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Aspects of the Fluid Mechanics of Night-Purging Multi-Storey Buildings

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Declaration

I herewith certify that all material in this dissertation which is not my own work has been properly acknowledged.

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Abstract

This research concerns the mathematical and physical modelling of the buoyancy-driven flow of warm air at night from a multi-storey atrium building by displacement ventilation. The process of clearing warm air from a building at night is known as 'night-purging'. The primary aim of this research was to enhance understanding of these flows to thereby facilitate efficient design of passively night-purged buildings.

The thesis begins with a review of research on natural ventilation and night-purging. Particular focus is given to the conditions for achieving classical displacement flow, in which there is an absence of mixing between warm and cool air, as this has been shown to be the most efficient means of removing warm air from a space.

We identify that the dynamics of the plumes of warm air discharged from the storeys into the atrium play a crucial role in the development of the thermal stratification in the atrium. The majority of research on turbulent plumes has concerned plumes from horizontal sources, while ventilation openings are often oriented at some angle off-horizontal. We therefore investigate how varying the angle of orientation of the plume source (or ventilation opening) affects the dynamics of the plume to determine the implications for buildings ventilated via wall-mounted windows. This modelling reveals that, for a significant proportion of a typical night-purge in a single storey, a plume from a vertically oriented opening will not project away from the opening. Thus the simple plume model we have developed will not apply during the late stages of a night-purge. In order to develop a model of plumes which do not project away from the source, we investigate the limiting case of a plume from a vertically distributed source (such as a vent) with zero source momentum flux, such that the motion is entirely parallel to the source.

To investigate the overall flow in the building, guided by the results of the plume modelling, we develop a simplified mathematical model to predict the purging of warm air in a generic two-storey atrium building. The pre-

dictions of the model enable the classification of night-purging behaviours into three distinct classes of flow, based on the chronology of a number of key events in the progression of a night-purge. Interrogation of the predictions suggests that two transitional behaviours which fall between the three classes of flow provide 'optimal' purging behaviour: one for purging just the storeys in a minimum time and the other for purging the entire building in a minimum time. Adaptation of the mathematical model facilitates the development of design curves for building designers to appropriately size ventilation openings in order to achieve the optimal night-purges.

Complementary physical modelling in water-filled visualisation tanks enabled testing of the mathematical model predictions and optimal night-purging behaviours. Whilst demonstrating the suitability of a simplified mathematical approach to predicting what are complex patterns of airflow, the physical modelling highlighted the complexity of the developing stratification in the atrium and raises a number of new questions for future research.