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CFD-assisted experimental analysis and optimization of air quality in production space

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Air quality management plays a vital role in ensuring process and workplace safety. Consequently, an effective heating, ventilation, and air-conditioning (HVAC) system is essential for contemporary production operations. This is particularly critical in the pharmaceutical sector, where there is a significantly greater risk of hazardous product contamination or worker exposure.

Computational fluid dynamics (CFD) modeling has become an integral component of the HVAC system design and evaluation process. While parameters specified during HVAC design, such as volumetric flow rates, are typically straightforward to obtain, actual working conditions can significantly deviate from these values, particularly in older HVAC systems. To address this, a two-step experimental model validation approach is employed to ensure that the model accurately reflects the current state of the HVAC system. Hot-wire anemometry is primarily utilized to measure true velocity boundary conditions at the points where air enters or exits the area of interest. Additionally, a local tracer gas (CO_2) source is implemented to assess flow and mixing conditions within the areas where the flow direction may not be constant or well defined.

OpenFOAM is utilized to develop a CFD model of the actual production space. This model employs a RANS density-based solver and incorporates ideal gas thermodynamics for air mixture. This configuration enables the model to effectively capture high concentrations of CO_2 as well as the spatio-temporal distribution of composition and temperature. Once validated, the CFD model can be employed to analyze specific airflow characteristics produced by the HVAC system and their impact on effective air quality control. The mean age of air (MAOA) is selected as an indicator of air quality, while the overall volumetric flow rate serves as a measure of energy costs. The relationship between the parameters of the HVAC system and MAOA was thoroughly examined.