The R&D of Low-Noise Fan-Filter Units and a Numerical Study of Their Applications in Cleanroom Air Distribution

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Cleanrooms are needed for clean processing in the semi-conductor manufacturing industry, electronics industry, pharmaceutical industry and other industries where clean environments are essential for occupational health, product yield and storage and etc. Their coming to being evolves from traditional HVAC applications and, as such, axial-flow fans (sometimes called fan towers) have been used to service the inner airflow circulation systems of early cleanrooms. In the past five to ten years, however, cleanrooms with fan-filter units (FFUs) have been introduced and their presence has become ever more wide spreading, because, at least in theory, a cleanroom using fan-filter units holds the potential to adapt to the fast changing requirements of the above booming industries. This paper will discuss the results in developing energy-efficient and low-noise FFUs in our institute and investigate, via CFD simulations, the air flow quality and energy consumption inside comparable cleanrooms with fan-filter units and axial-flow fans, respectively. A brief discussion will also be made on the subject of a FFU cleanroom's adaptability to evolving in-situ conditions.

A cleanroom, put simply, is a space of defined air purity, airflow quality, temperature and humidity, as schematically depicted in figures 1a and 1b. The airflow is circulated from the ceiling chamber down to the workspace and, through the raised floor and side air passageway, back to the ceiling chamber. The space air purity is defined in terms of the number of particles present in a unit volume of space (1) and, hence, the class of the cleanroom. The airflow quality is in terms of the airflow uniformity and deviation from the average (perpendicular) velocity vector under the ceiling of the cleanroom (2).

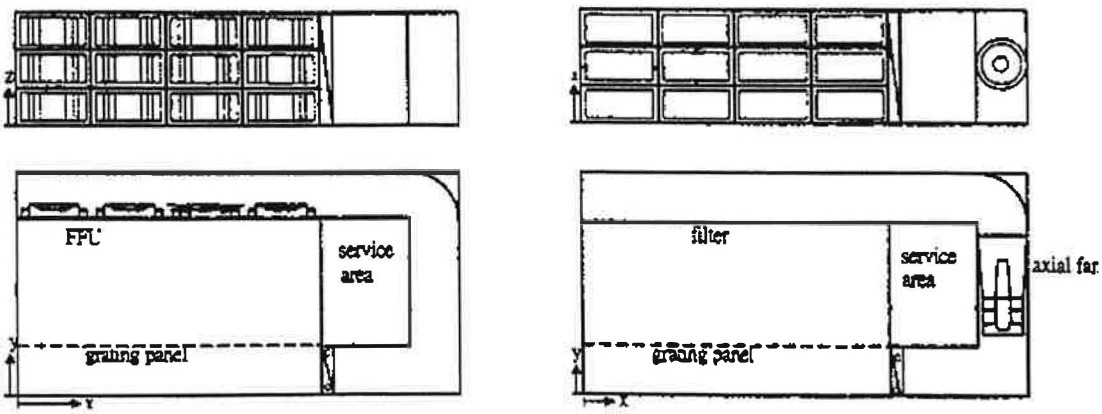

Figure 1. Schematics of Typical FFU and Axial-Flow Fan Cleanrooms

Cleanrooms are expensive to build and operate and the operational aspects often go unnoticed. It's expensive to operate because, depending on the class of a cleanroom, precise temperature, humidity and particle/molecule density need to be maintained in the workspace. To achieve the above objectives, especially the particle/molecule density control, a great deal of fresh air (ranging from a few hundred to more than a thousand air change rates per hour) is introduced to the conditioned space. Furthermore, for the fail-safe reason, cleanrooms are usually run 24 hours a day in manufacturing industries. The combined results are moderate to intensive energy consumption and, definitely, high operational costs (3).

Figure 2 shows that market units are quite mixed in terms of energy efficiency and, in general have significant rooms for improvement. It is also found that, although both the axial-flow fan type and the FFU type cleanrooms can achieve airflow qualities required

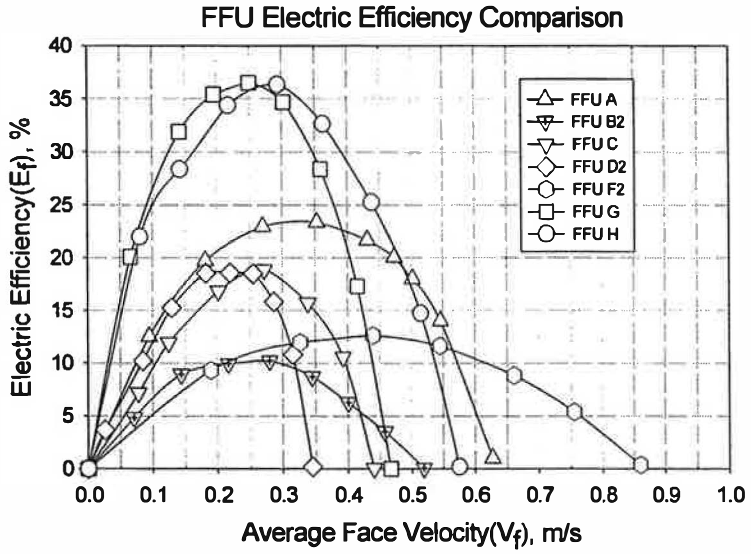

Figure 2. Nominal Electric Efficiency Values of Market FFUs Tested

by the industries, the flow and pressure characteristics for each type are different inside the clean space and the circulation system, as shown in figures 3a and 3b. The differences may entail different safety and contaminant control strategies for the two types of cleanroom. The different method of handling the circulation air also tends to make an axial-flow fan cleanroom more energy intensive than its FFU counterpart, unless care is taken in the design of the airflow circulation system to be aerodynamically compatible with the usage of the axial-flow fan. Furthermore, the FFU system may promise great energy- and cost-saving potentials, especially for clean space below class 10 as shown in figure 4, but the exact method of control to achieve them is subject to further refinement.

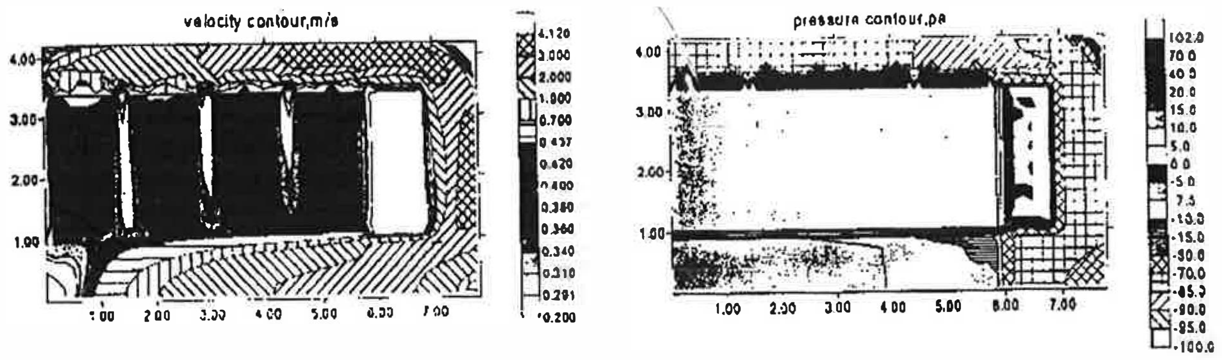

Figure 3a. Flow and Pressure Contours inside a Simulated FFU Cleanroom

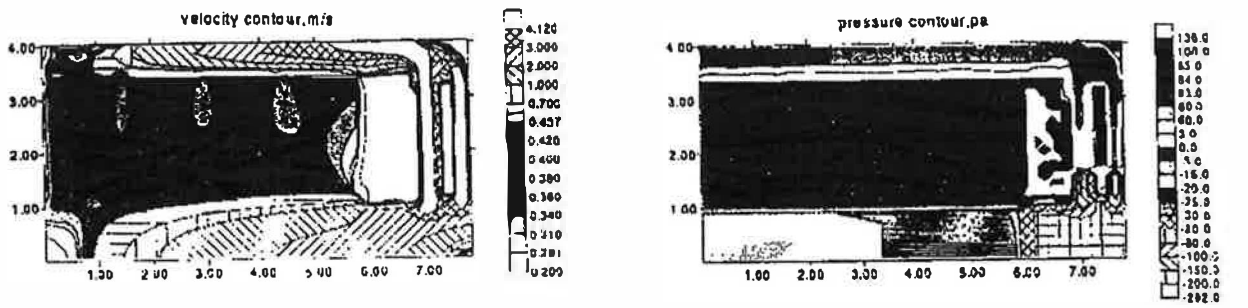

Figure 3b. Flow and Pressure Contours inside a simulated Axial-Flow Fan Cleanroom

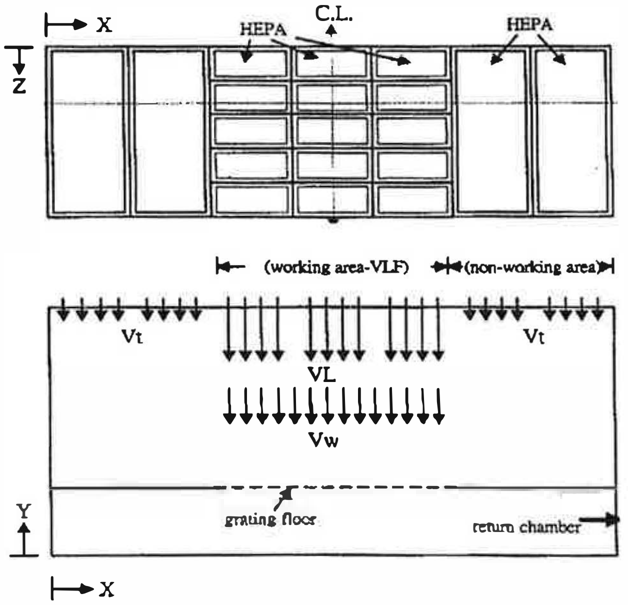

Figure 4. A Schematic of a Mini-environment Clean Space

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