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LOW FREQUENCY NOISE EMITTED BY COMPUTER DISK DRIVES - EFFECT OF MULTIPLE DISK DRIVE INSTALLATIONS

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1. INTRODUCTION

Low frequency noise problems are not usually associated with computer disk drives, the more normal problem, if any, being in the 4 to 6 khz octave bands associated with the read/write mechanism during file operation. The reason for this is that disk drive rpm's have normally been low enough for the out of balance vibration,and hence structurally borne noise, to be outside the frequency range of interest ,as specified in ISO 7779 , Measurement of Air Borne Noise emitted by Computers and Business Machines. This is from the 100 Hz one-third octave band to the 10000 Hz one - third octave band

For example ,the norm for high performance 3.5 inch form factor drives was around 5000 to 5400 rpm with a fundamental frequency just below the lowest frequency in the 100 Hz one- third octave band.

However, the technology is changing rapidly and the norm for a high performance drive is now around 7200 rpm with a fundamental frequency of 120 Hz which is well within the frequency range of interest. This change , combined with the increasing use of multiple disk drive arrays in one box, has given rise to a number of technical problems in both noise control and noise measurement since the low frequency tone emitted by a box containing an array of disk drives is non- stationary at the fundamental frequency of the drive rpm..

The intent of this paper is to outline the measurement problems which have arisen in obtaining consistent and repeatable sound power measurements on multiple disk array products and to describe the technique used at Xyratex to give consistent results which can be used for noise declaration purposes.

2. PROBLEM DEFINITION

The problem only becomes significant when measurements are made on products containing multiple disk drives; typically 8 or more. Since all the drives are running at slightly differing rpm's the sound pressure level measured at any given position around the product in the one third octave band ,containing the tone , varies with time as the disk files go in and out of synchronisation . This leads to a number of anomalies when attempting to make standard measurements for noise control engineering work and noise declaration purposes. Measurement anomalies occur when the sound pressure level in the one third octave band is so high , compared to the level in the other bands ,that the A weighted sound pressure level also varies with time leading to a problem in calculating the sound power level from the surface spatial average sound pressure measurements which are also time variant.

Essentially there are three problems: a measurement procedure which will give consistent answers and the ability to measure noise reduction improvements in A weighted sound power without the effect being masked out by variations in the 120 Hz tone , secondly a method of measuring any reduction in the tone itself. Thirdly : how to declare a statistical upper noise level for sound power as required in ISO 9296 (Declared noise emission values of computer and business equipment) ,when the variance with time is greater than the variance of Reproducibility and Production ,the latter two numbers being used to determine the declared statistical upper limit.

3.MEASUREMENT PROCEDURE

The measurement problem is addressed to some extent, in ISO 3744:1994(E),7.5.3 Procedure and ISO /DIS 11201.2 , paragraph 3.3.1 time averaged emission sound pressure level, where time averaging is defined. However , in both instances , the wording allows a good deal of latitude so long as the procedure is carefully defined in the final test report.

Initial measurements in the semi- anechoic chamber using the standard rotating microphone technique resulted in wide variations in sound power when measurements were made at different times .It was therefore decided to make use of existing measurement software which allowed sound power measurements to be made at discrete continuous time intervals as described below.

Sound power measurements were made using the rotating microphone boom technique as specified in ISO 3744 for free field measurements over a reflecting plane The boom rotates one revolution every 32 seconds and the spatial average sound pressure level is measured in quadrants at each microphone height over an 8 second time period. The sound power level is therefore calculated from the average value of 20 measurements over the hemisphere in 160 seconds. By running the boom continuously a series of measurements with time can be made at nominal 160 second intervals.

4.MEASURED RESULTS AND DISCUSSION

Fig 1 shows the variation in the 125 one-third octave sound power level and the A weighted sound power level with time measured on a product containing 16 3.5 inch form factor drives with a drive rotational speed of 7200 rpm. Also included in the Fig 1 is the arithmetic average, energy average and arithmetic standard deviation of the measurements over a 2 hour time period The figure demonstrates the large variation in the 125 one -third octave sound power band level with time with a maximum variation of 70.1 to 59.5 dB ,a swing of 11.3 dB giving a variation of 2.75 dB in the A weighted sound power level. The results appear to be randomly superimposed on to a long term cyclic variation with a time period of approximately 80 minutes, with differences of up to 8 dB occurring in the 125 1/3 rd octave, between each 3 minute measurement.

The question is whether both effects result from variations in file rpm or is one a result of the measurement procedure? With 16 disk drives both the short term random variation and the longer term cyclic variation can be explained. At some period in time all 16 drives will either all be in phase or all completely out of phase. This causes the peaks and troughs in the long term cycle whereas the random variation is the result of small groups of files out of the 16 total moving in and out of phase.

From these results it is evident that single measurements cannot be used with any degree of confidence for either noise control engineering work or for noise declaration.

Noise control engineering

For noise control engineering work the recommended method is to use the measurement procedure as described using a measurement time sufficiently long to cover one cycle of the long term sound power variation. The energy average of the total number of measurements can then be used as the basis for comparison. This is tedious but necessary if consistent and meaningful comparisons are to be made. This is clearly demonstrated in Fig 2 where the effect of disk drive isolation on the 125 one-third octave band has been evaluated .A number of single measurements would result in conflicting answers whereas the average over a 40 minute cycle shows a definite improvement of 4 dB.

Noise declaration

The noise declaration issue is more questionable. Should the declaration be based on :

1. The maximum value measured in any one time cycle plus the statistical adders for Reproduction and Repeatability
2. The energy average over the cycle but with an additional statistical adder for the time variant measurement.
3. The same as already specified but replacing the single sound power measurement with the time energy average over the measurement cycle.

Time averaging in the ISO Standards is normally used to measure noise variations with time due to machine operation cycles. However, this could be extended to include long term variations in noise level provided that the time averaging conditions are specified as required in ISO 9296. The view has therefore been taken that the noise declaration as in (3) above should be used and that in doing so the procedures of ISO 7779 and ISO 9296 are fulfilled

The same problem also occurs when measuring at the fixed By-stander positions in order to declare the A weighted sound pressure level. In this case octave band measurements were made at each of the 4 microphones at 2 minute intervals .The variation in the 125 octave band with time is given in Fig 3. In this case the ISO Standards requires an arithmetic mean value with no statistical adder. Again the same reasoning as for the sound power declaration applies and the time averaged value of the sound pressure level can be used for declaration purposes.

5.SUMMARY AND CONCLUSIONS

An inherent problem with measuring the A weighted sound power level of products having multiple disk drives has been described and the following conclusions have been reached :

1. The A weighted sound power level can vary considerable with time due to the variation in the low frequency tone generated by the disk files.

2. The only consistent method of measuring the A weighted sound power level in a semi -anechoic chamber is to use the energy average calculated from sound power measurements made at discrete continuous time intervals.

3. For noise declaration purposes the time energy averaged A weighted sound power level should be used when calculating the statistical upper limit as defined in ISO 9296. Similarly the time average sound pressure level should be used when declaring the Bystander A weighted sound pressure level.

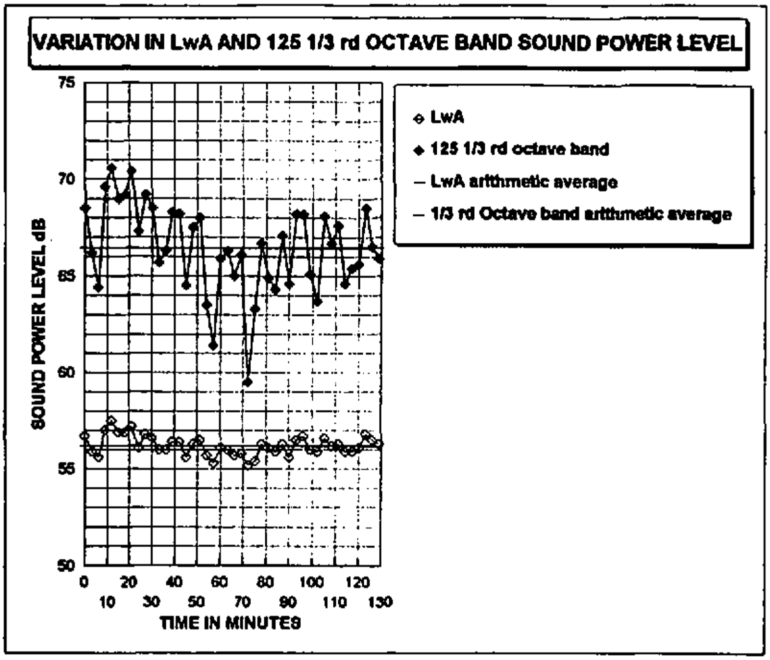
4. Disk drive vibration isolation mounts reduce the 120 Hz tone but the variation with time is the same the standard deviation of the sound power measurements in the 125 third octave band remaining approximately the same.

6.REFERENCES

1. Private internal IBM communication with Dr D Yeager - January 1995

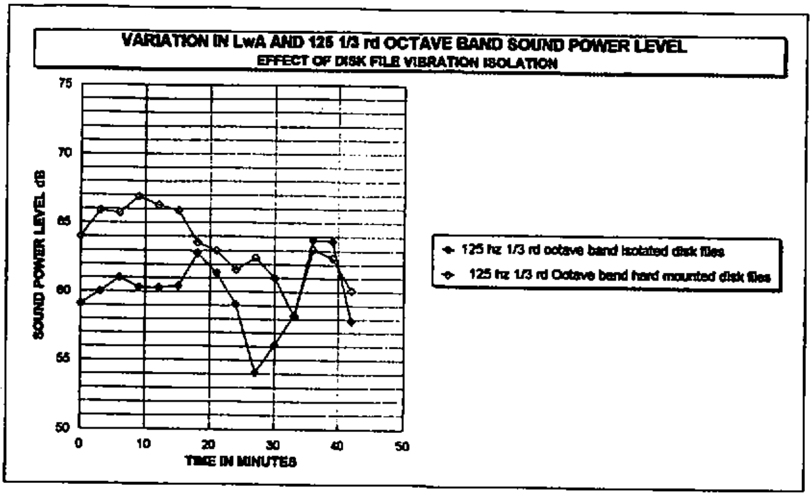
2. Private communication with Dr R Lotz - Chairman ECMA TC 26 -Acoustics -March 1996

NOISE FROM COMPUTER DISK DRIVES



	LwA	1/3 Octave
ARITHMETIC AVERAGE	56.2	66.46
STANDARD DEVIATION	0.51	2.3
ENERGY AVERAGE	56.25	67.1

FIG 1



		STD
ARITHMETIC MEAN HARD MOUNTED	64.0	2.5
ARITHMETIC MEAN WITH VIBRATION ISOLATION	59.9	2.65

FIG 2

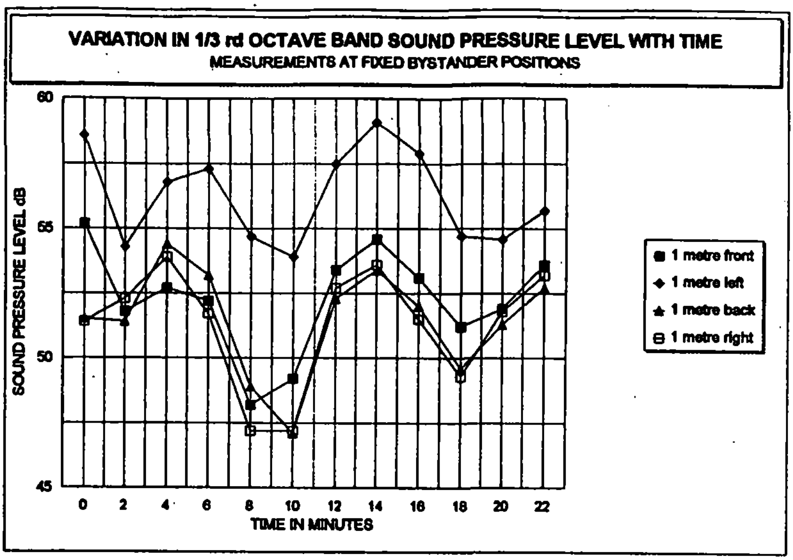

VARIATION IN 1/3 rd OCTAVE BAND SOUND PRESSURE LEVEL WITH TIME
MEASUREMENTS AT FIXED BYSTANDER POSITIONS
SOUND PRESSURE LEVEL dB
60
55
50
45
0 2 4 6 8 10 12 14 16 18 20 22
TIME IN MINUTES
1 metre front
1 metre left
1 metre back
1 metre right

FIG 3