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Experimental study on airflow characteristics and temperature distribution in non-unidirectional cleanrooms for electronic industry

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ABSTRACT

A non-unidirectional airflow cleanroom in electronic industries is prone to be challenged by the wide spread of hot air and contaminants dissipated from process tools to surrounding area, resulting from the collision of the uprising hot air current from the tools and the downward cold air from ceilings. To effectively remove the dissipated heat and maintain the required cleanliness level, we proposed an innovative fan dry coil unit (FDCU) return air system (referring to Figs. 1 and 2), consisting of ceiling-supply grilles and ceiling-return fans/coils, and demonstrated that the FDCU-return air system can effectively eliminate sub-micron particles from the cleanroom, compared with a conventional ceiling-supply and wall-return air system [1]. This study further investigated the effect of the heat dissipation from the tools on airflow characteristics and temperature distribution in the FDCU-return and wall-return airflow type cleanrooms. Comparisons of velocity vector, turbulence intensity, and temperature distribution between the FDCU-return air system and the conventional wall-return air system were presented. The results showed that the FDCU-return air system can significantly provide better air motion characteristics and temperature distribution in a high heat source case in comparison with the wall-return air system.

1. Introduction

The advancement in electronic-product manufacturing technology in recent years helps to scale down the devices into the nanometer generation, and consequently increases the sensitivity of electronic-product manufacturing process to the contamination of particles into the sub-micron regions. Most of the electronic cleanrooms are herded with process tools dissipating high-temperature heat and emitting particles, which cause higher airflow resistance than the normal level and reduce the quality of the cleanrooms by reason of the accretion of heat and particles within the cleanrooms.

A non-unidirectional airflow cleanroom is one of the most common systems applied in the electronic industries to control the concentration of airborne particles and the relevant temperature and relative humidity ranges. In a traditional arrangement of the airflow pathway in the cleanrooms, the fan filter units (FFUs) are installed to introduce the supply air from ceilings and the return air is extracted from the return air shafts (RASs) and wall-retunr air grilles which are close to and vertical to the floors. Despite of reducing the cost of construction by eliminating the requirement of return air plenum, the wall-return air system exhibits several drawbacks such as (1) the requirement of high external static pressure for FFUs due to the long airflow paths to overcome the resistance of the wall-retunr air grilles, RASs and dry cooling coils (DCCs, only sensible heat exchanged in the coils), (2) the unchangeable positions of the wall-retunr air grilles and DCCs, (3) the uneven temperature distribution due to the interception of the cold air from the ceilings and the hot air from the process tools [1], and (4) the negative pressure in the supply air plenum (SAP) where un-conditioned air, particles, and moisture may be intruded.

Several numerical and experimental studies on the conventional wall-return type cleanroom have been conducted to better understand the airflow patterns and contaminant diffusion characteristics in the cleanrooms, and demonstrated that contaminant particle sizes smaller than 4.5 μm in diameter are regarded as having no gravitational sedimentation effect on the diffusion [2–4]. Kato et al. [5] have proposed a locally balanced ceiling-supply/exhaust airflow rate system which allows more efficient exhaust of contaminants and less extensive diffusion of particles in the cleanrooms. No extra exhaust force is introduced on the return air in their system. Meanwhile, Lin et al. [1,6] have proposed an innovative fan dry coil unit (FDCU) return air system, containing ceiling-supply and ceiling-return air grilles, to maintain the cleanliness level within the standard

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