Acoustic Conditions in and Propagating from Orchestra Pits

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Introduction

Orchestra pits are not always easy environments to perform in. Noise levels in most pits often exceed safe levels. In fact, most acoustical research in this area has concentrated on hearing loss. With the emerging understanding of performer related acoustics, it seems timely to expand the investigation of the acoustical conditions in pits.

Measurement Procedure

The measurement system has been described in the companion paper[1]. Measurements were performed at and between three locations inside the pit and between those three locations and the five standard locations measured on stage (Soloist, Violin, Viola, Horn and Bass). Measurements were also performed between the three pit locations and two audience seats and between three stage sources and the same seats. Unless stated otherwise, Support measurements have been measured at 0.5 m. Three rooms were measured including the Queen Elizabeth Theatre (QET) in Vancouver, the Princess of Wales Theatre (POW) and MacMillan Theatre, both in Toronto. Of the three, only the latter pit was empty. The Princess of Wales pit is partially covered while the other two are open, at least in the configurations measured here. At the Princess of Wales, extended coverage of the base building pit was provided by the temporary stage for the musical *Miss Saigon*.

Hearing of Self

Average ST_{total} measurements are higher in the pits than on most stages, as expected. A summary of the results is shown in Table 1.

Table 1
1kHz Support (@0.5 m) and MTF

	STtotal	STearly	MTF
	Self	Hearing of Other	
QET	-14.0	-14.4	0.84
POW	-10.7	-10.8	0.80
MacM.	-16.2*	-17.1*	0.74*

* Erratum - supersedes O'Keefe[2]

Hearing of Other

Gade has found that STearly, measured at 1.0 m, correlates better with Ensemble or Hearing of Other than his Early Ensemble Levels measured across the length and width of the stage[3]. Intuitively this seems a bit odd but when one considers the stage *average* measurements correlated to a group of musicians' *average* response, the findings are perhaps not all that surprising. The assumption, of course, is that all the musicians are in essentially the same acoustic environment. The reasoning breaks down when one considers the communication between a stage and the orchestra pit. In this situation, the two groups of musicians are located in significantly dissimilar acoustical environments. In the measurements presented here, STearly was, on average, 8 dB higher in pits than on stages.

Naylor found the Modulation Transfer Function (MTF) to be a good descriptor of Hearing of Other[4]. Unlike STearly, the MTF is measured between distant locations. In the pit to stage scenario, the MTF seems the more likely alternative to quantify Hearing of Other. At both the Princess of Wales and Queen Elizabeth Theatres, the Mean MTFs are 0.56 between the pit and the stage. There is however a broad range in measured MTF with poor communication between the pit and the back of the stage.

Stage to Pit Balance

In proscenium arch theatres presenting opera or musicals, one of the most important acoustical characteristics is the balance between singer and orchestra. To date, this has received little attention, with the exception of Barron[5]. In the present study, two sets of impulse response functions were measured for a given seat, one with the sources in the pit and the other with the sources on the stage. Barron used a directional source on the stage and an omni-directional source in the pit. This study used an omni-directional source in both locations. The measurements were performed at a single seat on the orchestra level, a few rows in front of the balcony overhang and a single seat on the first balcony. The balance between stage and pit sources was quantified as follows:

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

Three variations of the Stage to Pit Balance (SPB) have been considered:

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

A 50 ms early energy temporal threshold was chosen rather than the 80 ms that has been used by many for musical clarity. This was done in light of the recent work by Julien et al.[6] suggesting a shift in clarity thresholds. It should also be remembered that in a performance that makes use of an orchestra pit, speech intelligibility or diction is, by definition, more important than orchestral reverberance.

It is not clear that an SPB of 0 dB represents an optimum condition. Given the acoustic energy generated by the orchestra, compared to a singer, it most likely greater than 0 dB. Recognising the importance of singers' formants, the optimum SPB may vary with frequency.

Barron's measurements correspond roughly to SPB_{total}. He found a limited range of about 4 dB inside individual opera houses. The measurements performed here find a similar range for SPB_{total} for the two seating locations that were measured, perhaps even narrower. The SPB_{early} curves in Figure 1 however show a broader range and demonstrate more obvious frequency characteristics. In Figure 1 the QET measurements on the balcony indicate a flat spectrum. The subjective experience on the balcony is one of good balance.

On the QET orchestra level it is difficult to hear the singers. The corresponding SPB_{early} curve 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. The objective SPB_{early} measurement appears to agree with subjective experience.

Audience related measurements were performed by John Bradley and Gilbert Soulodre in the QET at the same time as the stage measurements reported here. SPB ratios have been extracted from the data and are shown in Figure 2. The data demonstrates lower overall ratios but similar spectral behaviour, notably at 4000 Hz. Bradley's data was measured over more seats but fewer sources than ours.

These findings are interesting but, for now, anecdotal. Clearly there is room for more work, notably in determining an optimum range for SPB, developing a database from existing rooms and, as demonstrated by comparing Figures 1 and 2, establishing a consistent measurement procedure.

Acknowledgements

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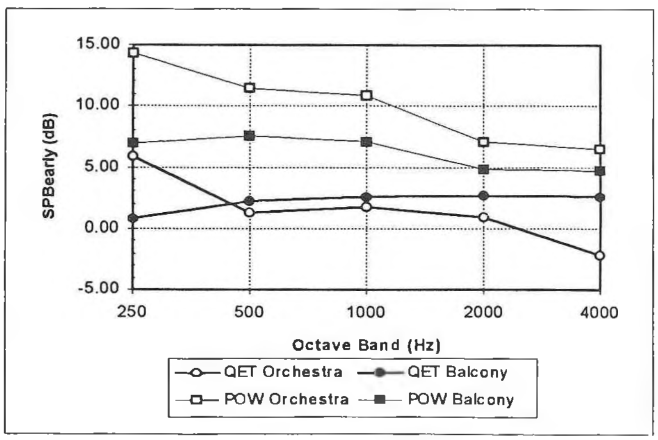

Figure 1 *Stage to Pit Balance (SPB) measured by O'Keefe.*

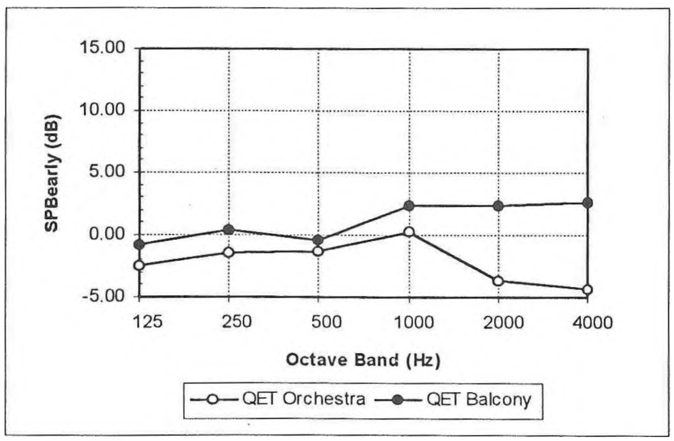

Figure 2 *Stage to Pit Balance (SPB) extracted from Bradley's measurements.*