PRELIMINARY SIMPLIFIED MODELS FOR PREDICTING SOUND PROPAGATION CURVES IN FACTORIES

Murray Hodgson

Occupational Hygiene Programme / Department of Mechanical Engineering,
University of British Columbia,
2324 Main Mall, Vancouver, BC V6T 1Z4.

1. Introduction

Predictions of factory noise levels are based on predictions of the factory sound propagation curve - the variation with distance from an omnidirectional point source of the sound pressure level minus the source sound power level; $SP(r)=L_p(r)-L_W$. While more accurate approaches such as ray tracing exist [1], from a practical point of view there is considerable scope for developing simplified empirical prediction methods. In fact, several such models exist [2]. However, these have short-comings which warrant the development of a new model. The approach taken here was to predict the slope(s) and absolute level(s) of the sound propagation curve, approximated by one or more straight-line segments. With this in mind, octave-band sound propagation measurements were made in a number of empty and fitted factories. The curves were approximated by one or two straight-line segments. The intercepts and slopes of the segments were then determined. In this paper the development of preliminary simplified prediction models from the results is discussed.

2. Factories and measurements

Test factories were chosen to be of modern steel-deck construction. Eleven were nominally empty. A further 13 were fitted; the fittings were compact and fairly uniformly distributed over the factory floor areas. Four of the fitted factories contained a sound-absorptive ceiling treatment. The factories had a wide range of dimensions, with aspect ratios varying from low to high.

In each factory the sound propagation curves were measured in octave bands from 125-4000 Hz. An omnidirectional loudspeaker radiating random noise was located near one end of the building. Octave-band sound pressure levels were measured at a number of distances away from the speaker. From these and the octave-band source sound power levels the sound propagation curves were determined. Observation of the shapes of the curves revealed certain consistent characteristics, as illustrated in Fig. 1. In the case of smaller factories, with major dimension less than about 50 m, the slopes of the curves were approximately constant. In larger factories, the slopes were approximately constant to source/receiver distances of about one half of the length; at larger distances the slopes increased sharply, particularly in fitted factories.

3. Best-fit procedure and results

It was apparent that the measured sound propagation curves could, with good accuracy, be approximated by a single straight-line segment in the case of smaller factories, and by two straight-line segments in the case of larger factories. With this in mind, all measured curves were approximated in this way using regression techniques. To date results have only been analysed for the initial portion of the curves for the larger factories. In any case, for each segment the SP value at r=1m (the 'intercept') and the slope in dB/dd (dd=distance doubling) were determined. The averages and standard deviations of the values in each octave band were calculated separately for the empty, fitted and fitted+absorptive cases.

Table 1 shows the results for the intercept. This varies with frequency from -11.1 to -11.6 dB in empty factories, from -7.8 to -9.7 dB in fitted factories and from -7.5 to -9.7 dB in fitted+absorptive factories. Also shown in Table 1 are the changes in intercept when fittings are 'added' to the average empty factory (increase of 1.7-3.3 dB), or when an absorptive treatment is 'added' to the average fitted factory (little change).

Table 2 shows the corresponding results for the initial slope. This varies with frequency from 1.9-2.6 dB/dd in empty factories, from 3.4-4.3 dB/dd in fitted factories and from 4.0-5.0 dB/dd in fitted+absorptive factories. Also shown in Table 2 are the changes in slope when fittings are 'added' to the average empty factory (increase of 1.3-1.7 dB/dd), or when an absorptive treatment is 'added' to the average fitted factory (increase of 0-1.5 dB).

4. Preliminary prediction model

From the above results it is possible to develop preliminary empirical models for predicting the initial sound propagation curves in empty and fitted factories, without and with absorption. Two types are proposed - frequency-independent models based on the average octave-band results, and frequency-dependent, octave-band models. They are as follows:

<u>Frequency-independent models</u>

Empty: $SP_E(r) = -11.4 - 18.6 \log r$

Empty+absorption: $SP_{EA}(r) = -11.4 - 26.2 \log r$

Fitted: $SP_F(r) = -13.7 - 31.3 \log r$

Fitted+absorption: $SP_{FA}(r) = -13.7 - 38.9 \log r$

<u>Frequency-dependent model</u>

$$SP(r) = (I_E + \Delta I_F) - 8.5\,(S_E + \Delta S_F + \Delta S_A) \log r$$

Band	I_E	ΔI_F	S_E	ΔS_F	ΔS_A
125	-11.6	1.9	2.2	1.7	0.6
250	-11.3	2.1	2.1	1.7	1.0
500	-11.5	2.6	2.2	1.3	1.5
1000	-11.1	3.3	1.9	1.5	1.4
2000	-11.4	2.4	2.1	1.3	0.6
4000	-11.2	1.7	2.6	1.7	0

5. Conclusion

Models have been developed for predicting the initial sound propagation curves. While this has yet to be analysed in detail, the proposed models predict the average initial curves with good accuracy; typically within 1 dB. It would be of interest to combine the models into one model which includes the absorption coefficent of absorptive treatments and some measure of the fitting density as parameters. Clearly, models based on average results are of limited accuracy. It is important to extend the models to account for variations of sound propagation with room dimension or other applicable parameters. It also remains to extend them to predict the final part of the curves in the case of large factories.

References

[1] M.R. Hodgson, Canadian Acoustics **19**(1) 15-23 (1991).

[2] M.R. Hodgson, J. Acoust. Soc. Am. **88**(2), 871-878 (1989).

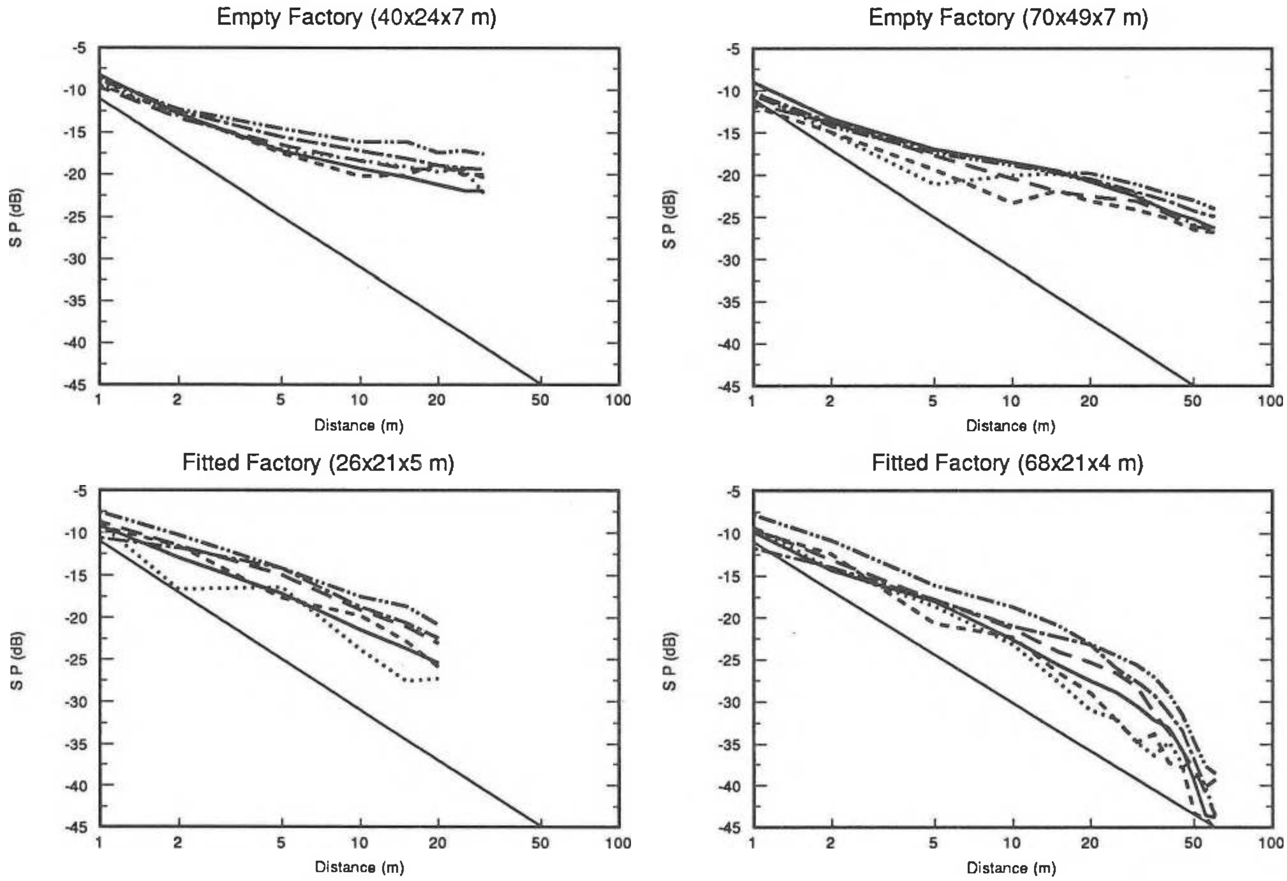

Fig. 1. Measured octave-band sound propagation curves for typical small and large, empty and fitted factories: (———) free field; (••••••) 125Hz; (– – – –) 250 Hz; (—— ——) 500 Hz; (—••—) 1000 Hz; (—•—•) 2000 Hz; (———) 4000 Hz.

Table 1. Averages, standard deviations and changes (Δ) of octave-band intercepts (SPs at 1m) in dB for the measured factories.

Band (Hz)	Empty	Fitted	Fitted+ Absorption	Δ(E→F)	Δ(F→F+A)
125	-11.6 (1.6)	-9.7 (0.9)	-9.4 (0.5)	+1.9	+0.3
250	-11.3 (1.4)	-9.2 (1.0)	-9.2 (0.5)	+2.1	0.0
500	-11.5 (1.4)	-8.9 (0.7)	-9.0 (0.2)	+2.6	-0.1
1000	-11.1 (1.0)	-7.8 (0.8)	-7.5 (0.4)	+3.3	+0.3
2000	-11.4 (1.4)	-9.0 (0.9)	-9.4 (1.3)	+2.4	-0.4
4000	-11.2 (1.8)	-9.5 (0.5)	-9.7 (1.4)	+1.7	-0.2

Table 2. Averages, standard deviations and changes (Δ) of octave-band initial slopes in dB/dd for the measured factories.

Band (Hz)	Empty	Fitted	Fitted+ Absorption	Δ(E→F)	Δ(F→F+A)
125	2.2 (0.6)	3.9 (1.3)	4.5 (0.3)	+1.7	+0.6
250	2.1 (0.6)	3.8 (1.3)	4.8 (0.4)	+1.7	+1.0
500	2.2 (0.5)	3.5 (1.1)	5.0 (0.2)	+1.3	+1.5
1000	1.9 (0.5)	3.4 (1.1)	4.8 (0.2)	+1.5	+1.4
2000	2.1 (0.6)	3.4 (1.2)	4.0 (0.5)	+1.3	+0.6
4000	2.6 (0.6)	4.3 (1.4)	4.3 (0.6)	+1.7	0.0