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Particle-Laden Plumes in Confined Spaces

Nicola Mingotti and Andrew W. Woods

BP Institute, University of Cambridge, CB3 OEZ, England

Introduction

A series of experiments have been carried out to explore the dynamics of relatively dense particle-laden plumes in a confined space. The particle-laden plume leads to a net mixing of the fluid in the space, following a filling-box type of flow. Particles are transported to the base of the space, spread out over the floor of the vessel and are then re-suspended up to the height at which their fall speed matches the upward speed of the fluid in the ambient. This upward flow supplies the fluid which is entrained into the plume through turbulent mixing. Controls on this mixing and the concentration of the particles will be discussed and compared with the outcomes of new laboratory experiments.

Method

The experiments use a light attenuation technique to measure the concentration of the particles in suspension as a function of the position within the system. The models developed to interpret the observations are based on classical works describing the dynamics of turbulent buoyant plumes (Morton et al., 1956) and the associated filling box flows (Baines and Turner, 1969; Linden, 1999). However, the presence of particles which can separate from the flow owing to the non-zero slip velocity leads to some new aspects of the flow and important new questions about the ultimate fate of the particles.

Results

In the case that there is a net downflow through the space, the mixing becomes more complex, with a fraction of the particles being vented from the space and a fraction settling on the floor of the space, while there is again a lower layer of particle-laden fluid and an upper layer of particle-free fluid. The height of the interface between these two layers, and the concentration of particles in the ambient fluid are described using a simplified theoretical model, and the predictions of the model are compared with a series of new laboratory experiments.

Dense, Particle-Laden Plume

The implications of the model and experiments for the transport of particles in a turbulent plume in a confined space are discussed, and the implication of the results for the case of a plume of relatively dense, particle laden fluid descending into the space are discussed. In this case, it is shown that two interfaces develop, with a lower layer of dense particle laden fluid, an intermediate layer of dense fluid with no particles, and an upper layer of the less dense fluid. Again a model is developed to predict the concentration of the particle laden layer, and the fate of the particles in terms of settling to the floor and ventilating from the space is discussed.

References

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*corresponding author: euromech567@damtp.cam.ac.uk