which could be unsettling for an actor, and/or cause coloration to the sound. These two issues related to enclosed spaces can result in decreased intelligibility.

If an enclosed space is required, wall surfaces could be angled in a fan-like shape to project sound downstage. Additionally, the ceiling could be angled upward. Not only will these angles help push the sound downstage toward the audience, but it will also help clear up any flutter that may occur between surfaces. Further, it could be helpful to add absorptive material on at least one of the parallel surface to dampen such reflections.

While it is unlikely that changes to the set will be made mid-run, a few improvements can be made related to blocking. In the instance that spoken lines are not coming out as well when an actor is speaking within an enclosed space, consider repositioning the actor just outside of the enclosed space.

[2] Flutter, or flutter echo, is sound that reflects rapidly and detectably between two parallel walls. The angle of incidence and reflection are 90º.

3. Acoustic Barriers[3]
   The author has attended multiple performances during which actors use overlapping set pieces to come on- and off-stage. While exit/entry routes are often unavoidable, they can be unhelpful to intelligibility.

   To counteract the barrier effect of set walls, actors should not have lines upon entering and exiting the set. Rather, they should hold lines until they come into sight of audience. If offstage dialogue is necessary, consider providing an opening such as an open window, through which an actor would speak during such transitions. Similarly, in the event that backstage dialogue is required, a clear line-of-sight should be provided through which the actor is clearly audible, if not slightly muffled (for effect). A non-illuminated area could be deemed appropriate from a visual perspective.

CONCLUSION

Shaping of set wall and ceiling surfaces, especially in somewhat enclosed forms can introduce highly problematic intelligibility. At issue, are on-stage considerations of sound reverberation, focusing, and flutter – all of which can be dealt with if considered early enough.

If problematic shaping forms are required, or otherwise desired, or if the set elements already exist, solutions are available to minimize their negative effects on speech intelligibility. This paper has explored the reasons for such challenges and provided solutions such as re-establish walls and/or ceilings to become somewhat convex and/or splay outward, and consider application of sound absorptive and/or reflective surfaces on these surfaces as well as floors.

Works Cited

Johnson, D., Eddy, M.S. *Whose Noise is it, Anyway?* Entertainment Design Magazine, September 2002

[3] Acoustic barriers are any solid surface of reasonable mass that is between the source (actor) and the receiver (audience). These are often set pieces, and curtains in the theatre.