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EMPIRICAL PREDICTION OF SOUND PROPAGATION AND RT IN FACTORIES

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CURRENT FACTORY NOISE RESEARCH

Research into factory noise at the Department of Architecture has been in progress for several years in collaboration with the Institute of Sound and Vibration Research at Southampton University, and is continuing. The work has followed two paths:

1. Factory scale modelling - the application of acoustic scale modelling techniques to factories and to the optimisation of noise-reduction treatments;
2. Factory sound fields - the study of factory sound fields and of their prediction.

Details of the scale modelling work will be presented at the International Congress in Paris. The study of factory sound fields comprised theoretical and experimental investigations, the latter involving measurements in scale-model and full-size factories /1/. Two measures have been used to characterise the sound field:

1. Sound propagation (SP) - the SP is the variation of the sound pressure level (L_p), normalised to the source output power (L_w), with distance from an omnidirectional source; thus, SP = $L_p - L_w$. The SP is required for the determination of factory noise levels;
2. Reverberation time (RT) - the RT is useful in the diagnosis of the acoustic properties of a factory, for example prior to introduction of noise-reduction treatments. Further, it is likely that the RT is a measure of the annoyance caused by impulsive sounds.

The research has led to a better understanding of the factors influencing, and the characteristics of, SP and RT in empty and 'fitted' (containing machines etc - the 'fittings') factories. In particular, the influence of the fittings has been found to be significant. The

results also demonstrate that the classical Sabine and Eyring theories are not applicable to factories; their use can lead to highly inaccurate predictions /1/.

FACTORY SP AND RT PREDICTION

A further aim of the current research has been to consolidate a factory SP and RT prediction method. Analytic prediction theories have been developed by Jovicic /2/ and Lindqvist /3/. These are comprehensive and have been found qualitatively to describe many observed factory-acoustic effects /1/. However, their utility is seriously limited by difficulties with the estimation of values of the various theoretical parameters for a specific factory. For example, what is the total scattering cross-section density of the fittings in a factory?

The limitations suggest that only empirical prediction methods, derived from measurements of SP and RT in factories, may be efficacious. Friberg /4/ has developed such a method for the prediction of the slope of the dBA SP curve and of the RT at 1kHz. These are determined from the absorption coefficient of the factory ceiling and from constants describing the factory shape and fittings. The method is limited in scope and accuracy for the following reasons:

a) It provides limited frequency information;
b) The SP curve is assumed to be of constant slope;
c) Only the SP curve slope, but not its absolute level, can be predicted;
d) The method does not account for the influence of non-flat (e.g. pitched or sawtooth) roofs.

Work is in progress to develop more comprehensive empirical predictions.

TOWARDS IMPROVED EMPIRICAL PREDICTIONS

To date, the octave-band SP and/or the third-octave-band RT have been measured in three empty and seven fitted factory configurations. The measured RT spectra are shown in Figure 1; the dBA SP curves, derived from the octave-band results, are presented in Figure 2. The factory volumes and fitting densities (empty, low, medium or high) are given; further details of the measurement results and their implications are to be published /5/. In all cases the factories had roofs constructed of double panels mounted on a metal framework, a construction typical in Britain. Further extensive measurements are in progress aimed at expanding the data base.

The results of the full-size factory measurements, and of the factory investigations, suggest that the following empirical prediction procedures will be effective:

a) RT - the RT at 1kHz is first predicted and then the RT at other frequencies is determined;
b) SP - SP curves are characterised by two straight line segments which intersect at a source/receiver distance of m. The slopes

and absolute levels of the two segments of the dBA SP curve are first predicted and then the slopes and levels of the segments for other frequencies are determined.

Several facts, relevant to empirical prediction of factory SP and RT by the above methods, have become apparent in the course of the research (refer also to Figures 1 and 2):

a) Factory roofs of panel construction have high apparent diffuse-field absorption at low frequencies due to their vibration and sound transmission properties;
b) The shapes of the RT curves in all panel-roof factories are similar and are the inverse of the factory total absorption curve. The RT is lowest at low (due to ceiling absorption) and high (due to surface and air absorption) frequencies and is highest near 1kHz;
c) The absolute level of the RT curve mainly depends on the factory volume, total absorption and fitting density;
d) The initial and final slopes of the SP curves mainly depend on the factory shape and fitting density;
e) The absolute levels of the SP curves mainly depend on the factory volume and total absorption;
f) SP levels at short source distances usually increase with frequency;
g) SP levels at large source distances usually vary with frequency as does the RT;
h) As far as SP is concerned, non-flat roofs act as directionally-dependent fittings at low frequencies.

Following completion of the further factory measurements, the above effects will be quantified in order to derive improved empirical predictions. The problem of how best to quantify the factory fittings remains to be solved.

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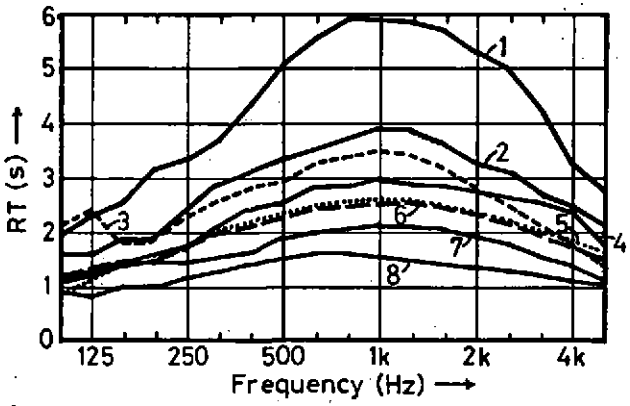

FIG 1. MEASURED RT IN EMPTY AND FITTED FACTORIES

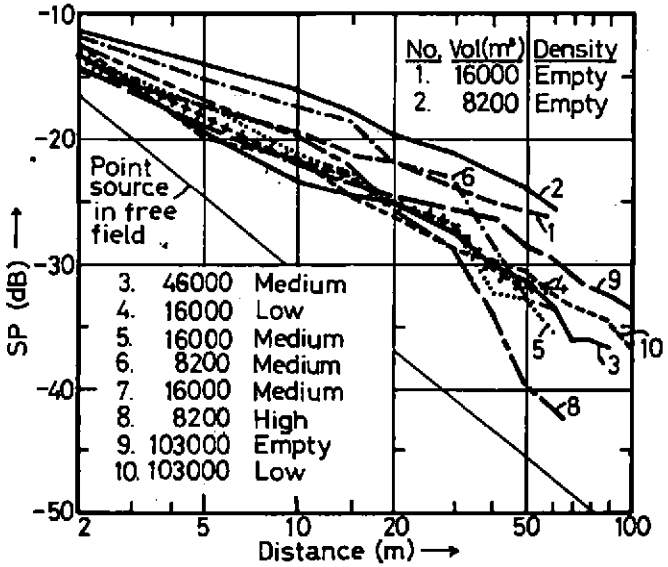

FIG 2. MEASURED DBA SP IN EMPTY AND FITTED FACTORIES