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ACOUSTIC CONDITIONS IN ORCHESTRA PITS AND PROSCENIUM ARCH THEATRES

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1. INTRODUCTION

Orchestra pits present the third and perhaps last frontier of acoustical measurements in performing arts facilities. In the companion paper to this [1] it was shown that the acoustical conditions on a stage differ significantly from the audience chamber. As much as stages are different from the audience chamber so are pits different from stages. Orchestra pits are not always friendly places to work in and musicians are often exposed to noise levels that can and do damage to their hearing. In Naylor's survey of 1985 [2] he found that:

- Singers' sound levels are 25 to 30 dB lower than musicians'
- Pits have short reverberation times - typically 0.4 to 0.7 seconds
- There is poor coupling to the audience chamber - typically -10 dB
- It is unlikely that musicians hear the sound of the audience chamber while performing.

The propagation of sound from a pit onto the stage and into the theatre audience chamber has received little attention in the literature. The major exception is found in Barron's acoustic survey of British auditoria [3]. He measured three rooms and found the balance between stage and pit source locations to be similar in all three, in the range of 2 dB (expressed as a ratio of stage to pit source locations).

2. MEASUREMENTS

The measurement procedure used here is similar to the one used in the companion paper [1]. On stages measurements were performed at the five typical locations. In orchestra pits measurements were performed at three locations starting at the first violin's chair then moving across the width of the pit and toward the back. Three rooms were measured, The Princess of Wales Theatre [4], The Queen Elizabeth Theatre in Vancouver [5] and the MacMillan Theatre, a 800 seat single balcony room in the University of Toronto's Faculty of Music. The Princess of Wales Theatre has a partially covered pit and the latter two rooms have open pits. A 50 mm acoustic blanket was placed underneath the source at MacMillan Theatre but not under the source in the other two theatres.

To quantify the balance between stage and pit sources, the following parameter has been proposed:

$$SPB = \frac{\int_{t1}^{t2} p^2_{stage}(t)dt}{\int_{t1}^{t2} p^2_{pit}(t)dt}$$

	t1 (ms)	t2 (ms)
SPB_{early}	0	50
SPB_{late}	50	∞
SPB_{total}	0	∞

The SPB measurements shown here were performed with an omni-directional source on both the stage and in the pit. Barron later suggested that a directional source might be more suitable on the stage but that an omni-directional pit source is appropriate. His reasoning seems sound and the author will adopt the procedure in future measurements.

3. PIT MEASUREMENTS

As might be expected, support ratios are much higher in pits than they are stages. This is due primarily to the proximity of reflecting surfaces, notably the ceiling in a covered pit. These measurements, previously published in [6], show Support ratios for the single covered pit (Princess of Wales) to be 6 dB higher than the other two open pits. Preliminary data reduction indicates that the rate of attenuation of reflected sound in a pit is about the same as on a stage, in the range of 2 dB/m.

4. PIT TO STAGE MEASUREMENTS

Gade has found that a 'near field' support ratio, STearly, correlates well with Ensemble or Hearing of Other. This seems a bit surprising until one considers that the stage *average* measurements were correlated to a group of musician's *average* response. This of course assumes that the musicians trying to hear each other are in the same acoustical environment. Unfortunately this is not the case for singers on stage and musicians in an orchestra pit. In the measurements presented here, STearly was, on average, 8 dB higher in pits than on stages.

The more likely candidate for describing Hearing of Other between a pit and a stage is the Modulation Transfer Function (MTF) proposed by Naylor [7]. Unlike STearly, which is measured at 1.0 m from the source, the MTF is measured between distant locations, typically 2 to 10 m.

Figure 1, below, is typical of the MTFs measure in a pit and between the pit and the stage. In the MacMillan Theatre, the MTFs suggest that Hearing of Other is about the same inside the pit as it is between the pit and the front of the stage. From the pit to the back of the stage, Hearing of Other decreases significantly. A similar situation exists in the Queen Elizabeth and Princess of Wales Theatres. It may not be appropriate therefore to quantify spatial averages of MTF between a pit and a stage.

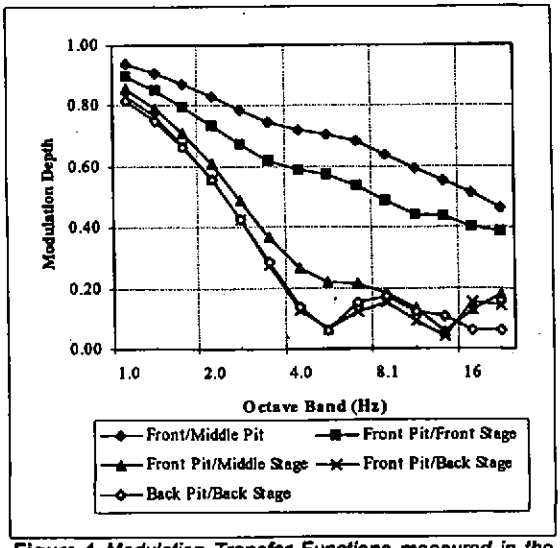

Figure 1 *Modulation Transfer Functions measured in the MacMillan Theatre, University of Toronto.*

5. PIT TO AUDIENCE MEASUREMENTS

Subjective assessment of SPB has not been performed. It seems likely however that the optimum condition lies slightly above 0 dB. Recognising the importance of singers' formants, the optimum SPB may be frequency dependant, notably in the 4000 Hz octave.

Three variations of the SPB have been measured, as outlined in the table above. Barron's measurements correspond roughly to SPB_{total}. Only the SPB_{early} curves have been shown here because they appear to be the most sensitive, that is in a terms of level and spectral content. Please see Figures 2 and 3.

The measurements from the Queen Elizabeth Theatre provide an interesting observation. On the orchestra level it is difficult to hear the singers. On the balcony, the balance is rather good. The SPB_{early} curve for the orchestra level shows a noticeable dip at 4000 Hz. This octave contains the important singer's formant which allows a soloist to be heard over the much stronger forces of an orchestra in the pit. In the Queen Elizabeth, the objective SPB_{early} measurement appears to agree with subjective experience.

In both and The Queen Elizabeth and Princess of Wales Theatres, the measured balance appears to be better on the balcony. The subjective experience in most proscenium arch theatres is that the sound is better on the balcony.

Similar to other early energy parameters, Stage to Pit Balance is sensitive to measurement procedures and equipment. Audience related measurements were performed by John Bradley and Gilbert Soulodre in the Queen Elizabeth Theatre at the same time as the stage measurements reported here. SPB ratios have been extracted from the data and are shown in Figure 3. The data demonstrates lower overall ratios but similar spectral behaviour, notably at 4000 Hz. John Bradley was using his RAMSoft software equipment and the author was using the set up described in [1] Bradley's data was measured over more seats but fewer sources than ours.

6. SUMMARY

Measuring the balance between the stage and pit has been overlooked in the past, probably because it is irrelevant in a concert hall. The findings shown here are interesting but clearly there is room for more work. An optimum range for SPB needs to be determined and the spectral sensitivity tested. Figures 2 and 3 indicate that a consistent measurement procedure also needs to be established.

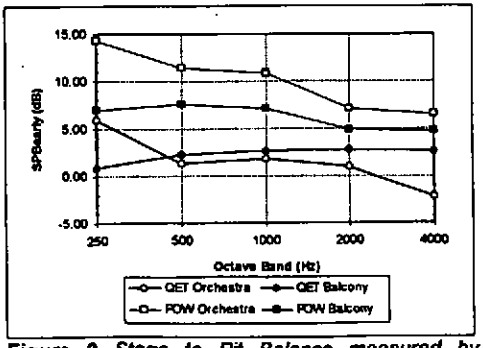

Figure 2 *Stage to Pit Balance measured by O'Keefe in the Princess of Wales (POW) and Queen Elizabeth Theatres (QET).*

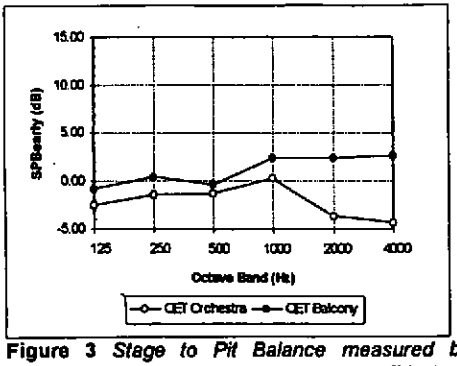

Figure 3 *Stage to Pit Balance measured by Bradley and Soulodre at the Queen Elizabeth Theatre, Vancouver.*

7. ACKNOWLEDGEMENTS

I would like to thank John Bradley and Gilbert Soulodre for their help with the measurements in Vancouver. Once again, I would also like to thank the management and staff of the venues mentioned in this paper. Their help is deeply appreciated.

8. REFERENCES

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