CONSIDERATIONS IN THE ACOUSTICAL DESIGN OF BLACK BOX THEATRES

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1 Introduction and Background

Black Box Theatres are essential teaching/performance spaces at educational facilities for the Performing Arts. They provide flexible space for the creative training of performers, technicians and theatre staff and encourage the development of experimental performance models and new means of artistic expression. Extremely flexible by design, they can be stand-alone spaces with integral control facilities and seating or components of larger interconnected teaching facilities which include performance theaters, recital halls and multimedia production facilities.

This article deals with the fundamental acoustical design elements and collects useful information concerning the interaction of the acoustical and programme requirements in terms of multi-use functionality for Back Box Theatres. Consideration of sound isolation, acoustical treatment for interior acoustical control and background heating, ventilation, and air conditioning (HVAC) sound levels are discussed.

A discussion of several recently completed Black Box Theatres is presented along with the achieved acoustical parameters.

2 Criteria

In 2002, the American National Standards Institute Inc. published ANSI S12.60-2002 – "Acoustical Performance Criteria, Design Requirements and Guidelines for Schools", a standard developed to give guidance to designers of educational facilities to achieve good acoustical listening conditions in school classrooms and other core learning spaces. It was revised in 2010. It contains criteria for reverberation, background noise, and sound isolation between spaces as well as design guidelines for meeting those criteria. Black Box Theatres fall under the classification of special purpose classrooms which are technically exempt from the minimum requirements of the standard although those minimum requirements should be considered in the design respecting the unique acoustical requirements.

2.1 Reverberation

For teaching spaces including classrooms and theatres, reverberation must be controlled to enhance speech intelligibility, sound system performance and often audio recording capability. A lack of early reflections and the excessive use of absorptive treatments result in low levels of reverberation (a 'dead' space). While such an acoustic environment may be suitable for some audio recordings it is generally inappropriate for interactive performance activities. Excessive levels of reverberation cause the space to sound noisy or boomy, limiting speech intelligibility, sound system functionality and audio recording capability.

Reverberation is measured by the time it takes sound to die away by 60 decibels in the space, using a quantity known as the reverberation time (RT_{500}) measured in the mid-frequency (500 Hz) octave band. The ANSI standard specifies reverberation criteria based on volume, and the authors typically find that a target RT_{500} in the range of 0.7 to 1.5 s achieves a good level of acoustical control, allowing for some multiuse functionality. In many Black Box Theatres, particularly those which also function as multimedia spaces for video recording, there may be elements such as cyclorama or retractable curtains which can provide an additional level of acoustical control when deployed. The target values are for the base room without such additional controls.

2.2 Background HVAC Sound Levels

The most universally accepted criteria for background sound levels are based on Noise Criterion (NC) curves developed by the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE). ANSI S12.60-2010 uses A-weighted decibels (dBA).

Based on the ASHRAE Guidelines and the ANSI Standard, the following target maximum background sound levels are typically recommended. Actual background sound levels can usually exceed these targets in practice by up to 5 points due to economic considerations without serious degradation of acoustic performance for an academic environment; conversely, excesses of more than 5 points can lead to the space being considered "noisy".

Source Space	Target dBA	Target NC Level
Black Box Theatre with live recording	25	NC-20
Black Box Theatre, no live recording	30	NC-25

Table 1: Target Background Sound Levels

2.3 Sound Isolation

ANSI S12.60-2010 provides criteria for sound isolation in terms of the Sound Transmission Class (STC) rating system. Black Box Theatres are not mentioned specifically but are considered to be equivalent to music rooms, and in fact, many Black Box Theatres incorporate live or recorded music in their activities.

Source Space	Receiving Space	Minimum STC Rating
Black Box Theatre	Studios or Classrooms	STC-60
Black Box Theatre	Corridor/Lounge/ Storage	STC-55

Table 2: Recommended Minimum Room Envelope STC Ratings

3 Discussion of Practical Considerations

3.1 Reverberation

Black Box Theatres typically have high ceilings to allow for the deployment of effective lighting, seating and stage props. This results in large physical volumes and the potential for high levels of reverberation. Crucial to achieving the target range is the provision of a high performance acoustical ceiling treatment. Lower walls are reserved for other theatre related paraphernalia and acoustically are best left reflective to encourage sound propagation within and around the space, considering that the space could be used in many configurations including theatre in the round. Additional acoustical treatments are therefore generally placed on the upper walls.

3.2 Background HVAC Sound Levels

The background sound level criteria apply to all sources of mechanical and electrical noise, operating together under any normal operating conditions. For spaces that do not include dropped T-Bar ceilings these criteria apply to the space in that condition, i.e., without a ceiling. Note that this will affect the selection of HVAC terminal devices as many manufacturers' noise specifications assume a room effect consistent with a carpeted floor and a T-bar ceiling. Variable air volume (VAV) or fan powered boxes should be located outside the space as they can radiate considerable sound. The manufacturer's noise specifications typically consider that they are mounted above a mineral tile T-Bar ceiling and they would typically be exposed if mounted inside the theatre. Silencers should also be selected in the context of the interior fit-up conditions.

3.3 Sound Isolation

Black Box Theatre exterior partitions must be full height (slab to slab) for sound isolation purposes. As a result, ducted supply and return air systems should be used, or air should be returned through the full height partitions via crosstalk silencers or internally lined elbow transfer ducts designed to maintain the sound isolation integrity of the partitions.

Typically, when the sound isolation requirements are met with well-designed partitions, the doors (and windows in the case of the sound and lighting booths) become the weak link in terms of sound transmission. All penetrations (eg, ductwork, conduits, piping etc.) must be well sealed. A suitable firestop system would typically satisfy this requirement.

Acoustically rated door assemblies with integral frames and seals are required. An alternate would be the use of entry/exit vestibules. These solutions can be expensive and may interfere with entry/egress, and are often overlooked in favour of aftermarket sound sealing hardware. Such hardware can provide a level of acoustical control, but can be hard to adjust and maintain and invariably is the cause of poor sound isolation, particularly if the doors open into active areas.

4 Case Studies

The authors have been involved in the design of many Black Box Theatres over the past several years, several of which have now been built and several of which are currently under construction. The recently completed projects are discussed below.

4.1 Theatre #1

This theatre was built as a part of an active school of Applied and Performance Arts Associated with a Community College in Ontario. Reverberation and background sound measurements were conducted before final completion and the installation of acoustical treatments. Both parameters were found to be excessive with an RT_{500} approaching 3.5 s and background sound levels approaching NC-60. The HVAC systems were rebalanced and adjusted and it is our understanding that the space is now functioning as intended.

4.2 Theatre #2

This theatre was built as part of Community College facility incorporating dance, rehearsal, acting and comedy studios and two film studios. Measurements were conducted for commissioning and it was noted that the specified wall and ceiling acoustical treatments were present. The RT_{500} was found to be 1.3 s. The background HVAC sound levels were quite low, not measurable due to sound penetrating the corridor doors which were not STC rated and found to have gaps in the sealing systems. Adjustments were made.

4.3 Theatre #3

This theatre was built as part of a private school performing arts faculty upgrade. It has a unique design in that it can be acoustically isolated (large moveable firewall with integral seating) from an adjacent performance theatre, or it can remain connected to the performance theatre becoming the main theatre fly-tower/performance area. Acoustical measurements conducted for commissioning indicated an RT_{500} of 1.1 s and background HVAC Sound Levels of NC - 39. A rebalancing of the HVAC system was conducted.

5 Conclusion

Acoustical criteria and guidance are provided for the design of Black Box Theatres in academic settings. Practical considerations are discussed and actual results provided. Successful results can be achieved through a rigorous design process although budget constraints can lead to compromised results.

References

[1] American National Standard, "Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools", ANSI/ASA S12.60-2010 (Revision of ANSI/ASA S12.60-2002)

[2] American Society for Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), "HVAC Systems Applications Handbook", Atlanta, GA, 2007.