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"THEATRE ACOUSTICS - GENERAL PRINCIPLES"

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Sound is part of theatre, such an important part that acoustics must be a dominant feature in theatre design. Yet the author is not aware of any comprehensive text book or design guide which includes a review of the practical acoustic problems of modern theatres. Of course, acoustic design in this area shares many of the principles of acoustic design for other auditoria, and many theatres, because of their small size, present few acoustic problems. But at a time when multipurpose halls demand conflicting criteria and following the developments in theatre architecture over the last thirty years, it is surely time to review our knowledge in this area and aim research work at current practical problems. As an introduction to today's session, this paper will discuss, in outline, some of the main factors which influence good aural conditions in theatres.

Standards

We are looking to achieve (a) conditions where speech can be clearly heard without distraction or masking - this means control of noise and vibration (b) a geometry and absorption pattern to allow adequate distribution of sound to achieve speech intelligibility and enhance voice quality (c) appropriate extension of this into high quality electro-acoustic systems for sound effects and possibly to assist the natural acoustics (d) some feedback to the actor/actress to help in gauging his/her performance.

Noise and Vibration

Sources of noise and vibration are likely to include :- External road, rail or air traffic, industry, construction, Underground railways; Adjacent noisy areas e.g. green room, another auditorium, music practice room, foyers; Sources immediate to the theatre e.g technical equipment control rooms, audience noise; Impact noise sources; Mechanical services noise.

Excessive noise from mechanical services systems is a frequent failing, even in the very latest theatres (see Fig 1). This is a two part problem - firstly, is the correct standard set at the outset ? secondly, is enough consideration given to whether the proposed a/c system is capable of achieving the required standard ?

The use of PNC 20-25 is perhaps a reasonable range for a/c noise in a large theatre. But low noise levels can easily produce other problems - the need for greater sound insulation and perhaps increased awareness of audience and technical systems noise. The extent to which low frequency noise can be allowed to exceed these PNC values is an important economic consideration as low frequency noise is usually more expensive to deal with. Even though masking of speech by low frequency noise is limited, its own character may prove a distraction, making listening hard work. Standard procedures of planning and noise and vibration control for mechanical services apply. There is a problem of achieving adequate air volume and throw without excessive noise. But given adequate space and time at the early design stages there is no reason why suitably low background noise criteria should not be met.

Intermittent noise is very distracting in a theatre. Subject to the noise character, reduction to 5dB below the a/c noise provides a guideline for most sources (e.g voices from control room, p/a announcements in the foyer, road traffic noise). It is often unreasonable to attenuate emergency police or fire sirens or occasional aircraft to a level which is not perceptible in the auditorium. To allow some perspective it is worth noting that one well-loved London Theatre is subject to regular underground railway noise peaking at 40dBA. Technical equipment e.g sliding or revolving stage sections, could perhaps be slightly noisier than suggested above since this is seen and understood by the audience.

Surrounding an audience with hard surfaces is likely to encourage distraction from audience noise. Furniture design may also contribute to audience noise.

Good planning will normally remove the need for very high sound insulation (eg 70dB+ nominal) such as would be needed for auditoria adjacent to one another in an arts centre, or a theatre next to e.g. music practice rooms, noisy plant rooms, rehearsal halls or studios. Sound lock lobbies on all access to the auditorium are normally needed. Control room windows can become a weak area, allowing speech in the control room to be picked up at the rear of the audience. If the window is fully open during performance the operator will normally remain quiet (but mechanical services noise may spill over into the auditorium). If the window is closed, the operator tends to feel protected and a higher standard of insulation may be needed e.g 40dB+ nominal.

Room Acoustics

Speech intelligibility and quality starts with the performer. Variation in voice characteristics and projection between performers is wide and the adverse influence of close-mike techniques on the art of voice projection is clear.

The need for obtaining strong direct and early sound and the appropriate Reverberation Time influence the shape and form of the Theatre. A seating capacity of 1500 is an approximate maximum for good natural acoustics although extension by electroacoustic systems is possible. A volume of 4-6m^3/seat tends to work out well. In the traditional proscenium form side walls can provide early reflection. The distance to the rear of the audience must be limited. The use of balconies will reduce the distance from the stage. But raking in the upper levels tends to become very steep and the roof height may get pushed up affecting the volume. Reinforcement by reflected sound to seating more than 10m away from the performer is important.

As the plan widens to a fan shape, arena and finally to theatre in-the-round, the more distant side wall surfaces become less helpful. The increase in the time a performer has his back to the listener presents a particular problem for the acoustic consultant. If an actor is turned away, the direct sound level falls, with little change in the 'late' sound. Without early reflections to boost the direct sound, intelligibility will become difficult. Wide plan forms therefore become more difficult to handle. In this situation the ceiling geometry is more important.

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Listeners will hear well if there is strong direct and early sound and little reverberation to mask the speech. Of course, short RT values lead to good intelligibility if there is adequate signal to noise ratio. But too 'dead' a space limits the quality of the speech and makes the performer work harder than necessary. Mid frequency RT values of 0.9-1.2 seconds are suitable for most theatres - but the relationship with early energy is also important. Fig 2 gives examples of measured RT values in existing theatres. Where the early energy is weak (e.g. when an actor turns away on a thrust or open stage) late sound will tend to confuse the speech more and a shorter RT is helpful. This leads to a situation where different optimum RTs apply subject to the direction in which a performer is speaking. The effect of long RT values at low frequency masking across to the major speech frequency range is also interesting, since increase in low frequency RT can help voice quality e.g. assisted resonance has been found to contribute to voice quality.

The calculation of RT in a theatre (usually with an allowance for a flytower and a partly connected roof void) is still tricky. As with all auditoria the absorption of seating and occupants is a dominant feature in the calculation. The contents of the flytower can affect conditions markedly particularly if the tower is well connected to the auditorium.

There is often a clash of interests between lighting designers and the acoustic consultant over the front part of the ceiling. The valuable surfaces closest to the stage can be opened out extensively for lighting - this runs counter to the acoustic need to obtain early reflections which are not always available from walls.

The text-book acoustic faults in auditoria - connected reverberant spaces, echoes, flutter echoes, dead spots, focussing clearly need to be checked. The shorter RT typical of theatre design results in increased awareness of such faults which are not so easily masked by subsequent reverberation.

But good listening in the theatre is not all good acoustics - comfort and visual clues play a large part. Where vision is good, clear reception of direct sound is normally good. In some larger theatres, the set and stage floor may feed energy away from the listener to the more remote parts of the auditorium contributing to 'late' sound which is not helpful. But, on the whole, reflective sets and stage floors can provide useful reinforcement.

Sound Systems

The proper integration of the sound systems into the acoustic design clearly produces mutual benefits. The principles to be applied to achieve quality, realism and sensible control are better discussed by others with a wider experience of this particular field than that of the author. Nevertheless it is interesting that live theatre is one of the last areas in entertainment/education where the microphone has not completely taken over. The design of theatres for good acoustics would become a much simpler exercise were speech reinforcement to be accepted. The explosion in radio, TV, tape recording, hifi has accustomed people to listen without effort often to the detriment of the quality of the sound. Many difficult areas in existing theatres could be improved as far as intelligibility is concerned with discreet loudspeaker systems. The use of electroacoustics as an extension of (rather than a replacement for) the natural acoustics of a theatre must surely be justified if it is well done. We may well see substantial use of loudspeakers as is already the case in many theatres in the USA - as a means of overcoming the disadvantages of large capacity theatres or open theatre forms.

Performers

From discussions with a large number of actors it is clear that the feedback from the auditorium - not just audience reaction - is important to help in gauging the pitch of the voice. As with musicians, there is a tendency for actors and actresses to prefer reverberation towards the top end of the recommended range. But early reflection from local surfaces is the most helpful element such as is provided by e.g. a flank wall to the side of the stage or projecting boxes close to the stage, as in many of the older theatres.

Theatre Acoustics in practice

The author's job produces a particular interest in being effective when advising a design team on a theatre. We need to know how accurate we can be, how far we can use model work, how this fits into a design programme and in particular much more feedback from existing theatres.

Conclusion

Perhaps the most important aspects of theatre acoustics for attention are - standards for background noise and means of achieving this with mechanical service systems; dealing with thrust and open stage forms where performers turn away from the listener; the role of electroacoustics in theatre design; setting of acoustic paramaters when theatres have to be integrated into multipurpose halls; and perhaps, most important - developing ways of providing the most effective advice to design teams (e.g. use of models, more feedback from existing theatre etc).

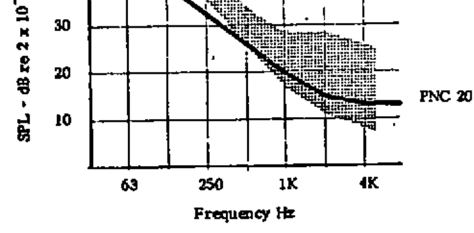

Fig.1. Range of mechanical services noise from recent measurement in six theatres in the UK

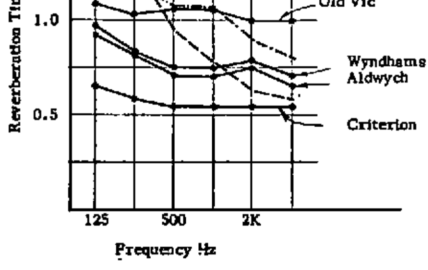

Fig 2 Some examples of RT in empty theatres.