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Interlaboratory Variability in the Determination of Sound Power

by R.E. Halliwell

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RÉSUMÉ

La puissance du son d'une source de référence a été mesurée dans un certain nombre de laboratoires au Canada et aux États-Unis, en utilisant le même équipement et la même source. La variabilité des résultats indique des différences d'un laboratoire à l'autre.

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Interlaboratory variability in the determination of sound power

R. E. Halliwell

National Research Council of Canada, Division of Building Research, Ottawa, Ontario, Canada K1A 0R6

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Sound power measurements of a reference sound source were made at a number of laboratories in Canada and the United States. The same reference source and the same measurement equipment were used in all cases. The variability of the results reflects differences in the laboratories.

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INTRODUCTION

A recent round robin on sound absorption measurements¹ in which the same sample and measurement equipment were taken to a number of laboratories in Canada and the United States also provided an opportunity for sound power measurements to be made on the same source in a number of different reverberation rooms. Any differences in the measured levels should reflect the variations in the geometry, absorption, or diffuser configuration of the reverberation rooms.

I. MEASUREMENT PROCEDURE

The direct method for determining sound power as defined in ANSI S1.31-1980² was followed, allowing the empty room reverberation times previously determined for the absorption measurements to be used.

To obtain the reverberation times, the room was excited with four loudspeakers, each driven with an independent noise source. Sound decays were collected in 1/3-oct bands from 80–5000 Hz using a real time analyzer interfaced to a minicomputer. This system provided simultaneous level measurements on all 19 bands every 1/16 s. For each of the eight microphones, the average of 20 decays was obtained using the decay curve averaging procedure described by Chu.³ The reverberation times were calculated from a least-squares straight line fit to the top 25 dB of decay for each band from the average decay curves and then averaged over the eight microphones. This procedure is described in detail in Ref. 1. The sound pressure levels from an ILG reference sound source were measured on each of the eight microphones with a 32-s integration time, corrected for any microphone calibration, and then averaged to get the mean sound

level in the room. The microphones, 1/2-in. B & K type 4149, have a flat response in a free field. To provide correct sound pressure levels in a reverberant field, a correction was applied as a function of frequency to give the random incidence response. The absolute sound pressure level was obtained by the use of a B & K 4230 calibrator. Sound pressure levels were measured for six positions of the source (except in Laboratory E); reverberation times were then used with the mean sound levels to obtain the mean sound power level and the standard deviation about the mean. The sources were positioned at least 1.5 m from any reflecting surface, other than the floor, and at least 1.8 m apart.

The sound power levels were corrected for the air temperature but not for the barometric pressure. There is a possible error of ~0.2 dB due to possible changes in barometric pressure. The relative humidity was monitored to ensure it remained constant during the measurement period.

II. PARTICIPATING LABORATORIES

Nine laboratories in Canada and the United States participated in this round robin. Details of the reverberation rooms are given in Table I. All of the rooms were rectangular except one; it had five walls, although they were vertical and met both floor and ceiling at right angles. Four of the rooms did not have rotating diffusers and one did not have fixed diffusers.

III. RESULTS AND DISCUSSION

The mean sound power levels for each laboratory, the overall mean sound power level, and the overall standard deviation are given in Table II and plotted in Fig. 1. The mean sound power and standard deviation for each laborato-

TABLE I. Participating laboratories.

Laboratory	Volume (m ³)	Surface area (m ²)	Floor area (m ²)	Fixed diffuser area (m ²)	Rotating diffuser area (m ²)	Total diffuser area (m ²)
B	251	246.1	51.6	23.3	9.1	32.4
C	303	277.4	55.2	22.9	18.2	41.1
D	267.8	255.3	50.1	25	0	5
E	536.6	400.2	67.2	0	0	0
F	284.3	262	53.8	29.1	11.9	41.0
G	291.3	266.1	44.8	19.2	11.8	31.0
H	422.9	338.3	72.5	14.9	0	14.9
I	315.1	284.3	55.7	8.9	0	8.9
J	282	262.9	54.3	17.8	16.4	34.2

TABLE II. Sound power levels.

Frequency	Laboratory designation										Mean	Sigma
	B	C	D	E	F	G	H	I	J	C ^a		
80	71.9	73.7	72.4	73.8	71.9	73.7	73.4	70.4	70.8	73.2	72.4	1.32
100	73.6	75.1	73.5	73.5	73.5	72.4	74.7	73.2	73.5	74.3	73.7	0.82
125	74.6	76.3	74.1	75.5	74.8	74.3	75.2	75.5	75.1	75.9	75.0	0.74
160	76.0	76.2	75.2	75.8	74.9	74.8	74.7	74.7	75.2	76.1	75.3	0.65
200	76.0	76.6	75.0	75.7	75.0	74.6	74.9	75.0	74.9	76.4	75.3	0.77
250	75.9	76.6	75.5	76.2	75.9	75.8	75.8	75.8	76.0	76.5	75.9	0.37
315	76.6	76.9	76.1	76.4	76.1	76.0	75.9	75.9	76.4	76.9	76.3	0.43
400	76.0	76.8	75.7	76.4	76.0	75.7	75.6	75.7	76.1	76.5	76.0	0.42
500	75.9	76.7	75.8	76.3	76.0	75.7	75.4	75.7	76.1	76.2	75.9	0.41
630	75.7	76.5	75.4	75.8	75.6	75.4	75.1	75.3	75.7	75.8	75.6	0.39
800	75.5	76.0	75.1	75.7	75.4	75.2	75.0	75.1	75.4	75.5	75.4	0.35
1000	75.9	76.3	75.3	76.0	75.7	75.5	75.3	75.3	75.7	75.7	75.7	0.33
1250	76.1	76.6	75.8	76.3	76.0	75.8	75.6	75.6	76.1	76.0	76.0	0.32
1600	76.1	76.5	75.8	76.3	76.1	75.9	75.6	75.7	76.1	76.1	76.0	0.29
2000	76.1	76.5	75.7	76.0	76.0	75.8	75.5	75.5	76.0	76.0	75.9	0.33
2500	75.7	76.5	75.3	75.9	75.7	75.4	75.1	75.1	75.6	76.0	75.5	0.45
3150	75.6	76.4	75.1	75.6	75.5	75.3	75.0	75.0	75.5	76.1	75.4	0.50
4000	75.2	76.4	74.7	75.0	75.0	75.0	74.6	74.6	75.0	76.0	75.1	0.64
5000	75.1	76.1	74.4	75.1	75.0	75.0	74.6	74.5	75.1	75.5	75.0	0.51
Number of positions	2 ^b	6	6	4	6	6	6	6	6	6		

^a Levels obtained using the ILG belonging to Laboratory C. These data are not used in calculating the mean and sigma.

^b Due to an error, some of the data from this laboratory were lost, thus the mean given is for only two positions. The standard deviation shown in Fig. 2 is from a subsequent measurement using the same ILG reference source but different instrumentation.

ry, plotted as deviations from the overall mean, are shown in Fig. 2, and the standard deviation about the mean for each laboratory is shown in Fig. 3.

The sound power measured for the ILG source at Laboratory C is higher than the overall mean. This would suggest that there is a signature associated with a particular room geometry, particularly at low frequency. The increased level and standard deviation at high frequencies found at Laboratory C are a result of rf contamination of several of the microphone outputs for these bands. It is not clear from the room specifications which parameters are important in de-

FIG. 1. Mean and standard deviation of sound power for all laboratories.

FIG. 2. Mean sound power and standard deviation for each laboratory plotted as deviations from the overall mean.

FIG. 3. Standard deviation about the mean sound power for each laboratory.

termining the room signature as there does not appear to be any correlation with room volume, presence of a rotating vane, or presence of fixed diffusers. Although six source locations were used at most of the laboratories, rather than the eight specified in the standard ANSI S1.31-1980 to qualify a laboratory for broadband sound power determination, it is clear that all of these rooms would qualify for measuring the sound power levels of broadband sources in the frequency range 100–5 kHz.

IV. CONCLUSIONS

The requirements of ANSI S1.31-1980 to qualify a room for performing sound power measurements of broadband sources is easily met by most reverberation rooms.

There is a small dependence on room geometry which will only be understood through further careful measurements. Although there are differences between the laboratories, the small overall standard deviation indicates that the reproducibility of the measurement (in which instrumentation is kept invariant) is quite good.

¹R. E. Halliwell, "Inter-Laboratory Variability of Sound Absorption Measurement," *J. Acoust. Soc. Am.* **73**, 880 (1983).

²"American National Standard Precision Methods for the Determination of Sound Power Levels of Broad Band Noise Sources in Reverberation Rooms," ANSI S1.31-1980, American Institute of Physics, New York.

³W. T. Chu, "Comparison of Reverberation Measurements Using Schroeder's Impulse Method and Decay Curve Averaging Method," *J. Acoust. Soc. Am.* **63**, 1944 (1978).

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