Melbourne City Council Development

Computational Fluid Dynamics Investigation

Prepared for: Melbourne City Council

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design advice

passive systems

design analysis

low energy services

April 03

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EXECUTIVE SUMMARY

The aim of this report was to consolidate the findings and recommendations detailed within Advanced Environmental Concept's Environmental Design Schematic and Chilled Panel Ceiling Configuration reports by modelling the systems proposed using Computational Fluid Dynamics Software – Phoenics.

The systems to be modelled include:

1. Underfloor supply system – checking that the existing system configuration proposed was adequate with respect to air distribution and pressure drop.

2. Night Purge - comparing low and high window positions effect on the resultant night purge air and temperature distribution and to assess the effectiveness of the night purge ventilation system.

The underfloor investigation found that the single façade supply was sufficient for whole underfloor distribution.

The night purge investigation found that the higher window position created improved air distribution across the ceiling thermal mass resulting in lower thermal mass temperatures as a result of night purge operation.

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Date	29th April 2003	
Revision and Status		
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1 INTRODUCTION

The aim of this report was to consolidate the findings and recommendations detailed within Advanced Environmental Concept's Environmental Design Schematic and Chilled Panel Ceiling Configuration reports by modelling the systems proposed using Computational Fluid Dynamics Software – Phoenics.

The systems to be modelled include:

1. Underfloor supply system
   - Pressure distribution
   - Air distribution

2. Night Purge with low and high window positions
   - Wind/no wind scenario
   - Air distribution
   - Temperature distribution

2 APPROACH

2.1 Computer Modelling

The systems proposed were modelled using a computational fluid dynamics (CFD) 'Phoenics' program.

Unlike 'Ambiens', utilised in the chilled ceiling configuration report, which is a 2 Dimensional CFD package, 'Phoenics' is a 3-Dimensional CFD package enabling more advanced analysis of a space, due to the detailed models which are able to be created.
Phoenics utilises an iterative process to solve the models for the required parameters.

2.2 Underfloor System

The underfloor system was modelled for pressure and air velocity to determine that:

a) the floor height was sufficient for the supply air flow required (pressure at any point to not exceed 15Pa) and
b) the air distribution was adequate when supplying from the south façade only.

The underfloor system model included south façade supply air with floor supply air diffusers and incorporated the columns and electrical and data cable rack modelled as solid obstacles for the air path.

2.3 Night Purge System

The night purge system was modelled for air velocity and temperature to determine:

a) optimum position of openable window (high or low).
b) extent of air distribution on high and no wind nights.
c) Temperature distribution as a result of night purge on high and no wind nights.

The night purge model incorporates openable windows, sized to 1% of the floor area, referenced from AEC's Passive Design Report issued February 2003. Air quantities and surface temperatures incorporated were taken from the Thermal Analysis Software (TAS) modelling conducted for the night purge scenario.

The wind modelled within TAS was taken from a day deemed to be typical. A no wind night was investigated as a “worst case” performance scenario, however they occur infrequently.

10% of the equipment load was modelled to simulate personal computers left operating overnight.

3 RESULTS

3.1 Underfloor System

The profiles detailed within the following sections are orientated such that North is located to the right of the page. The grey lines running east to west indicate the data/electrical cable trays with the grey squares indicating column placements.

3.1.1 Velocity

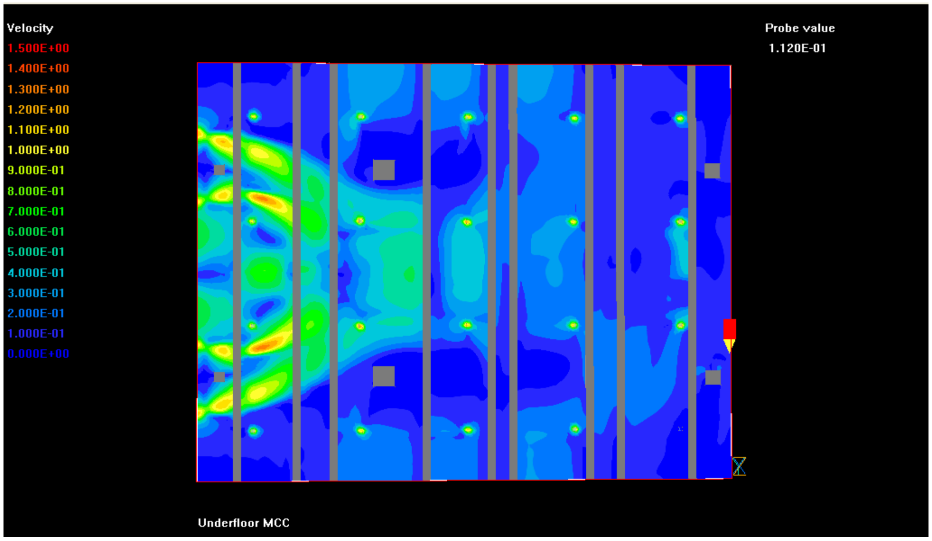

Figure 1: Underfloor Velocity Profile

From figure 1 we find that the air distribution profile, while inhibited by the data/electrical cables at times, covers the whole floor plate. As expected higher velocities are experienced on the southern side of the façade, however the magnitude (<1.4m/s) is within the expected and acceptable range.

3.1.2 Pressure Distribution

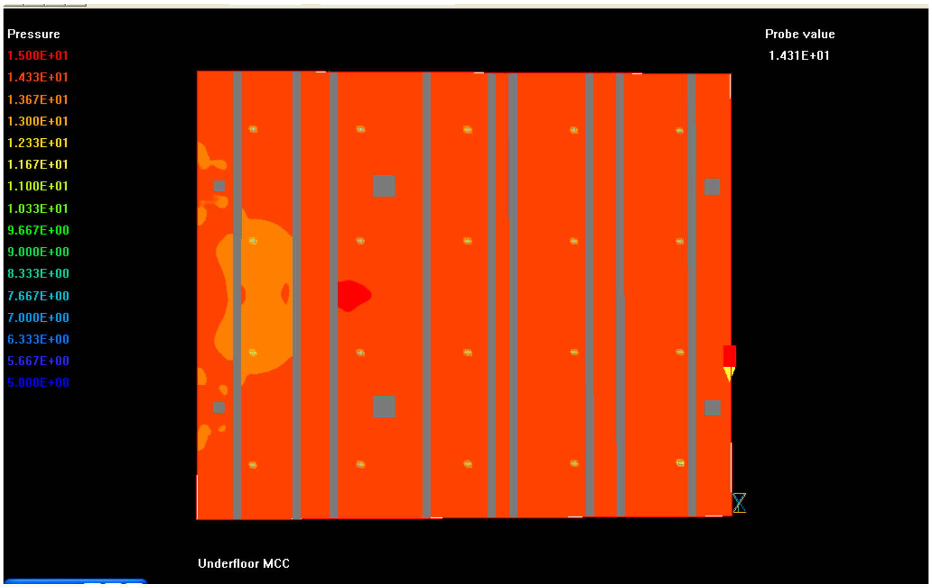

Figure 2: Underfloor Pressure Distribution

The pressure distribution calculated throughout the underfloor is generally uniform and below the desired 15Pa.

A dead spot can be seen on t he south façade between the two air inlet positions. It is recommended that a perforated baffle plate be installed at this location within the floor void to prevent this.

3.2 Night Purge

Again the profiles detailed within the following sections are orientated such that north is to the right of the page. The square blocks located at low level are to simulate 1m3 workstations. The red blocks indicate workstations with a heat load associated to them, simulating the 10% equipment load on the floor as a result of equipment left operating over night.

3.2.1 High Window Position- Wind Affected - Temperature

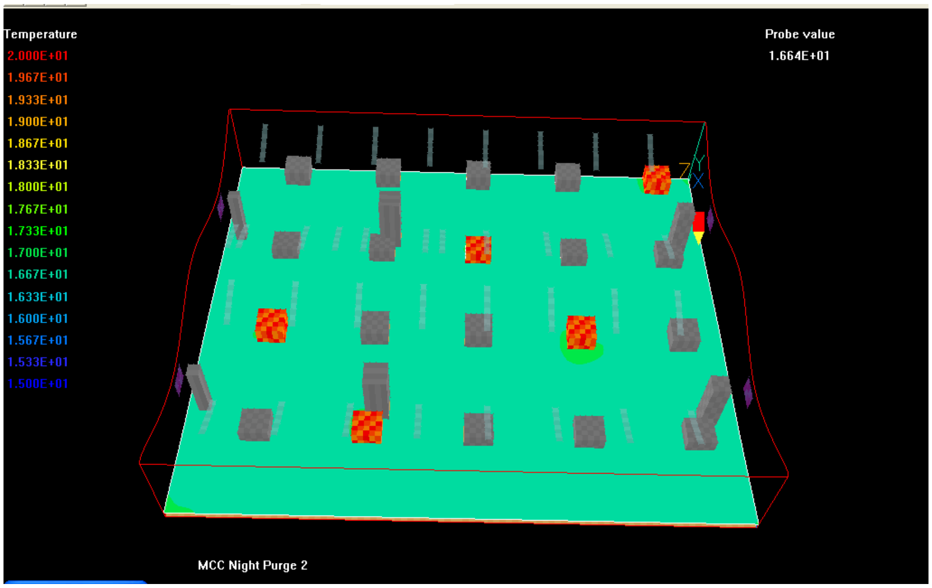

Figure 3: High Window Wind Affected Temperature1.

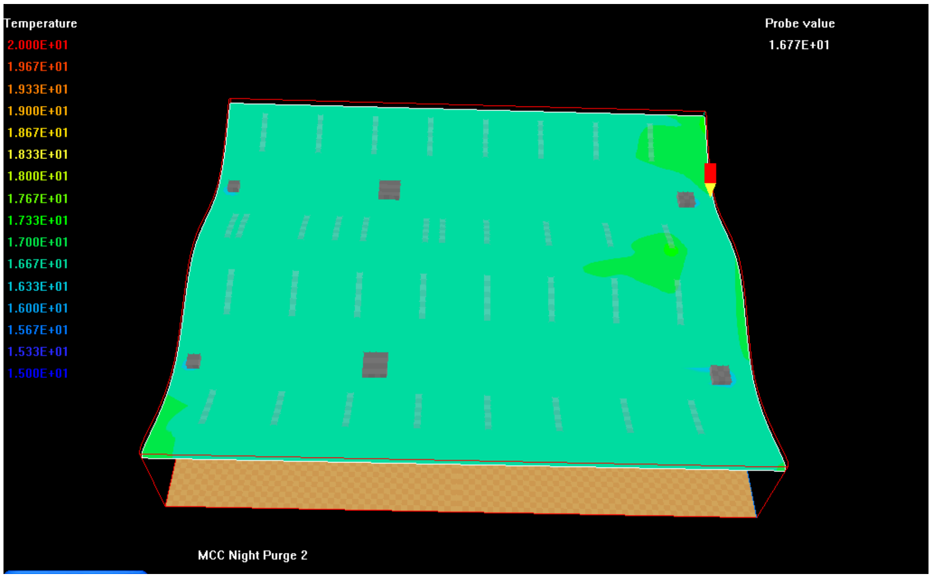

Figure 4: High Window Wind Affected Temperature2.

The high window position for a wind affected night purge results in a uniform temperature distribution (in the order of 17degC) at both high and low level across the floor.

3.2.2 High Window Position- Wind Affected - Velocity

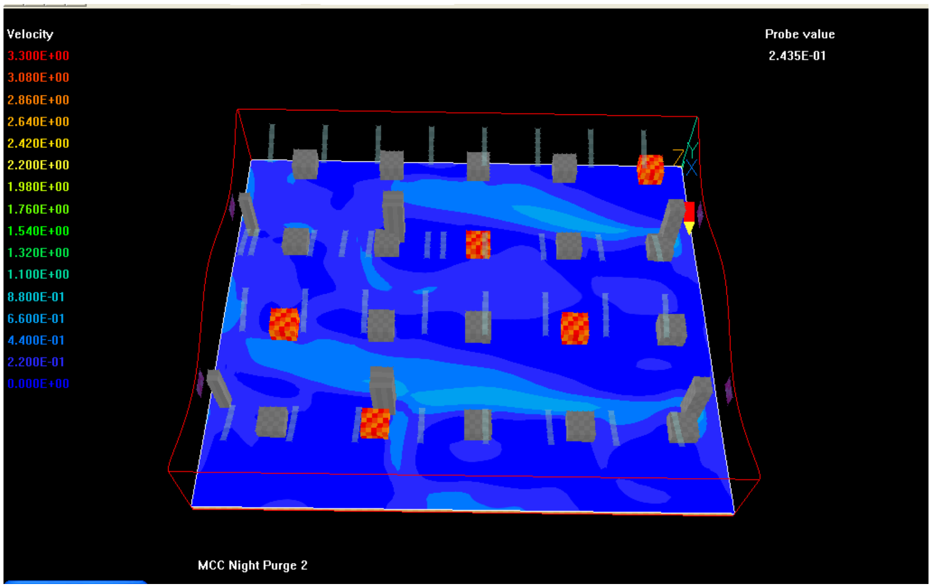

Figure 5: High Window Wind Affected Velocity1

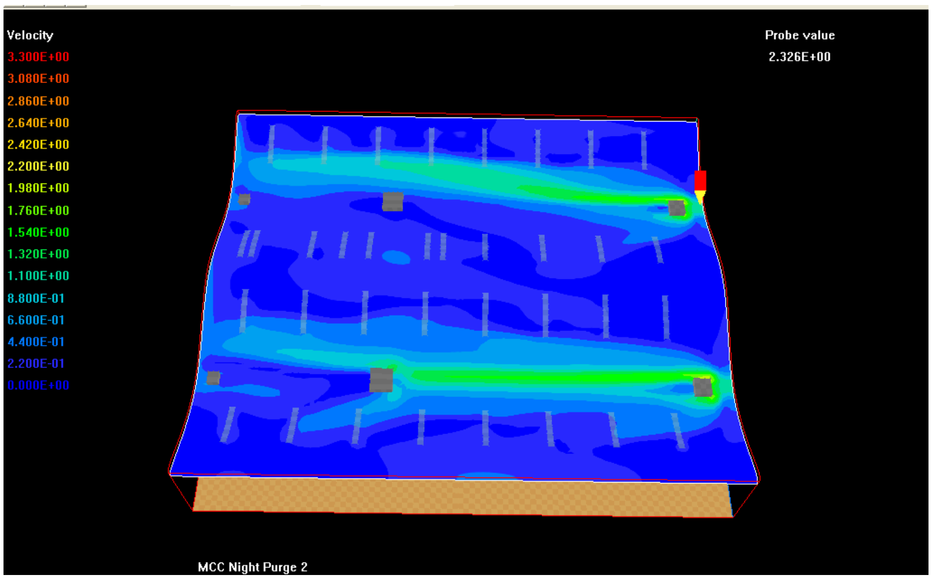

Figure 6: High Window Wind Affected Velocity2

The night purge TAS model wind analysis resulted in three times more air supply from the north façade than the south façade. This is due to the typical wind direction. This is clearly indicated in the above velocity profiles. Figure 6 shows good air distribution coverage over the ceiling thermal mass.

3.2.3 Low Window Position- Wind Affected – Temperature

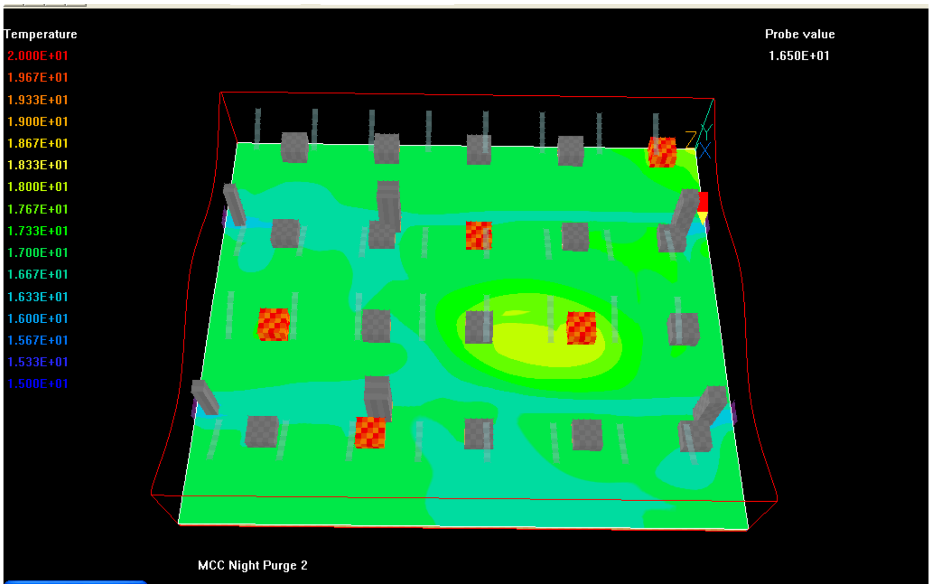

Figure 7: Low Window Wind Affected Temperature1

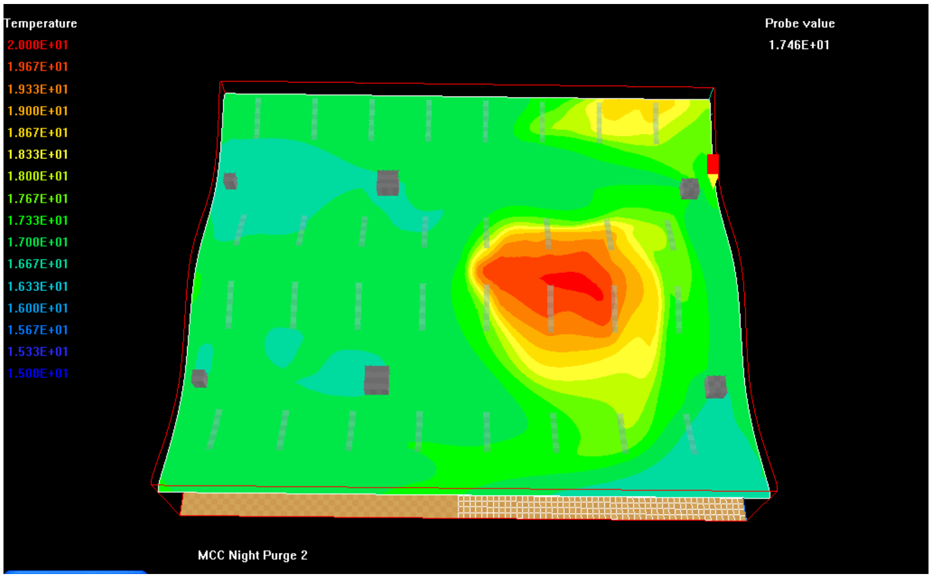

Figure 8: Low Window Wind Affected Temperature2

The low window position wind affected night purge mode results in a temperature profile generally the same as the high level positions, however there is the tendency for higher temperature patches as a result of concentrated heat sources due to the reduced air distribution across the thermal mass (see figure 10 in section 3.2.4)

3.2.4 Low Window Position- Wind Affected –Velocity

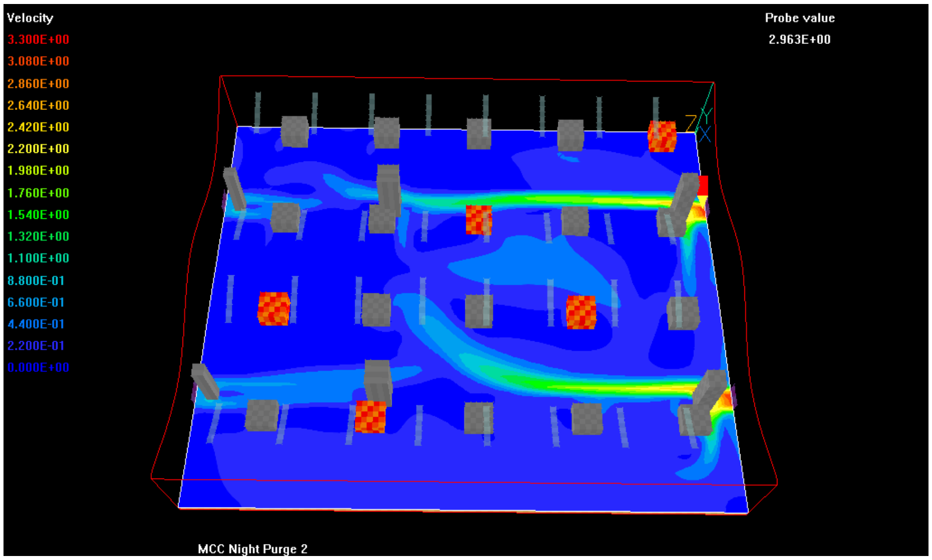

Figure 9: Low Window Wind Affected Velocity1

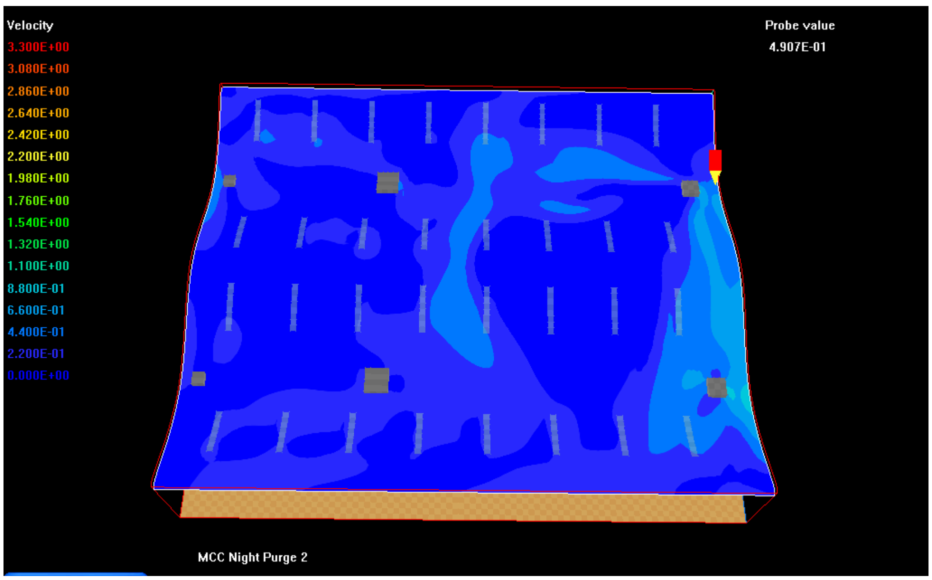

Figure 10: Low Window Wind Affected Velocity2

The low level window wind affected night purge mode creates more air movement at low level than the high level window position(figure 9), however has limited air movement across the thermal mass (figure 10).

3.2.5 High Window Position- No Wind Effects –Temperature

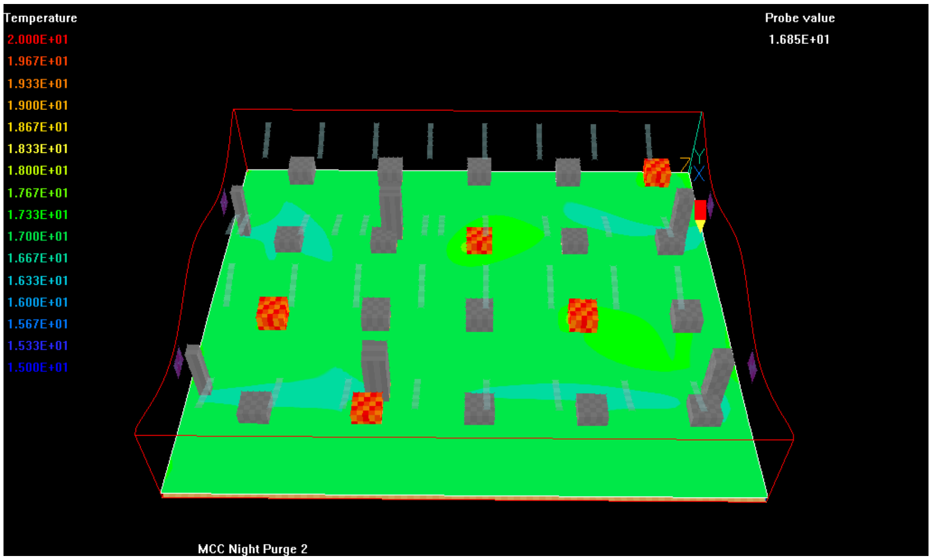

Figure 11: High Window No Wind Temperature1

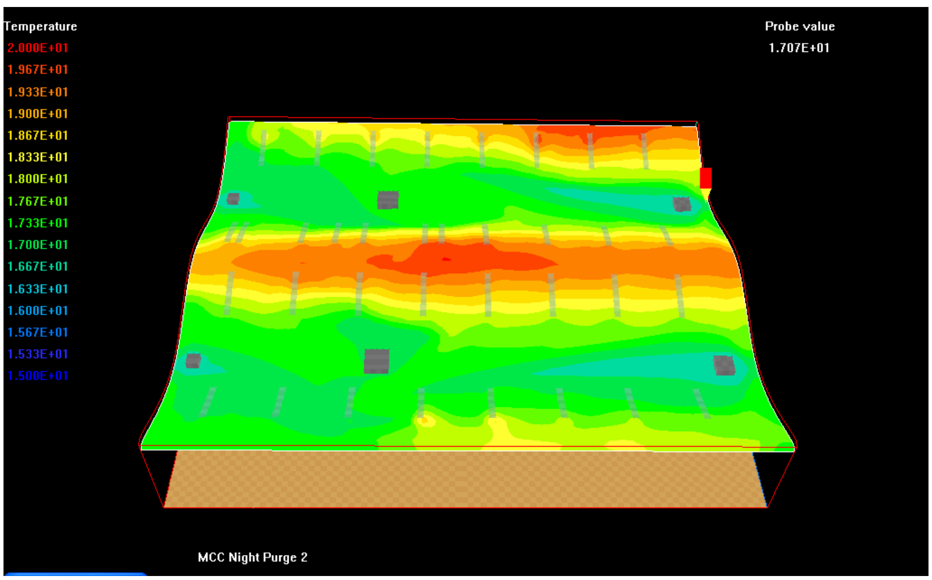

Figure 12: High Window No Wind Temperature2

The no wind scenario results in a higher temperature profile across the floor to that of the wind affected scenario. The temperature of the thermal mass is considerably more with temperatures ranging from 17 deg to 20deg. However, these temperatures are acceptable in providing cooling to the space during the day.

3.2.6 High Window Position- No Wind Effects –Velocity

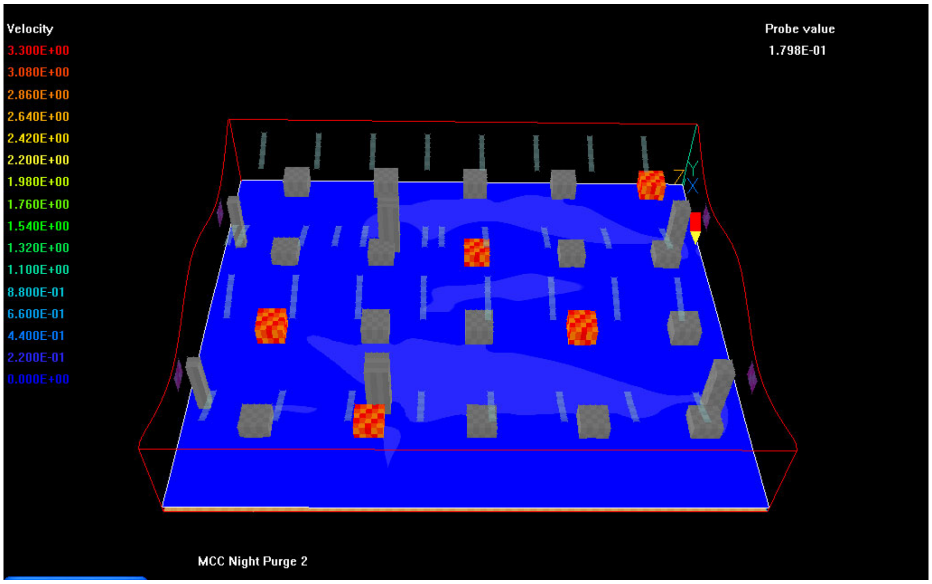

Figure 13: High Window No Wind Velocity1

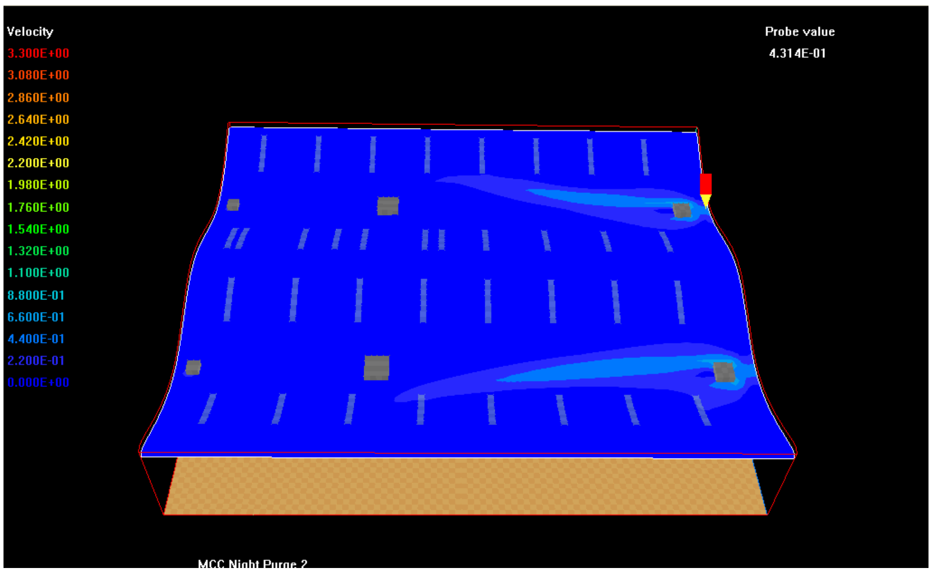

Figure 14: High Window No Wind Velocity2

The velocity profile reflects the reduced air quantity that is supplied during the no wind night purge scenario. The air distribution across the thermal mass is significantly reduced resulting in the higher temperature profile detailed within figure 12.

3.2.7 Low Window Position- No Wind Effects - Temperature

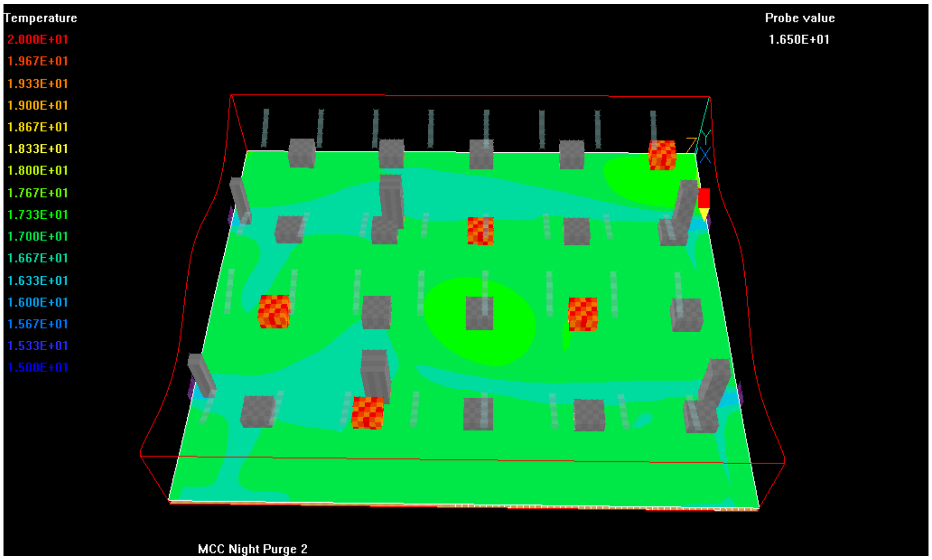

Figure 15: Low Window No Wind Temperature1

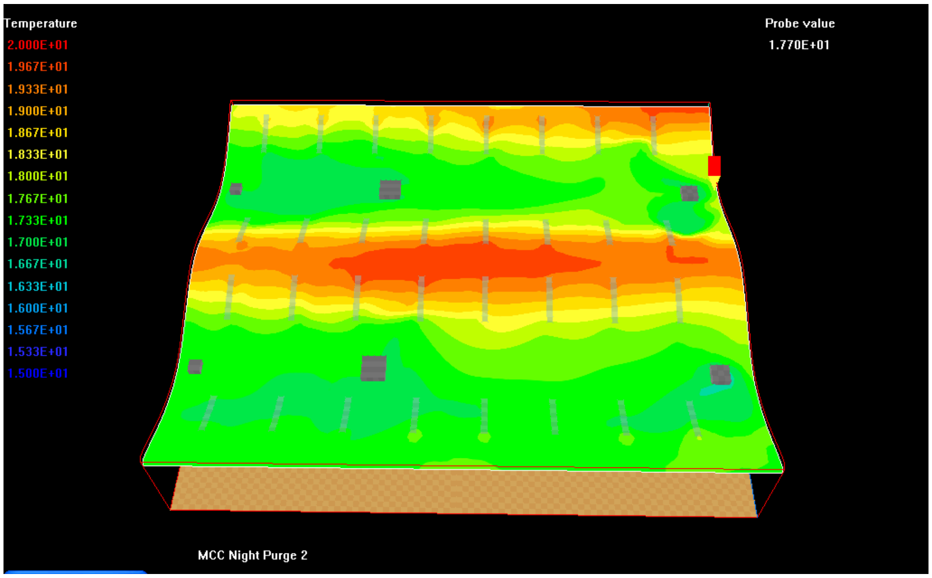

Figure 16: Low Window No Wind Temperature2

Again the lower night purge supply air quantity results in higher temperatures across the thermal mass. Temperature profile similar to that of the high window position.

3.2.8 Low Window Position- No Wind Effects–Velocity

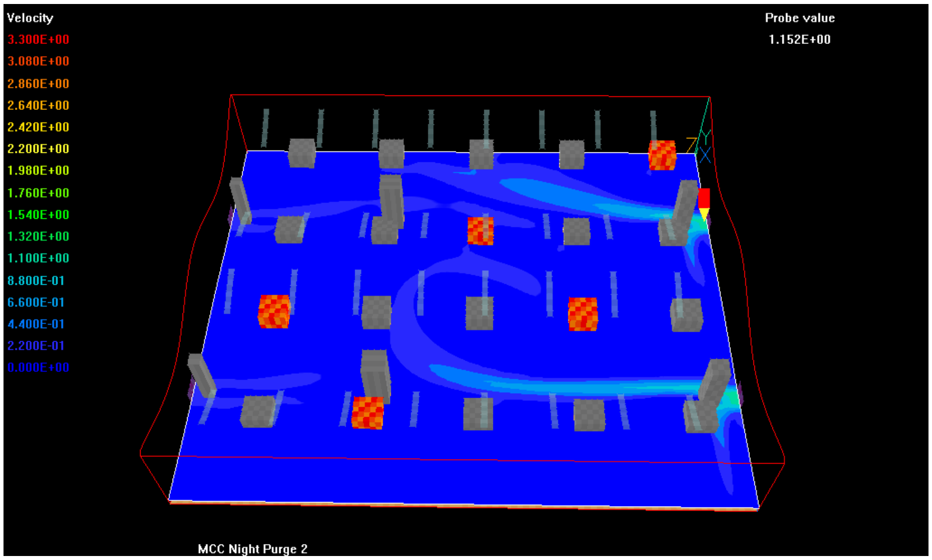

Figure 17: Low Window No Wind Velocity1

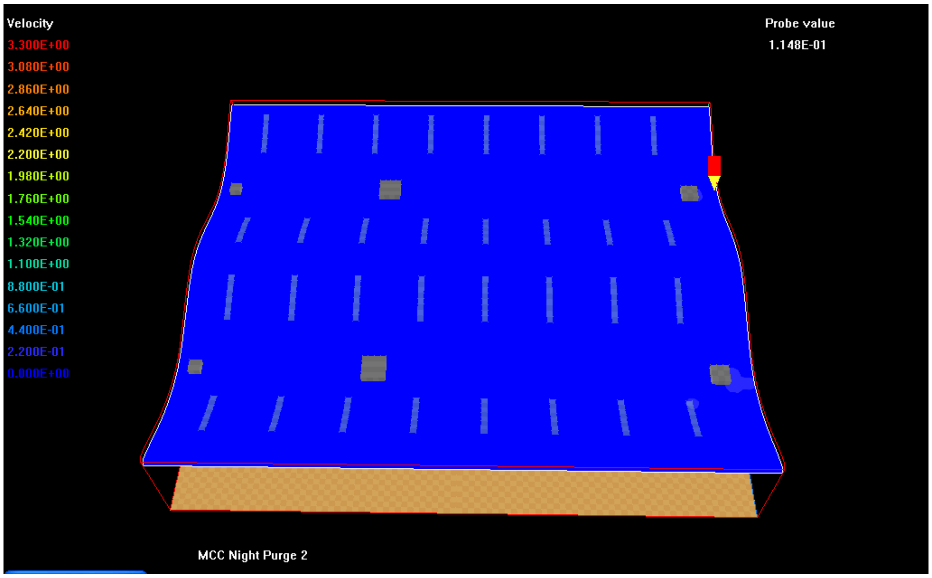

Figure 18: Low Window No Wind Velocity2

Figure 18 shows that there is virtually no air movement across the thermal mass as a result of the reduced night purge air supply from low level windows.

4 RECOMMENDATIONS/CONCLUSION

4.1 Underfloor

The velocity distribution (Figure 1) indicates that supply from the south façade only is sufficient to provide adequate air distribution across the whole width of the underfloor.

The pressure distribution (Figure 2) resulted in a relatively uniform distribution across the floor of less than 15Pa. This indicates that the current underfloor height of 220mm (clear internal) is sufficient for the air quantity and obstacles proposed.

We recommend a perforated baffle plate to be installed adjacent to the southern façade openings to help prevent a 'dead' patch.

4.2 Night Purge

Comparing the high window position to the low window position results for both the wind affected and no wind scenarios, we find that the high window position results in greater air distribution across the thermal mass, which in turn results in lower thermal mass temperatures as a result of the night purge operation.

It may be concluded that the higher the openable window position, the better the effect of night purging on thermal mass temperatures.

The findings also reaffirm the importance of having the ceiling relief air slots at the high point of the curve to minimise 'hot spots' through de-stratification.