Proceedings of the Institute of Acoustics

SOUND POWER LEVEL FROM ROLLING STOCK
A CRITICAL REVIEW OF THE AUSTRIAN STANDARD S 5024

M T Kalivoda

Federal Environmental Agency, Dep. for Noise Control, Vienna, Austria

1. INTRODUCTION

Increasingly, noise from railbound vehicles is a problem in Austria. Therefore, in the late 80's a broad-ranging study concerning noise immissions from railways [1] was made. Results of this study were used to create a calculation model for railway noise immissions [2] and to standardize the methods for determination of sound power level of railbound vehicles in the Austrian Standard S 5024 [3].

I would like to briefly present the method of the Austrian Standard S 5024 and my critical remarks on some details of this model. These remarks will not address themes like: Will time average 'slow' fit better than 'fast' to determine noise? Rather, my comments concern fundamental theoretical discrepancies.

2. SOUND POWER LEVEL ACCORDING TO AUSTRIAN STANDARD S 5024

When we talk about sound power levels here, we always mean normalized sound power levels for a train length of 1 meter. A single railbound vehicle or a train - the Austrain Standard S 5024 does not distinguish between them - is said to consist of a series of l incoherent point sources passing by at a heigth of 0.3 meters above the rails where l is the length of the vehicle or train in meters (Fig. 1).

The measurement surface is - adapting a hemisphere for a cross section - a semicircle centered on the theoretical emission point E (Fig. 2) Sound pressure level is recorded while the whole train passes this measurement arch - we cannot call it measurement surface any longer for now it is in fact only an arch - and the average level (L_{eq}) is calculated.

The radius R of the semicircle measurement arch can be chosen within a range of 7.5 to 15 meters. When choosing your radius you have to be sure that neither background noise nor aerodynamic noise will influence the measured level. In practice a radius of 7.5 meters is prefered.

Two microphone positions are required which lie on the measurement arch. Microphone #1 has to be level with the emission point (0.3 meters above the rails) but at least 1.2 meters above the ground and microphone #2 has to be 30° over the horizontal line. There is no need for additional microphone positions because sound power level is extrapolated using a dipole directivity:

$$L_{W,i}' = L_i + 14 - 10\,lg\,[\,s^2 / r^2 * (\,2/r * \arctan(z/2r) + z / (r^2 + (z^2/4)\,)\,)\,]$$

with L_i ... SPL for one-octave-band i, z ... train length and $s = r * \cos\varphi$

Ground attenuation has to be considered and the Austrian Standard S 5024 gives a model for calculating the correction factor for either reflecting or absorbing surfaces.

3. RESULTS

Since 1990 several measurements have been made by the Federal Environmental Agency in cooperation with the Austrian Federal Railways to determine noise emissions from different kinds of locomotives, coaches and wagons. Therefore, a newly developed multi-channel recording device [4] was used which allowed 6 microphones to be put in various positions on or around the semicircle measurement arch (Fig. 3). Microphone #1 was put on a radius of 15 meters and at an angle of 30° above the horizontal line to make the results comparable to former measurements. Four microphones were arranged on a quarter circle within an angle of 7° to 74°. In addition, one microphone (#5) was posted 3.5 meters over microphone #6 to form a part of a parallelepiped or conformal measurement surface.

Figures 4 to 7 show some typical noise cross sections - that is, the equivalent sound pressure level as a function of the angle above the horizontal line - of an electric locomotive and three goods wagons. The results show that there is only a diploe directivity for low microphone positions (angle $\varphi < 30°$) for the locomotive and the wagons. The higher microphones are posted on measurement arch, the greater the difference between the theoretical dipole (line) and the measured sound pressure level (black triangles). Only the conform measurement point #5 shows negligible differences to the dipole directivity.

There is a great discrepancy in A-weighted sound power level depending on the calculation methode. If we only take microphone positions #2 and #6 - according to the Austrian Standard S 5024 - sound power level will be 4 to 6 dB lower than the exact value from positions #2, #3, #4 and #6!

At first sight these results contradict the literature. More closely observed there are many non comparable results. Some of the quoted measurements [5, 6] used only low microphone positions and many authors [5..8] only consider the wheels as a noise source and therefore use the dipole directivity. Hohenwarter [9] shows results for different kinds of railbound vehicles from measurements with microphone positions up to 50.5° where there is a dipole directivity in some cases for frequencies from 630 Hz to 8 kHz. It must be mentioned that Hohenwarter used a measurement arch with radius R = 15 meters instead of the usually chosen R = 7.5 meters.

A study [10] from the international railway association (ORE) deals with the identification of noise sources on wagons. The measurement surface used is a conform surface and there are 11 microphone positions ranging from level with rail up to 3.5 meters (Tab. 9). Also for the conform surface in very short distance (1.6 meters from rail) there are divergences from a dipole directivity for almost all microphone positions of up to 4 dB. This is in agreement with our results that in short distances the is no dipole directivity. Car body construction has a greater influence on the total emission level than is generally assumed. A study [12] shows that the effect of a noise barrier strongly depends on the body construction of the railbound vehicle.

The selection of the measurement surface is very important. Using the criteria of ISO 3744 [11] in a modified form with b = 3.0 meters and h = 4.0 meters:

$$d_o = [\ (b/2)^2 + h^2]^{1/2} = 4.25 \text{ meters}$$

the radius R has to be equal or greater than 8.5 meters ($2 \cdot d_o$) for a hemispherical surface. If a distance of 7.5 meters is chosen, it would be to select the parallelepiped or conformal surface.

4. CONCLUSIONS

* The selection of an appropriate measurement surface considerably influences the results of measurements. It could be shown that in conformity with ISO 3744 and the results of ORE [10] the use of a parallelepiped or conformal surface produces better results than the hemispherical surface.

* In general, the hypothesis of a dipol directivity of rail noise is not valid. Dipole directivity may be accurate enough for modelling the noise immissions at some distance from the track but cannot be used to extrapolate SPL for sound power level.

* Extrapolation of sound power level from a few SPLs is not recommended neither for dipole nor for other directivities. All directivity models are based on results from existing railbound vehicles but cannot anticipate constructive changes of the directivity.

With a method following the Austrian Standard S 5024 we encourage constructors to put noise sources (f.e. radiators, air-conditioning) on the roof of the vehicle. The sound power level will diminish without having the noise emission reduced.

* There is a need for further investigations on the directivity of rail noise and the contribution of body construction to total emitted noise.

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SOUND POWER LEVEL FROM ROLLING STOCK

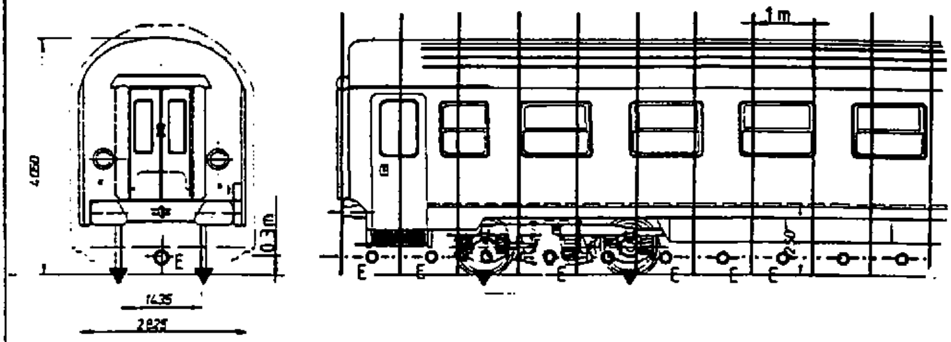


Fig. 1: Emissionpoint(s)

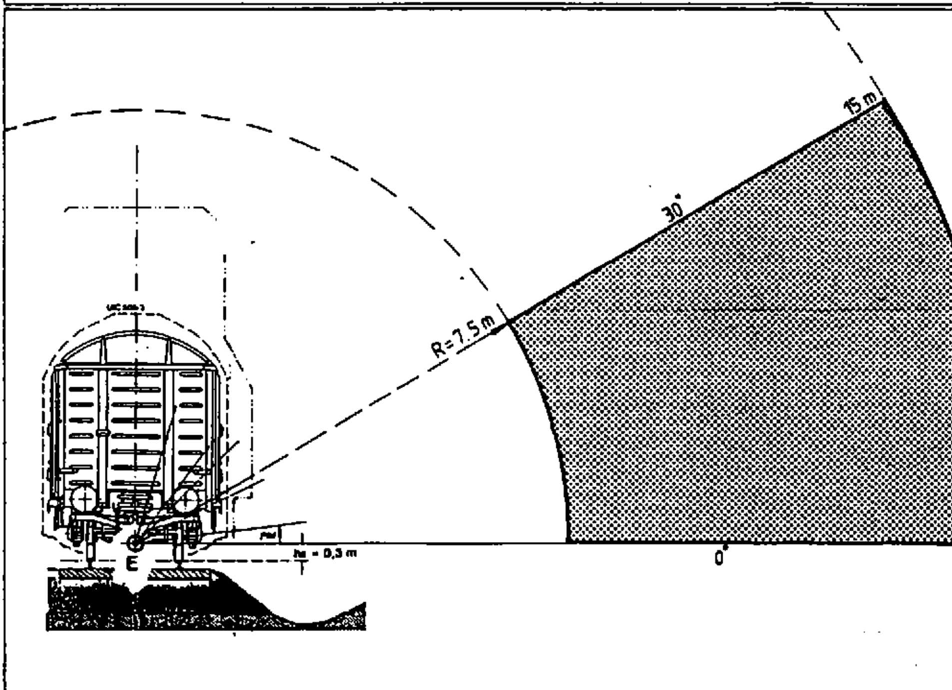
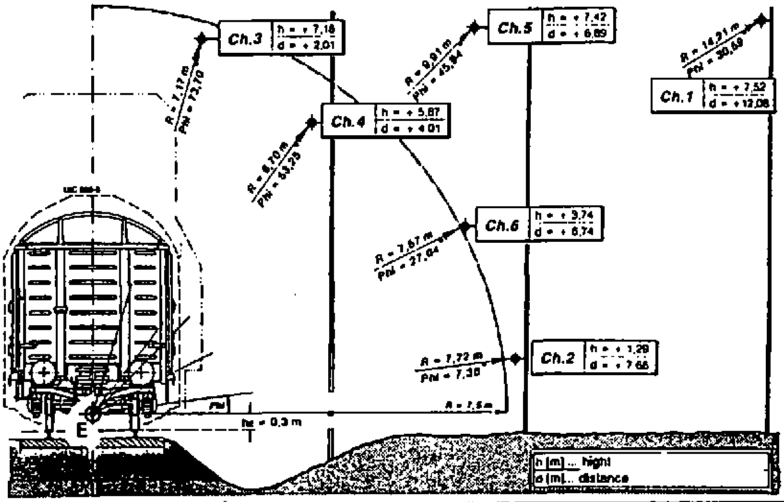


Fig. 2: Measurement surface according to Austrian Standard S 5024

Fig. 3: Microphone positions



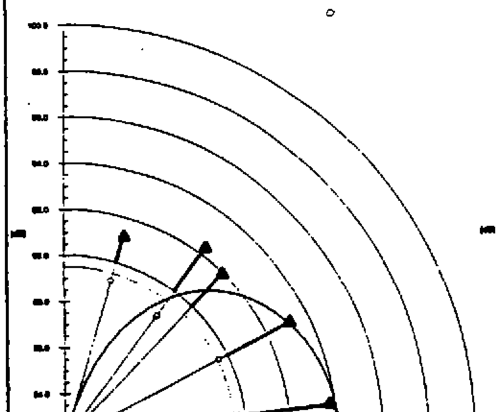


Fig. 4: Locomotiv class 1044.216

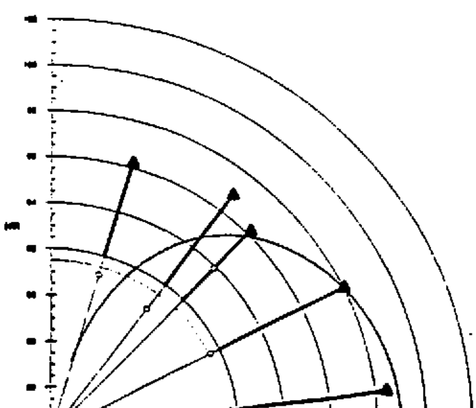


Fig. 5: Hopper 'Tds'

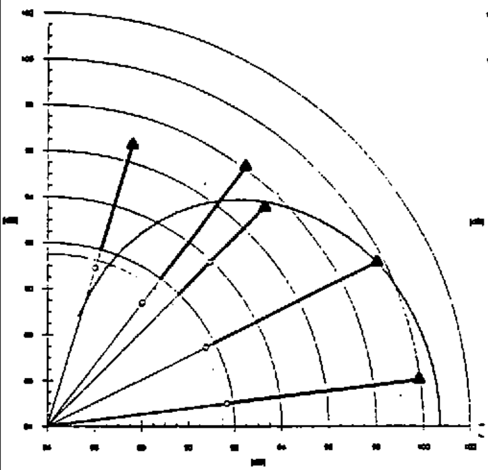


Fig. 6: Bogie high sides wagon 'Eaos'

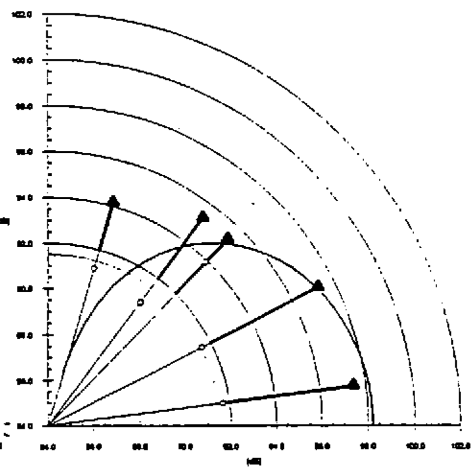


Fig. 7: Bogie flat wagon 'Rs'

Tab. 1: ORE result [10] compared with dipole directivity for three wagons

	Taes			Eaos			Res		
height [cm]	ORE [1]	dipole [2]	difference [1] - [2]	ORE [1]	dipole [2]	difference [1] - [2]	ORE [1]	dipole [2]	difference [1] - [2]
m0	98.5			97.5			97.0		
m10				98.0	97.5	+ 0.5	98.0	97.0	+ 1.0
m20	98.5	98.5	+ 0.0	98.0	97.5	+ 0.5	98.0	97.0	+ 1.0
m40	98.5	98.5	- 0.5	97.5	97.5	+ 0.0	98.0	97.0	+ 1.0
m60	98.0	98.4	- 0.4	97.5	97.4	+ 0.1	98.5	96.9	+ 1.6
m80	98.0	98.3	- 1.3	98.0	97.3	+ 0.7	97.5	96.8	+ 0.7
m100	97.0	98.1	- 3.1	97.5	97.1	+ 0.4	97.5	96.6	+ 0.9
m150	95.0	97.5	- 3.5	96.0	96.5	- 0.5	95.0	96.0	- 1.0
m200	94.0	96.6	- 4.1	93.5	95.6	- 2.1	92.5	95.1	- 2.6
m250	92.5	95.7	- 3.7	92.0	94.7	- 2.7	91.0	94.2	- 3.2
m300	92.0	94.8	- 3.3	91.5	93.8	- 2.3	90.0	93.3	- 3.3
m350	91.5	93.9	- 2.4						