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NOISE AND VIBRATION CHARACTERISTICS OF CLEANROOM FAN-FILTER UNITS

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BIOGRAHPY: Colin Gordon has worked in the field of acoustics research and noise and vibration control for thirty-five years. During his career, Mr. Gordon has worked on, and directed, several hundred projects involving research and consulting in a number of areas including aerodynamic noise, traffic noise, general environmental noise, and building vibration and noise control. In the latter areas, Mr. Gordon has worked extensively with the microelectronics industry in the design of low-vibration facilities for the research and fabrication of integrated circuit "chips." He has developed a strong and unique reputation in this specialized field.

Mei Wu has been working in the field of acoustics and noise control, since 1981. She has experience in both research and consulting. As a consultant she has provided services in architectural acoustics, mechanical system noise and vibration control and environmental impact assessment. She has worked on problems in existing buildings suffering from excessive mechanical system noise, poor acoustical separation between spaces and code violations involving interior and exterior (environmental) noise. Her R&D experience encompasses active noise cancellation, specialty silencer development, digital signal processing software development and work with finite element and boundary element modeling.

ABSTRACT: Fan-filter units are an increasingly popular alternative to packaged air handlers and fan-tower recirculation air systems. They are used in mini-environments and general cleanrooms, especially in retrofit cleanrooms with limited height. This paper presents noise and vibration data measured on 8 fan-filter units. It also presents measurement methods and performance criteria for fan-filter units.

KEYWORDS: fan-filter unit, fan-powered HEPA, noise, vibration, recirculation air system, cleanroom.

INTRODUCTION

Fan-filter units (FFU's) are used increasingly by the microelectronics industry to provide clean recirculating air for the fabrication of integrated circuits. There may be several hundred FFU's in a large cleanroom, covering 100% of the ceiling area. The units are located on the ceiling suspension system. There is no space for external noise control or vibration mitigation. The critical step to ensure that a cleanroom will meet the specified noise and vibration criteria is to select units with acceptable noise and vibration characteristics.

An FFU usually consists of a variable speed direct-drive blower with a small discharge plenum and a HEPA or ULPA filter. One design, which includes significant noise control is shown in Figure 1. Different FFU's have very different noise levels due to the difference in their design, fan selection, fan operating point, and the extent of noise mitigation included (if noise mitigation is included at all).

Because of their relative "novelty" there are no standards for specifying or measuring the vibration and noise characteristics of FFU's. Some manufacturers quote A-weighted noise levels, or noise criterion (NC) levels[1], at some, often undefined, distance from a single unit. To our knowledge, no manufacturer provides information that would allow one to predict noise levels in an operating cleanroom. Vibration isolation is supplied in some units and not in others. There are no manufacturers' data, that we know of, on the vibration characteristics of operating units.

This paper describes the results of tests carried out on eight different commercially available FFU's. This is a preliminary study, the purpose being to develop an overall understanding of the noise and vibration characteristics of these units.

[1] Noise criteria are discussed in "Handbook of Acoustical Measurements and Noise Control", Third Edition by C. M. Harris. McGraw-Hill 1991

The units tested were all 2 x 4 ft in size. For the tests they were suspended on "bungee" cords from a unistrut frame within a large office space. The face of the Hepa/Ulpa filter was about 5 ft above the floor. The floor was covered with a 4 inch thick blanket of acoustically absorptive polyurethane foam.

For the tests, the FFU's did not operate against an external static pressure, since the total FFU was located within the test area. In cleanroom installations the external static may lie in the range 0.2 to 0.4 inch WG. It is our opinion that this small external load will have a relatively small effect on the noise and vibration characteristics. Clearly, however, any standard that is devised for FFU's must include the effects of load. For this reason, the tests described here are preliminary only.

The units tested were all as supplied to us by the manufacturer. Some carried Hepa filters, other carried Ulpa filters. Filter thicknesses ranged from 4 to 6 inches. Tests on each unit were carried out at 2 or more face velocities. The units tested are listed in Table 1. In this table we include the model number, the approximate weight, and the filter face velocities at which data were collected.

Noise measurements were carried out using sound intensity methods across the face of the Hepa/Ulpa filter for each unit. Thus, for each unit, we measured the octave band sound power levels delivered to the cleanroom through the filter.

Vibration was quantified by measuring the "rigid body" vertical acceleration of each FFU using accelerometers at each of the four corners of the unit. Acceleration was measured in one-third octave bands over the frequency range 4 to 80Hz, consistent with the generic vibration criterion curves.[2]

NOISE MEASUREMENTS

The results of noise measurements are summarized in Figures 2 through 5. These plots show the range of measured sound power levels for the units tested, running at filter face velocities of 100ft/min (Figures 2 - 3) and 75ft/min (Figures 4 - 5) for ceiling coverages of 100% and 25%. On each figure we plot the single unit sound power level requirements at each frequency to achieve a noise rating in the cleanroom of NC-55, NC-60 and NC-65. Current practice in cleanroom design is to use a criterion of NC-55 to NC-60, this being a compromise between what is desirable or acceptable for personnel and tools, and what is reasonably achievable using conventional (non-FFU) recirculation air systems. As the industry moves towards 300mm wafer processing, and as metrology tools move into the cleanroom environment, we expect that tools will become more sensitive. We are currently recommending NC-55 *or less* as a preferred design goal.

The sound power level requirements in Figures 2 through 5 have been calculated based on a theoretical model that takes into account the absorptive characteristics of cleanroom finishes—metal panels, hepa filters, airflow return openings, etc.

Of the seven units used in compiling Figures 2 and 3 (100 ft/min) the number complying with the sound power requirements are as follows:

Coverage		100 %	25%
NC-55	—	0	0
NC-60	—	0	1
NC-65	—	2	4

Of the six units used in compiling Figures 4 and 5 (75ft/min) the number complying with the sound power requirements are as follows:

Coverage		100%	25%
NC-55	—	1	1
NC-60	—	1	5
NC-65	—	3	5

Based on these preliminary figures: of the units tested at 100ft/min, none meets the requirement for NC-55 and one meets the requirement for NC-60, at 25% ceiling coverage only. Of the units tested at 75ft/min, only one unit meets the requirement for NC-55 and five meet the requirement for NC-60 at 25% ceiling coverage only.

Fan filter units, as currently developed are, in general, not well suited for cleanroom environments in which noise levels of NC-60 or better are sought. Their noise is the outcome of the compactness of

[2] The vibration criterion curves are discussed in "Considerations in Cleanroom Design", IEST-RP-CC 012.1.

their design which provides little or no room for noise control.

VIBRATION MEASUREMENTS

The results of vibration measurements are summarized in Figures 6 and 7. Figure 6 shows the range of measured acceleration levels based on the arithmetic average of the levels measured at the four corners of each unit. Figure 7 shows the range of estimated force spectra assuming rigid body motion of the "bungee"-supported FFU. The force is taken as the product of acceleration and unit mass.

It is our opinion, based on these measurements, and on measurements in cleanrooms that utilize fan-filter units, that vibration is probably *not* a major issue, at least in the context of ceiling-mounted systems. Vibration, however, can be a significant issue when FFU's are used as close-mounted mini-environments.

IN CONCLUSION

In this paper, based on preliminary measurements on a limited number of fan-filter units, we have attempted to demonstrate the noise- and vibration-generating characteristics of typical units. The study indicates that FFU noise is an issue of concern. Hopefully, efforts will be expended to develop quieter designs that can allow cleanroom noise levels of NC-55 or less.

Table 1: Fan Filter Units Tested

Manufacturer	Model	Weight (lbs.)	Filter Face Velocities (ft./min.) 50	75	100
ASYST	New AstroCel II	72.5	x	-	x
ASYST	Old AstroCel II	84.0	x	x	x
Clestra	Fantom	-	-	x	-
DAW Tech.	720	70.0	x	x	x
DAW Tech.	Stratus	88.5	x	x	x
Envirco	MAC-10	50.0	x	x	x
Flanders	Airvelope 57P2	60.0		x	x
Flanders	New Model	65.0	-	-	x

Figure 1. View of Typical Fan Filter Unit Incorporating Noise Control

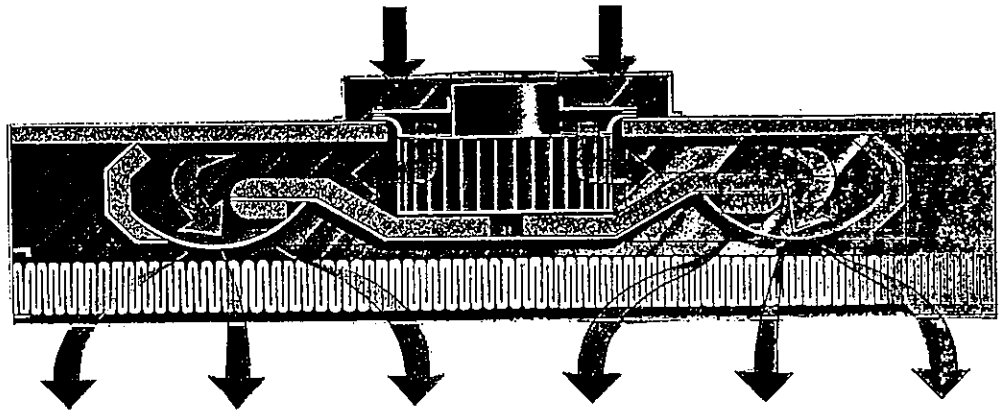

Figure 2: Fan Filter Unit Noise.
Range of Measured Sound Power Levels for Seven Units Running at 100 fpm versus Requirement for 100% Ceiling Coverage

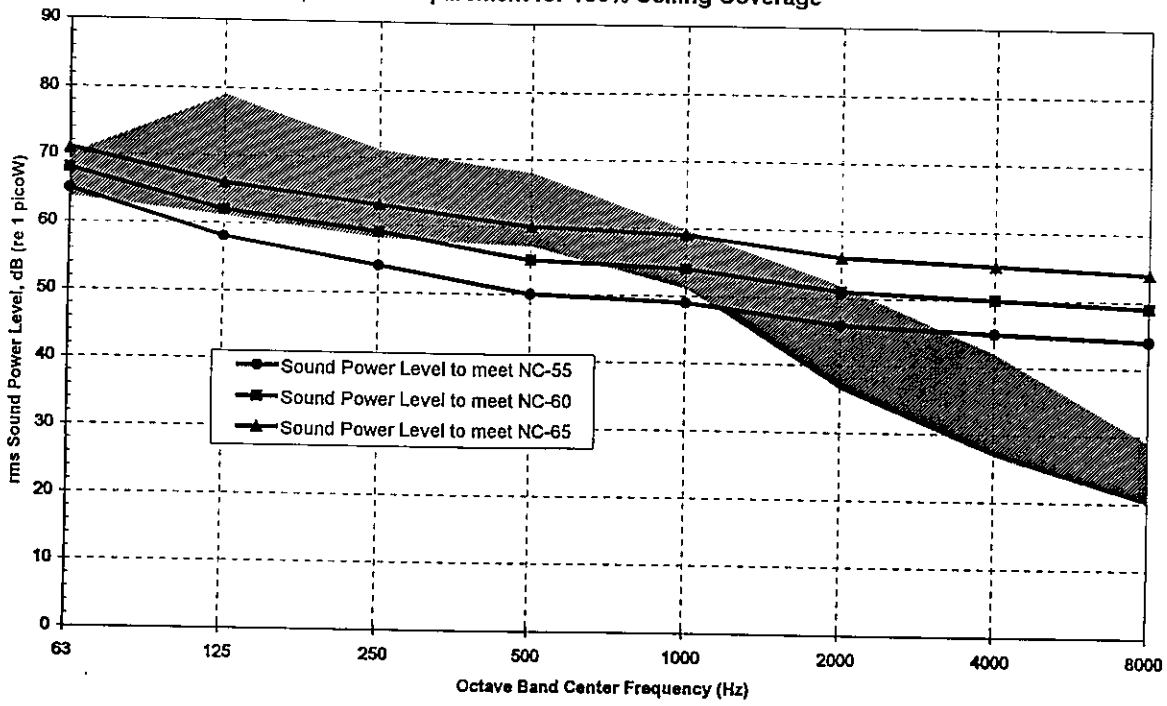

Figure 3: Fan Filter Unit Noise.
Range of Measured Sound Power Levels for Seven Units Running at 100 fpm versus Requirement for 25% Ceiling Coverage

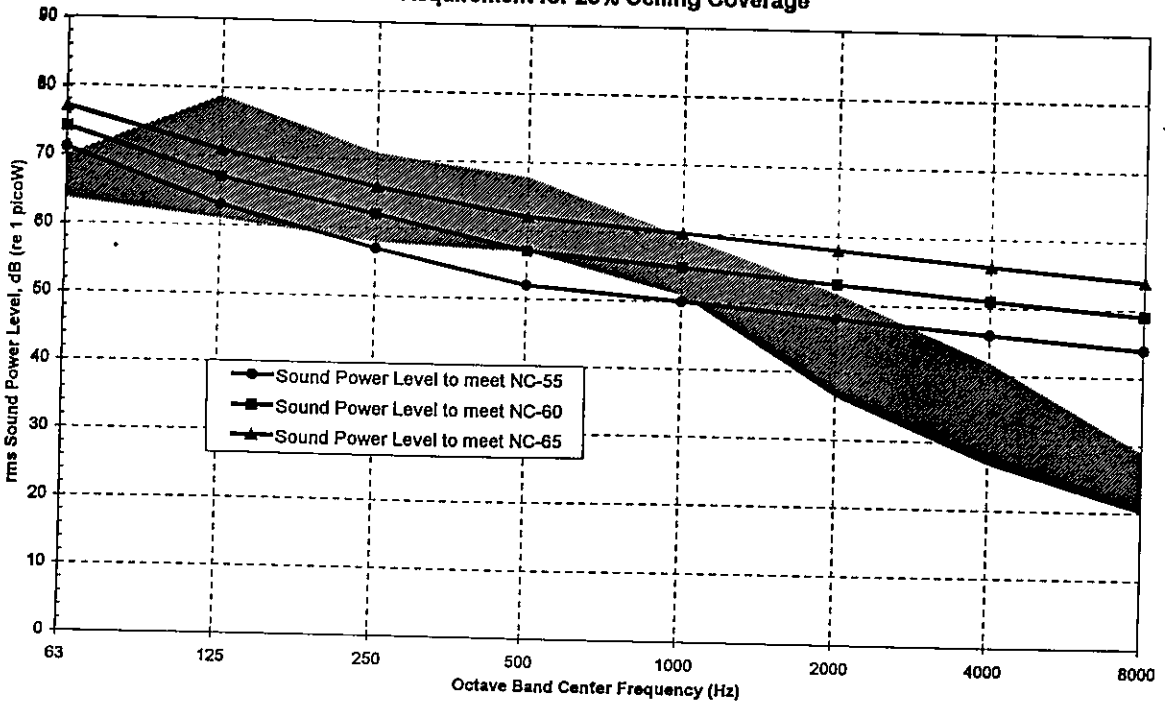

Figure 4: Fan Filter Unit Noise.
Range of Measured Sound Power Levels for Six Units Running at 75 fpm versus Requirement for 100% Ceiling Coverage

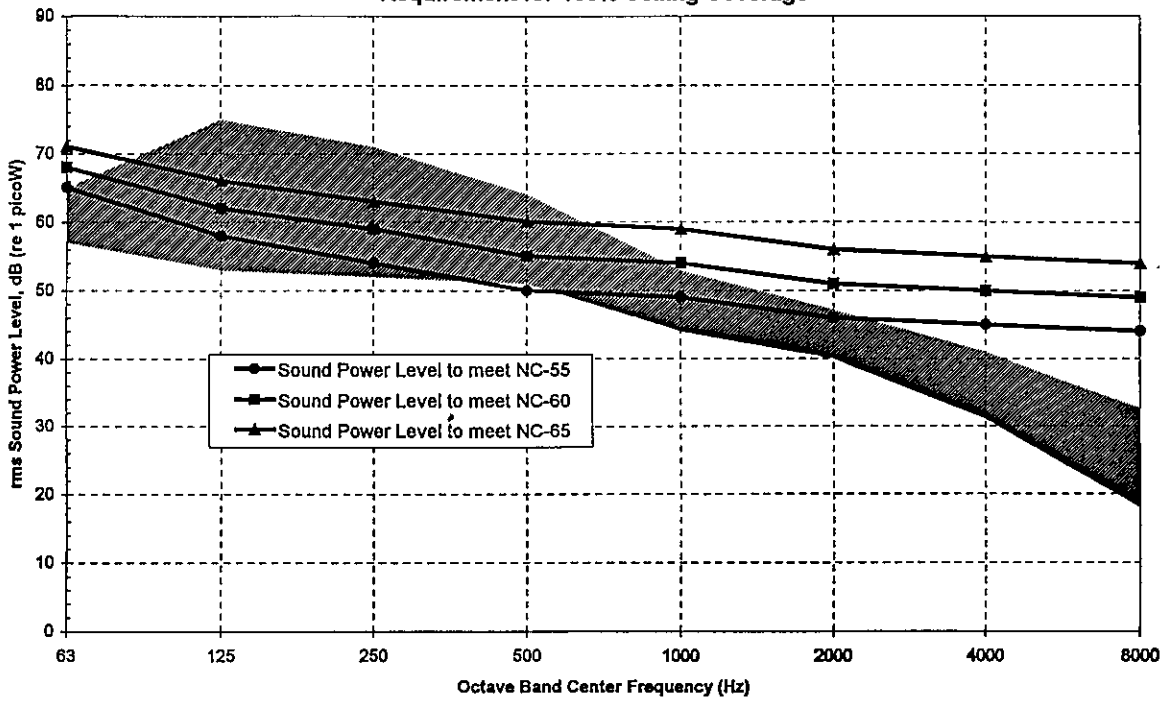

Figure 5: Fan Filter Unit Noise.
Range of Measured Sound Power Levels for Six Units Runnning at 75 fpm versus Requirement for 25% Ceiling Coverage

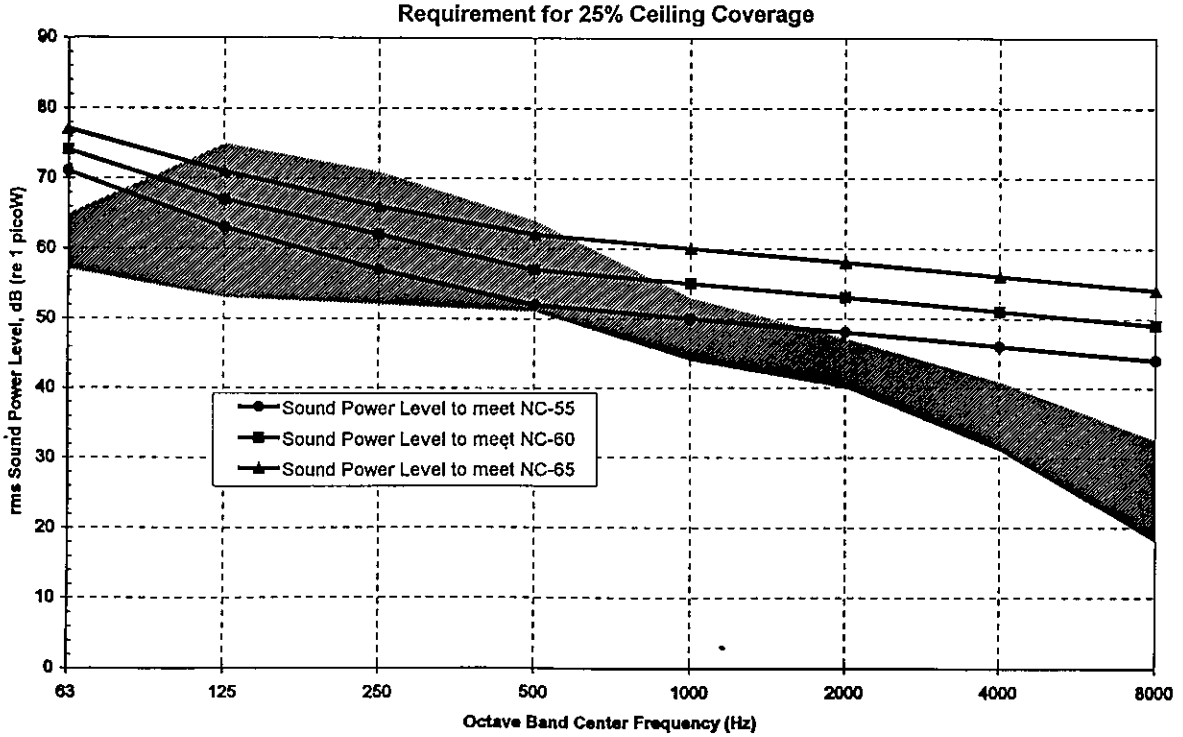

Figure 6: Fan Filter Unit Vibration.
Range of Measured Vertical rms Acceleration Amplitudes on Five Units Running at 100 fpm.

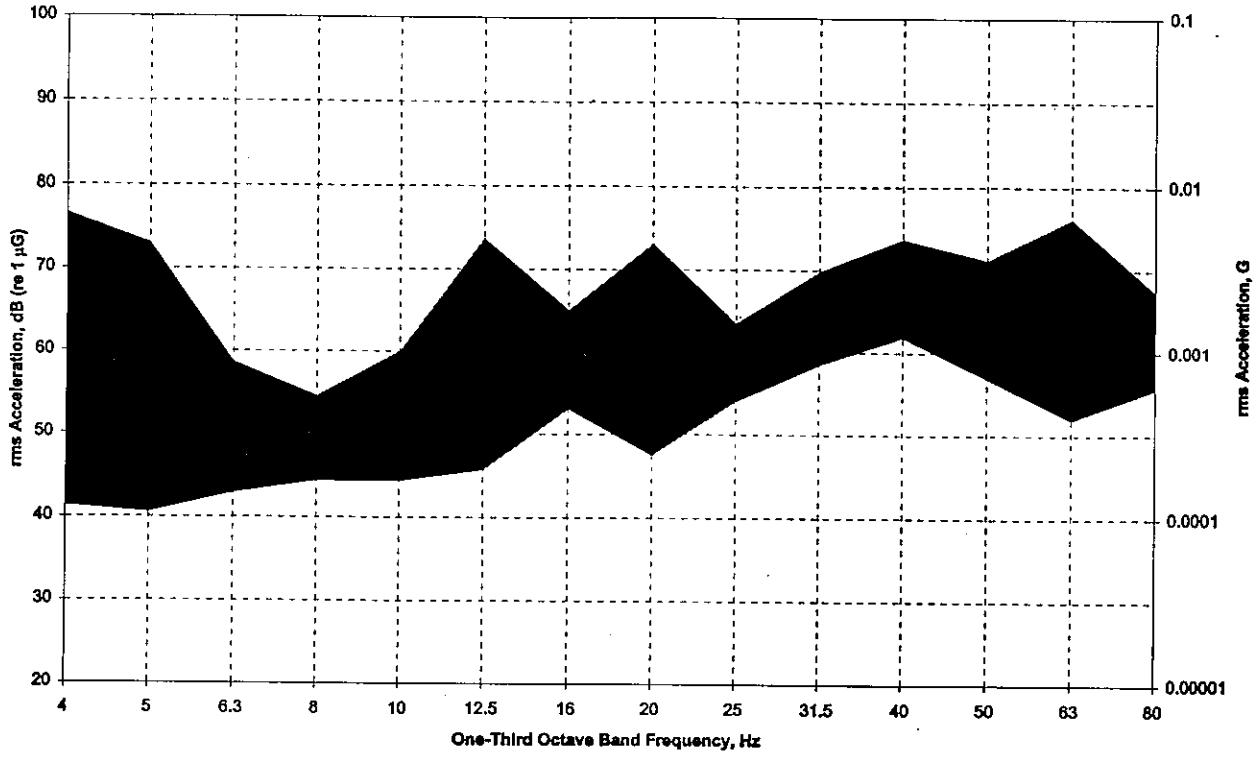

Figure 7: Fan Filter Unit Vibration.
Range of Calculated Vertical rms Force for Five Units Running at 100 fpm Based on Rigid Body Motion.