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Computer Fluid Dynamics Models Validation in Pharmaceutical Applications

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Computational Fluid Dynamics (CFD) has evolved into a powerful and widely adopted tool for analyzing and optimizing complex flow, heat, and mass transfer phenomena across many engineering disciplines. In the pharmaceutical industry, however, its broader potential remains underutilized, in part due to challenges in experimental validation and the interdisciplinary nature of pharmaceutical processes. This lecture introduces CFD to a non-specialist audience and demonstrates how validated CFD models can become reliable, decision-support tools in pharmaceutical development, manufacturing. and science.

The presentation begins with a concise overview of the historical development of CFD, followed by its gradual adoption in pharmaceutical applications such as solid dosage manufacturing, coating, drying, and containment. Emphasis is placed on the critical importance of experimental validation for ensuring model credibility—an aspect that is particularly demanding in pharmaceutical environments characterized by multiphase flows, transient conditions, and strict regulatory requirements.

A central focus of the lecture is the role of advanced in-process measurement technologies in bridging simulations and reality. The talk highlights the contribution of Opulus, a company that develops and manufactures a world-unique family of wireless data loggers (PBX family) specifically designed for challenging industrial environments. PBX-TH, PBX-THDP, and PBX-EO data loggers enable simultaneous, high-resolution measurements of temperature, humidity, pressure, and gas concentration within moving and enclosed systems. These capabilities provide unprecedented experimental datasets for the direct validation and refinement of CFD models under real process conditions.

Practical application examples are presented, including aqueous tablet coating and fluid bed processing, illustrating how validated CFD models can improve process understanding, reduce development time, mitigate scale-up risks, and support quality-by-design strategies. The lecture concludes with a forward-looking discussion on emerging applications, such as pharmaceutical packaging and plastic container processes (including blister and bottle systems), as well as the economic impact of CFD-driven optimization on development costs and manufacturing efficiency.

By combining fundamental concepts, real-world case studies, and novel validation technologies, this lecture aims to demystify CFD for pharmaceutical scientists and engineers and to demonstrate its value as a robust, experimentally anchored tool for modern pharmaceutical innovation.