MODERN ACOUSTIC MEASUREMENTS ON CANADIAN STAGES

John P.M. O'Keefe and Marc Bracken
Barman Swallow Associates,
1 Greensboro Drive, Rexdale, Ontario. M9W 1C8

INTRODUCTION

The acoustic requirements of listeners and performers are not the same. Over the past decade, a number of acoustical measurements have been derived to quantify the conditions preferred by performers. Broadly speaking these measurements are divided into two groups: SELF and OTHER. This reflects the fundamental dilemma of stage acoustics - the conflicting needs of a performer to hear both himself and the other musicians.

Gade[1] has proposed a ratio of reflected to direct sound as quantifier of SUPPORT, i.e. a performer's need to hear herself:

$$ST_x = \frac{\int_0^x p^2(t)\,dt}{\int_0^{10ms} p^2(t)\,dt}$$

The upper limit of integration in this parameter, x, was originally set at 100 ms. Gade later found that a 200 ms limit provided a better correlation with subjective response.

Naylor[2] found that the Modulation Transfer Function (MTF) was a good model for what he called Hearing of Other (HOO). He established that a correlation existed between MTF and HOO, much like the speech intelligibility curves developed by Houtgast and Steeneken.[3]

Other researchers, notably Meyer[4] and Marshall et al.[5] have found that the direction of sound arriving at a performer is important. None of the existing acoustical parameters however account for directionality.

MEASUREMENTS

To perform our measurements we used a Maximum Length Sequence System Analyzer manufactured by DRA Laboratories. Measurements were performed using a Maximum Length Sequence of order 15, i.e. 32,767 points per period. The stages were insonified with a single dodecahedron source complete with 12 75 mm diameter loudspeakers. Stage responses were measured with an omni-directional microphone.

Measurements were performed at and between five locations on the stages, roughly corresponding to positions in the violin, viola, horn and bass sections. The fifth position was between the conductor's podium and the violin section, roughly corresponding to the location of a soloist.

SELF measurements were performed *at* a given location, for example in the violin section with the microphone located 0.5 m from the loudspeaker. OTHER measurements were performed ***between*** two locations, for example between the violin and horn sections. The SELF measurements follow Naylor's practice, i.e. the microphone is located 0.5 m from the source. Gade used a 1 m source/receiver distance. For consistency with his data, our ST100 and ST200 measurements employ a +6 dB correction.

MTFs were measured in third octave modulation frequency intervals from .2 to 20 Hz. The results are expressed as an unweighted average of the third octave band data. Other parameters that we measured include: Level Difference, Clarity (C80), Centre Time (ts) and Early Decay Time (EDT).

RESULTS

Some of the results of our measurements are shown in the tables on the following page.

Our most interesting results were in the Centre in the Square, Kitchener Ontario. This is a multi-purpose hall with a large, single component reflector above the stage. The reflector height can be adjusted from 8.5 to 14.5 m. Measurements were taken with the reflector at three different heights: 8.5 m, 14.5 m and the height chosen by the resident conductor, 11 m.

The accepted wisdom is that stage reflectors or ceilings should be between 8 and 10 m high. It is intriguing that, given a choice, a conductor should set the reflector higher than this. ST100 measurements, shown in Figure 1, indicate levels close to Gade's proposed optimum when the reflector is 8.5 m high. Levels decrease significantly when the reflector is raised above this height. The ST100 measurements would therefore seem to support the 8 to 10 m height postulate.

So why was the reflector set at a height that our "rule of thumb" and the stage measurements tell us is less than ideal? Figure 1 also shows the EDT data for each of the three reflector heights. At the 11 and 14.5 m heights the EDTs are about 0.5 seconds longer. This represents a significant increase in perceived reverberance. It would appear that the conductor's criterion for the reflector height is based more on listeners' requirements (reverberance) than it is on the performers' (Support).

CONCLUSIONS

The purpose of this study was to add to the database of stage acoustics measurements proposed by Gade and Naylor. Some of our results are shown in the tables below. A fundamental conflict in stage acoustics is the performer's need to hear both herself and her colleagues. In a hall where an orchestra was provided with significant control of the stage acoustics, our measurements indicate that these conflicting requirements were superseded by the listeners' desire for greater reverberance.

REFERENCES

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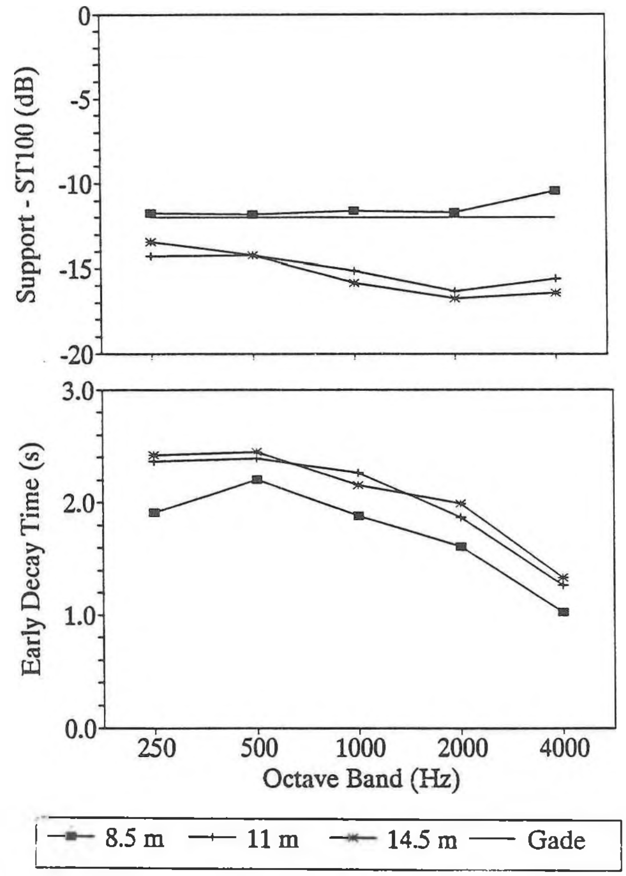

Figure 1. 100 ms Support and Early Decay Times for varying stage reflector heights at the Centre in the Square, Kitchener, Ontario.

Hall	City	Type	Seats
Cardinal Carter Academy	North York	Theatre	750
MacMillan Theatre	Toronto	Theatre	1000
Centre in the Square	Kitchener	Multi	2000
Massey Hall	Toronto	Concert	2200

Hall	MTF
Carter	0.66
MacMillan - Stage	0.83
MacMillan - Pit	0.80
Centre - Theatre	0.83
Centre - Concert (11 m)	0.64
Centre - Concert (8.5 m)	0.80
Massey	0.65

Hall	EDT (s) - Other				
	250	500	1000	2000	4000
Carter	1.25	1.23	1.33	1.15	0.88
MacMillan - Stage	1.26	1.30	1.37	1.21	1.04
Centre - Theatre	1.64	1.63	1.76	1.69	1.53
Centre - Concert (11 m)	2.37	2.39	2.26	1.87	1.27
Massev	2.14	2.40	2.32	2.14	1.79

Hall	ST100 (dB) - Self				
	250	500	1000	2000	4000
Carter	-12.7	-13.3	-14.6	-15.4	-14.2
MacMillan - Stage	-13.8	-15.8	-15.2	-16.2	-16.7
MacMillan - Pit	-9.0	-10.0	-11.1	-12.5	-12.2
Centre - Theatre	-19.5	-19.2	-19.8	-20.1	-18.5
Centre - Concert (11 m)	-14.3	-14.2	-15.1	-16.3	-15.6
Massev	-13.1	-14.3	-15.5	-16.6	-15.6

Hall	ST200 (dB) - Self				
	250	500	1000	2000	4000
Carter	-11.9	-12.9	-13.8	-14.1	-13.9
MacMillan - Stage	-12.5	-13.9	-13.4	-14.8	-15.2
MacMillan - Pit	-8.5	-9.5	-10.5	-11.9	-11.7
Centre - Theatre	-14.9	-15.6	-16.2	-17.1	-15.7
Centre - Concert (11 m)	-12.7	-13.0	-13.8	-15.0	-14.7
Massey	-10.9	-11.6	-11.9	-13.3	-12.7