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NOISE PREDICTION AND CONTROL IN MICROELECTRONICS CLEAN ROOMS

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INTRODUCTION

Modern clean rooms of the sort used by the microelectronics industry in the fabrication of integrated circuits are typically quite noisy with levels lying in the range PNC 55 to 75. The noise can degrade the performance of production and test equipment. It also interferes with speech and telephone use and adds generally to the environmental discomfort suffered by personnel.

In this paper we will discuss the causes of clean room noise and give examples of measured data. We will discuss criteria and the methods currently available to achieve these criteria in a modern clean room design.

THE PROBLEM

The modern microelectronics clean room consumes large quantities of power and circulates large volumes of air to maintain the environment free from contaminants and stable in terms of temperature and humidity. Some "statistics" will serve to illustrate:

> Air flow typically equals about 600 air changes per hour. The ceiling filters cover 100% of the ceiling area and run at 80 to 100 ft/min. For obvious reasons, about 90% of the air is recirculated. Total installed power of mechanical systems serving the clean room lie close to 100 watts per sq ft. The power of recirculation air fans alone lies close to 30 watts per sq. ft.

Typically, such a clean room consumes about 100 times the power and circulates about 100 times the air quantity as does a normal commercial building. The potential for high noise levels is, therefore, not surprising.

Two typical configurations for a modern Class 1 clean room are shown schematically in Fig. 1. The central air configuration (Fig. 1a) utilizes large recirculation fan modules (generally vaneaxial) located along the perimeter of the facility. The distributed air configuration (Fig. 1b) utilizes many small recirculation fan modules (generally plug) located above the clean room either in the interstitial space or on a mechanical mezzanine floor.

With both configurations, but especially with configuration (b), space is quite limited for noise control. Noise control is further hindered by general reluctance to use fibrous materials which could shed particulates into the airstream. Although these particulates would be removed by the hepa filters, there is industry concern about the premature loading of the filters. Hepa filters are extremely expensive.

A final contributor to the fan noise problem is the clean room itself which must be hard-surfaced and configured to prevent retention and build-up of particulates. The use of conventional acoustically-absorptive materials is not possible therefore.

Fan and airflow noise is not the only source of clean room noise. The process equipment itself often contributes significantly to the final environment. Typically, these contributions occur at the mid-and-high-frequencies.

NOISE LEVELS AND CRITERIA

Sound spectra that have been measured in three recently completed facilities are shown in Fig. 2. The first of these is a retrofit facility that utilizes somewhat old air distribution systems. The air distribution systems in the second and third facilities were designed to a noise criterion in the range PNC 55 to 60.

The spectra of Fig. 2 are noteworthy for the substantial low frequency energy that appears. (Note that the spectra of Fig. 2 extend to the 8 Hz octave band.) This is typical of modern clean rooms.

There is a dearth of reliable information on the noise sensitivity of process and test equipment commonly used in microelectronics fabrication. What little data there are, acquired on projection aligners, E-Beam systems, steppers, and scanning electron microscopes, suggest that maximum sensitivity often occurs in the 100 to 200 Hz frequency range and that the octave band sound pressure level in this range should not exceed about 75 dB. This corresponds to a criterion of PNC 65.

There is little doubt that in the future, as photolithography and test tolerances become more and more stringent, the noise sensitivity of photolithography and test equipment will increase. While it may be possible to counteract this to some extent with improved design within the equipment itself, the control of noise levels within clean rooms is becoming a major issue.

Clean room noise is also a significant issue in terms of personnel comfort and communications. Unfortunately here, the criterion range PNC 55 to 60 which has been achieved with some difficulty in the third facility of Fig. 2 must be considered as quite unpleasant adding to the several other environmental stresses that beset clean room staff.

At the present time, we are recommending PNC 55 as the design goal for noise generated by the recirculation air systems within a modern microelectronics production clean room. This goal appears to be a reasonable one from the point of view of current and projected process and test equipment. It appears to be achievable with some difficulty, especially in the case of "distributed air" systems as illustrated in Fig. 1.

NOISE CONTROL

Depending upon the configuration used for modelling the clean room--infinite room, infinite aisle, and finite room--the extent of noise control required for an "ASHRAE" fan (vaneaxial, centrifugal, or plug) to meet PNC 55 lies in the range 15 to 20 dB in the 125 Hz octave band.

Noise control generally involves a combination of techniques including:

At the source:
(1) Fan optimization - low tip speed, optimized blade design, variable speed drive (if necessary), etc.
(2) Minimization of system pressure loss.
(3) Use of plenum liners, duct liners, and silencers.

In the clean room:
(4) Acoustical lining of the hepa plenum. This is often not acceptable to the client.
(5) Use of tilt wall panels or panel resonators to provide added absorption and to improve absorption effectiveness. These are techniques that are currently being explored.

Some of these techniques are illustrated in Fig. 3, which shows the configuration of a typical plug fan recirculation air module and the cross section of a clean room aisle.

CONCLUSIONS

Noise control within a microelectronics clean room poses a substantial challenge which may become increasingly important in the future. Conventional methods of noise control have limited application. There is a need to develop alternative methods of noise control that can satisfy the stringent requirements of the clean room environment.

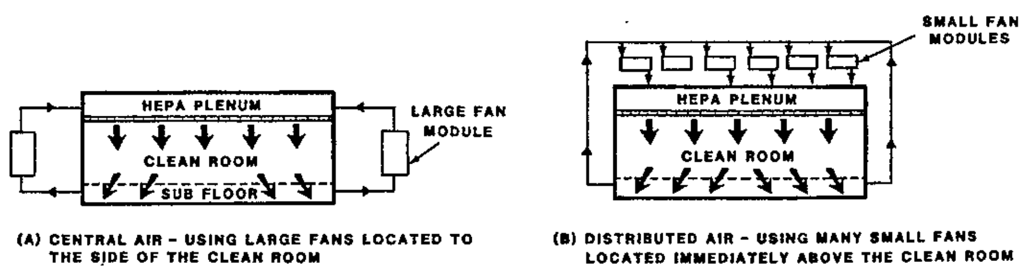

FIGURE 1 TWO TYPICAL ARRANGEMENTS OF RECIRCULATION AIR SYSTEM

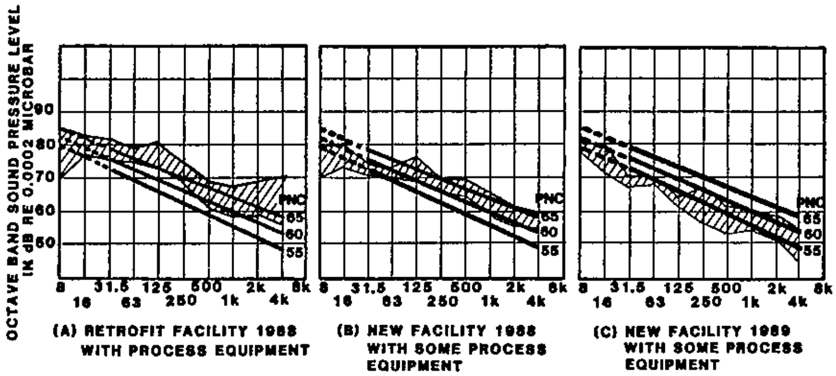

FIGURE 2 SOUND PRESSURE SPECTRAM MEASURED IN OPERATING CLEAN ROOMS WITH DISTRIBUTED AIR SYSTEMS

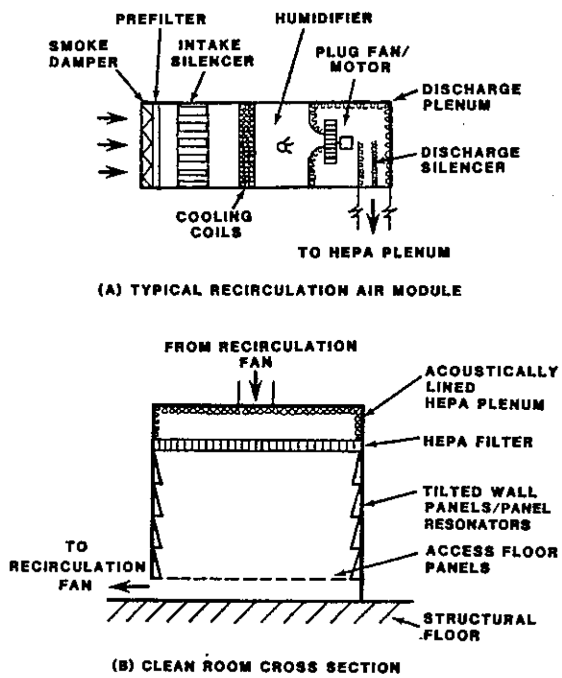

FIGURE 3 NOISE CONTROL ELEMENTS APPLICABLE TO TYPICAL RECIRCULATION AIR MODULES AND TO CLEAN ROOMS