Acoustics Memoirs - Some Byways

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Extract from Acoustics Memoirs, in course of preparation

Acoustics is both a science and an art – a science because it is a body of organized knowledge; an art because this knowledge requires imagination in its application. The science and art of Acoustics has a very long history: that of architectural and musical acoustics going back at least to the days of the Greek amphitheatres and the musical studies of Pythagoras (c. 570-500 BC). Most other branches of acoustics are of much more recent origin, such as the measurement and reduction of Noise (ie, unwanted sound).

The history of the conducting of noise tests in the sphere of public transport operations has quite a long history, in this country going back at least to M&MTB (Melbourne & Metropolitan Tramways Board) operations in the later 1920s. These early tests were conducted as a result of strong public complaint about "noisy" trams. Many of these complaints occurred in areas where, as a result of tram track construction, reconstruction or maintenance using tracks with concrete foundation, the wheel-on-rail noise ("wheel rumble" noise, including that of wheel "flats") had noticeably increased. Because it was known that a concrete track foundation was less resilient than ballast and sleepers, most of the early tests were conducted to compare the noise of a selected test tram travelling over tracks of ballast (both open and paved), concrete, and modified-concrete constructions. Modifications to a concrete foundation were generally of a kind that introduced some degree of resilience into the rail support by means of, for example, timber or rubber.

These early noise measurements made in the later 1920s were made with a locally developed "noise meter" consisting of a microphone, amplifier and indicating output meter. While the measurements of the noise made by a tram travelling over the various types of track enabled some *qualitative* comparisons to be made from the different output meter readings, there was then no satisfactory *quantitative* way of interpreting them. The noise testers of that time were still very much in the dark, for there were as yet no standardized form of noise meter and sound level and loudness units for satisfactorily interpreting the output meter indications in a fully quantitative way. In addition, such early instruments were not capable of coping with impulsive sounds.

With the introduction in the USA in the mid 1930s of national standards for *Noise Measurement* (ASA Tentative Standard Z24.2–1936), and for noise-measuring instruments such as the *Sound Level Meter* (Z24.3), the previous situation was greatly clarified. However, even then, many investigators concentrated too much on the sound level readings in decibels (dB), and tended to regard as of primary significance a change of ± 3 dB as representing a twofold change in sound energy (or intensity), or ± 6 dB as representing a twofold change in sound pressure, even though the relation between *Loudness and Loudness Level* (ASA Z24.3–1936, figure 2) showed that it was a change of the order of ± 10 dB which corresponded to a twofold change in the sensation of loudness.

For, in ASA Z24.3–1936 not only was *Loudness* only vaguely defined, but it was also not clearly stated that the loudness unit scale of ASA Z24.3–1936, figure 2 represented an arithmetic scale with scale numbers proportional to the sensation of loudness. This situation was not made clearer until, for example, in British Standard (BS) 661: 1955, Glossary of Acoustical Terms, *Loudness* was defined as "an observer's auditory impression of the strength of a sound (definition no. 3010)," and the sone (= 1 000 ASA Z24.3 loudness units) as "the unit of loudness on a scale designed to give scale numbers proportional to the loudness (defn 3011)."

Yet, these standard definitions, and other more general noise scales indicating, for example, that sound levels of 0 to 20 dB represented *very faint* sounds, 20-40 *faint*, 40-60 *moderate*, 60-80 *loud*, 80-100 *very loud*, and above 100 dB *deafening*, have not invariably been sufficiently persuasive to get the noise-makers to reduce their unwanted sound. It has taken other more detailed criteria – for example, the Maximum Permissible Speech Interference Levels for Reliable Speech Communication (AS 2822), and Maximum Noise Exposure Levels – and, ultimately, statutory Regulations for the Control of Noise to get the more stubborn noise-makers to act.

In Melbourne in the 1920s and 30s the chief remedies for minimizing tram wheel rumble were to maintain rail and wheel tread surfaces as smooth as possible, and free from corrugations and wheel flats. The M&MTB's continuing noise testing program was much helped by the purchase of a Sound Level Meter (a GR Model 759B) in the late 1930s, and by the establishment of an Engineering Testing Department in 1939 under the late Mr D H Eakins, whose organization included one or more engineers knowledgeable, inter alia, in making noise measurements. In this Testing Department, an early method of the statistical analysis of sound levels was developed in around 1950 by Mr K T Hall, by taking a large series of successive levels at about 3 seconds intervals, to obtain, for example, the resulting L_{10} and L_{max}. Also, the first M&MTB tape-recording of vehicle noise for later laboratory octave-band frequency analysis was carried out here by the author in 1957.

Over the intervening years, the problems of wheel-on-rail noise from trains and trams have been largely solved, through the use of resilient wheels, electric (including regenerative) braking, and resilient track foundations. The quieter operation of trains and trams in underground tunnels has been achieved, as is shown in the Melbourne Underground Rail Loop; and even "wheel squeal" on curved track has been significantly, if not always completely, reduced.