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PRECISION OF A NEW METHOD TO MEASURE FAN STRUCTURE-BORNE VIBRATION

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1. INTRODUCTION

Structureborne noise from small air moving devices (fans) installed in computer and business equipment is often as important as fan airborne noise. To reduce the noise associated with both, fan manufacturers and cooling system designers need meaningful and cost-effective methods of measuring both structureborne vibration and airborne noise for fan selection, fan specification, and system acoustical design. There is a standard for quantifying airborne sound from air moving devices (AMDs): ISO/DIS 10302 [1, 2]; however, there is no counterpart standard for structureborne vibration induced by such fans. The fan vibration subcommittee of the Institute of Noise Control Engineers (INCE) Technical Group on Information Technology and Telecommunications Equipment (TG/ITTE) has developed a draft recommended procedure for measuring and reporting vibration levels from small fans - the source of the structureborne noise [3,4].

To determine the precision of the draft procedure, the fan vibration subcommittee conducted a limited inter-laboratory round robin test. The round robin test is intended to determine if the procedure gives comparable results in different labs using different test apparatus, instruments, and personnel and to quantify the differences.

2. DRAFT MEASUREMENT METHOD

The subcommittee's draft Recommended Practice defines uniform procedures for measuring and reporting the vibration levels that small AMDs are expected to induce in typical structures of computers. The AMD is mounted on a damped panel, which approximates key mechanical properties of typical end-use enclosures [5], on an ISO/DIS 10302 plenum box for pressure loading of the AMD. Vibratory acceleration levels L_a (with a reference level of 10^{-6} m/s^2) are measured on the damped panel near the AMD attachments when the AMD is operated at each of three specified operating points according to ISO/DIS 10302: 100%, 80%, and 20% of free delivery (FD). For each operating condition, the energy average acceleration levels $\langle L_a \rangle$ of the measurements at the individual mounting points are determined. The primary descriptor of the vibration induced by the AMD is the unweighted acceleration level $\langle L_{a(25\text{-}5K)} \rangle$ for the frequency range encompassing the one-third octave bands from 25 Hz to 5 kHz. The detailed descriptors are the one-third octave band acceleration levels $\langle L_a \rangle$ for that frequency range. The primary descriptor $\langle L_{a(25\text{-}5K)} \rangle$ correlates well with the A-weighted airborne noise level radiated by a typical structure induced by the AMD vibration[4].

Test Samples

Five small air-moving devices from five different manufacturers were measured in the round robin. The fans' physical details, free delivery flow rates, and average acceleration levels, as determined from this round robin, are given in Table 1.

Table 1. Air Moving Devices [AMD] tested in Vibration Round Robin

AMD No.	Type	Size	Free Delivery Flow rate	$\langle L_{a(25\text{-}5K)} \rangle$, dB @ %FD 100	80	20
1	TA	40 mm	.0016 m^3/s [3.4 cfm]	90	89	89
2	TA	120 mm	.060 m^3/s [127 cfm]	91	90	90
3	TA	172 mm	.122 m^3/s [260 cfm]	91	91	93
4	SIFCB	160 mm	.034 m^3/s [73 cfm]	87	--	94
5	DIFCB	330 mm	.137 m^3/s [292 cfm]	100	99	107

TA = Tube Axial fan , SIFCB = Single inlet forward curved blower,
DIFCB = Double inlet double scroll forward curved blower

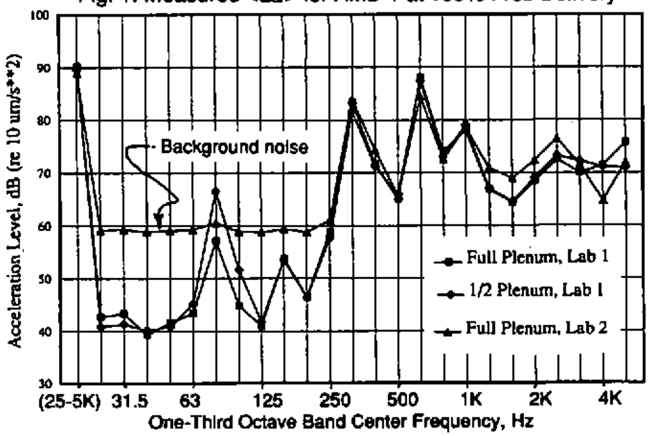
Round Robin Test Methodology

Two labs participated in the round robin yielding data from five fans, on three different plenums (two full-sized and one half-sized), and by five different operators. Each lab received a set of detailed instructions, a copy of the draft test procedure, information on the performance of the fan, and instructions on mounting the fan to the their damped plate(s). Vibration levels were measured and recorded as specified, after which the fan was remounted and retested as required by ISO 5725 [6]. Background acceleration levels were also measured.

Results

The one-third octave band L_a data from each accelerometer were analyzed to obtain $\langle L_a \rangle$ over the perimeter of the fan for each operating condition. Figure 1 presents the $\langle L_{a(25\text{-}5K)} \rangle$ and one-third octave band $\langle L_a \rangle$ obtained for AMD 1 from Labs 1 and 2 for two full sized plenums and one half-sized plenum for operation at free delivery. (The background levels were approximately 60 dB in Lab 2 and 40 dB in Lab 1; thus the low frequency measurements from Lab 2 are influenced by background levels and were not used in the subsequent analysis.)

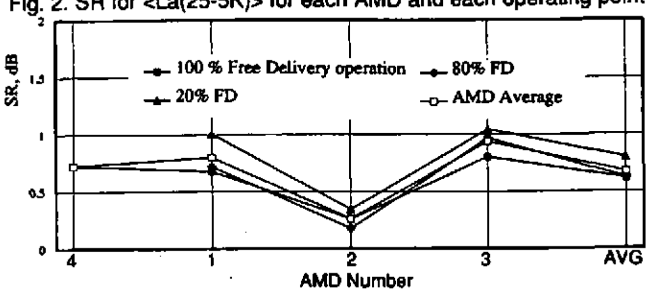
Fig. 1. Measured <La> for AMD 1 at 100% Free Delivery



The data for each condition were plotted, examined and analyzed according to the procedures of ISO 5725. Data that were not valid were excluded from final analysis.

The standard deviation of reproducibility SR is a measure of the precision of the test procedure due to all sources of variability including different laboratories, test apparatus and installation, operators, instruments and random error. SR was determined for $\langle L_{a(25\text{-}5K)} \rangle$ and for each one-third octave $\langle L_a \rangle$ for each AMD according to the procedures of ISO 5725. Figure 2 presents the SR for $\langle L_{a(25\text{-}5K)} \rangle$ for each AMD at each operating point. (There is no SR for AMD 5, since it was tested at only LAB 1 in one plenum.) The AMD order in Figure 2 is from lowest to highest $\langle L_{a(25\text{-}5K)} \rangle$ at free delivery. There is no apparent trend in SR as a function of $\langle L_{a(25\text{-}5K)} \rangle$ nor are there significant differences between the operating points, with the exception that SR at 20% free delivery is greater than at the two other operating points. Combining the values for all AMDs and

Fig. 2. SR for <La(25-5K)> for each AMD and each operating point

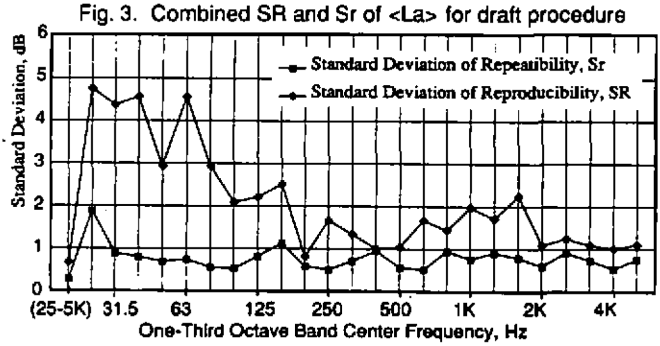


operating conditions, results in an average SR for $\langle L_{a(25-5K)} \rangle$ of 0.67 dB.

The final values for SR and the standard deviation of repeatability Sr, which is a measure of the random error, were obtained by averaging the SR's and Sr's obtained from the valid data from each lab, plenum, and operating point. In addition to the exclusion of the aforementioned data, all one-third octave band $\langle L_a \rangle$ which were within 10 dB of the background levels were excluded since the primary purpose of the test procedure is to characterize vibrations which are significant. (10 dB is the criteria in the draft procedure for such corrections)

The final values for SR and Sr for $\langle L_{a(25-5K)} \rangle$ and the one-third octave band $\langle L_a \rangle$ are presented in Figure 3. As noted previously, the value for SR for $\langle L_{a(25-5K)} \rangle$ is less than 1 dB; the values of SR for the one-third octave band $\langle L_a \rangle$ are less than 5 dB for the bands from 25 to 63 Hz, less than 3 dB for the bands from 80 to 160 Hz, and less than approximately 2 dB for higher frequencies. These values apply to AMDs which have not been damaged and are operating in a stable manner, and to data which are unaffected by background noise.

Fig. 3. Combined SR and Sr of <La> for draft procedure



3. RECOMMENDATIONS

The authors believe that the precision of the draft vibration measurement procedure for small AMDs is acceptable for its intended purposes and that it is a practical procedure that complements the airborne noise test procedure in ISO/DIS 10302. Furthermore, the authors recommend that it be considered as an INCE recommended practice for general use.

Acknowledgment

The authors wish to thank those who have actively participated in the development of this procedure: the members of INCE TG/ITTE vibration subcommittee and those who participated in the tests.

References: [1] ISO/DIS 10302; [2] R. Lotz, Noise-Con 91, p 119 (1991); [3] H.-S.Pei and L. Wittig, Noise-Con 90, p 31 (1990); [4] INCE TG/ITTE (subcommittee) draft recommended practice "Measurement of Structureborne Vibration Induced by Small Air Moving Devices", April 1995; [5] L.E. Wittig, Noise-Con 91, p 617 (1991); [6] ISO 5725.