Chapter 5

ACSC performance during windy conditions

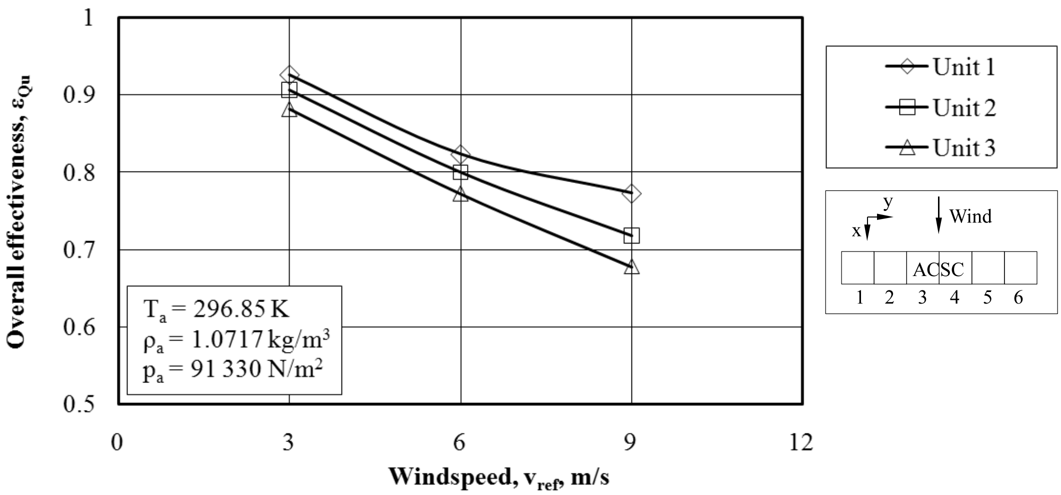
This chapter is dedicated to show the effect of wind on the performance of the Large ACSC under investigation, by means of the computational results obtained using the *Iterative* method, discussed in chapter 3. The effect of a positive x- and y-direction wind, with magnitudes of 3, 6 and 9 m/s will be examined respectively. The main contributers leading to a reduction in ACSC performance, identified as poor fan performance and plume recirculation are analyzed in order to compare their margin of influence on the effectiveness of individual cooling units. Finally the influence of surrounding power plant buildings on the condenser effectiveness is also investigated.

5.1 Overall heat-transfer effectiveness of the Large ACSC

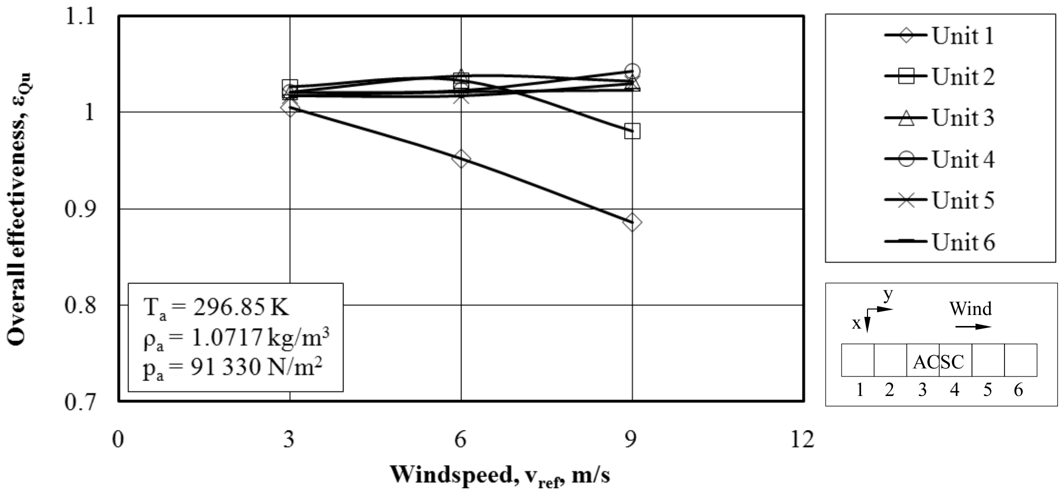
Figure 5.1 (a) and (b) shows the overall heat-transfer effectiveness of the individual cooling units in the ACSC, subject to positive x- and y-direction winds respectively. These results are discussed hereafter.

The results for the x-direction winds show a satisfactory trend compared to that found by previous researchers such as Van Rooyen (2007), Joubert (2010) and Owen (2010), since it was expected that the performance of each individual cooling unit will be reduced with an increase in wind speed and also be reduced progressively in the positive y-direction. Reduced fan performance and recirculation was found to affect the cooling ability of unit 1 differently compared to units 2 and 3, due to the extra open side of unit 1.

The results for the y-direction winds also show a realistic trend. The effectiveness of unit 1 shows a similar trend to that found by Van Rooyen (2007), Joubert (2010) and Owen (2010). This was expected since unit 1 shares some



(a)



(b)

Figure 5.1: Overall performance effectiveness of individual units in the ACSC subject to a positive (a) x- and (b) y-direction wind

similarities to the ACSC of Van Rooyen (2007). Unit 1 is the first to be impacted by the approaching wind compared to the other units further downstream of the Large ACSC. In actual fact, if the Van Rooyen (2007) ACSC were to be extended in the down-wind direction, a similar ACSC would be obtained compared to the Large ACSC analyzed in the present investigation. The effectiveness of the units further down-wind of unit 1 increases as the wind speed grows stronger and even shows performances surpassing 100 %. This is due to an increase in fan performance and will be discussed in section 5.4.

Fan performance and plume recirculation are subsequently discussed to investigate the individual influences of these components on the overall performance of the Large ACSC.

5.2 Reduced fan performance

The reduction in fan performance occurs due to distorted flow (separation) beneath the fan platform at the upstream periphery of the ACSC. The separated flow accelerates beneath the fan platform and causes an increase in dynamic pressure in this region. Consequently a decrease in static pressure occurs beneath a number of fans in proximity of the upstream periphery. The volume flow through individual fans in the separated flow region is reduced due to the static pressure decrease. Moreover these fans, having a limited ability to provide a certain static pressure rise, now need to overcome the static pressure decrease, in addition to the obstacles forming part of the ACSC. The decrease in volume flow, leads to a decrease in heat transfer and consequently cooling unit effectiveness.

The reduction in the performance of fans are discussed for the case of positive x- and y-direction winds respectively.

5.2.1 x-direction winds

The performance of various fans in the ACSC is shown in figure 5.2 for a positive x-direction wind.

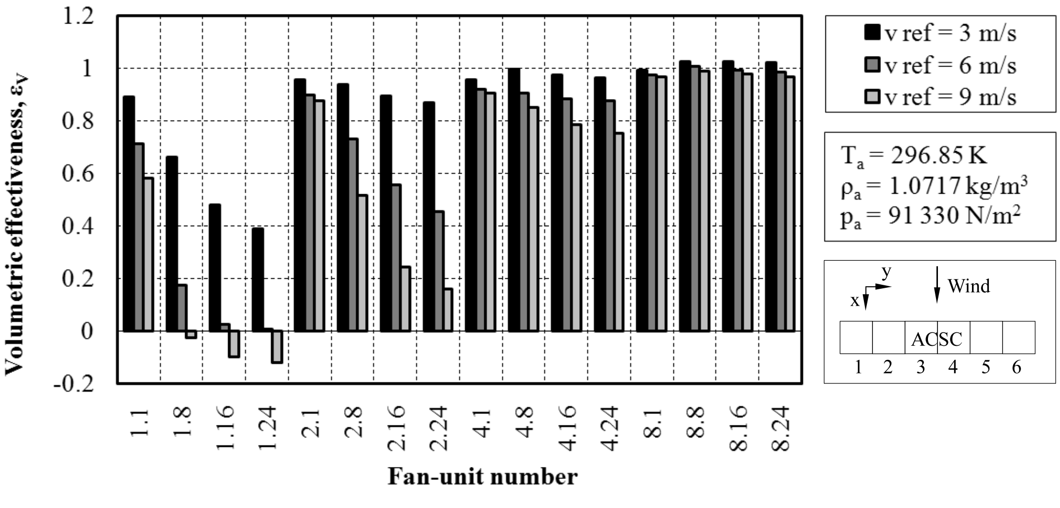


Figure 5.2: Change in fan performance of certain fans in the ACSC for positive x-direction winds

From this figure it can be seen that the the volumetric effectiveness is the worst for the fans in row 1. Furthermore most of the upstream fans between rows 1 to 4 are severely affected for a 9 m/s wind speed, especially the fans closer to the symmetry plane. Interestingly back flow is seen through some fans in row 1 for a 9 m/s wind, giving an indication of the large static pressure decrease beneath the fan platform for high wind speeds. It should however be mentioned that the actuator-disk model is not verified in this reason and the therefore the accuracy of the volume flow rates through these fans is questionable.

Figure 5.3 illustrates the significant static pressure decrease beneath the ACSC platform by means of static pressure contour plots on planes A-A and C-C (figure D.1) even for the low wind speed of 3 m/s.

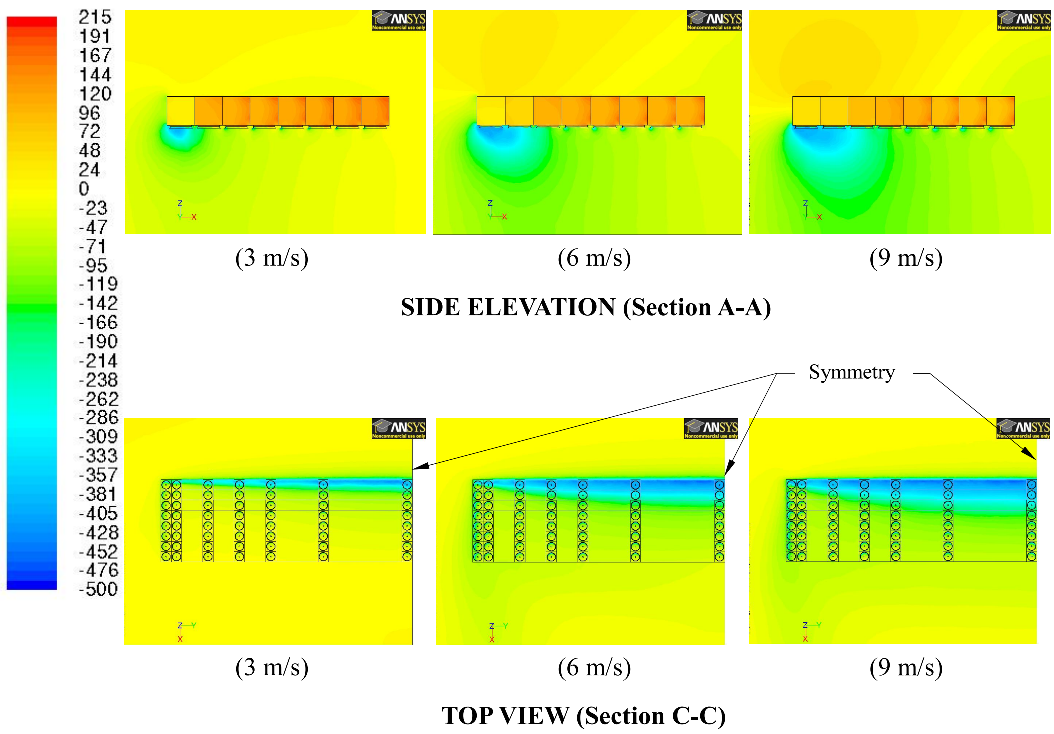


Figure 5.3: Contour plots of static pressure, N/m^2, on planes A-A and C-C respectively for a 3 m/s, 6 m/s and 9 m/s positive x-direction wind

From figure 5.3, it can also be seen that separation progressively increases towards the symmetry plane of the ACSC when the flow essentially becomes two-dimensional (parallel to the symmetry plane). The reason for this two-dimensional flow is that most of the fans situated in the region of unit 1 have the ability to draw in air from the open side, parallel to the wind direction as shown in figure 5.4. Consequently the fans situated more to the center of the ACSC, only have the ability to draw in air approaching parallel to the x-direction as shown in the side view of figure 5.4. Additionally, air entering the ACSC two-dimensionally have to be drawn in from a higher elevation, since a similar amount of air mass flow has to enter through the smaller inlet area (between the periphery of the ACSC platform and the ground) beneath unit 2 and 3, compared to unit 1. This flow crosses the upstream periphery faster compared to air entering the ACSC three-dimensionally, increasing the separation towards the symmetry plain of the ACSC.

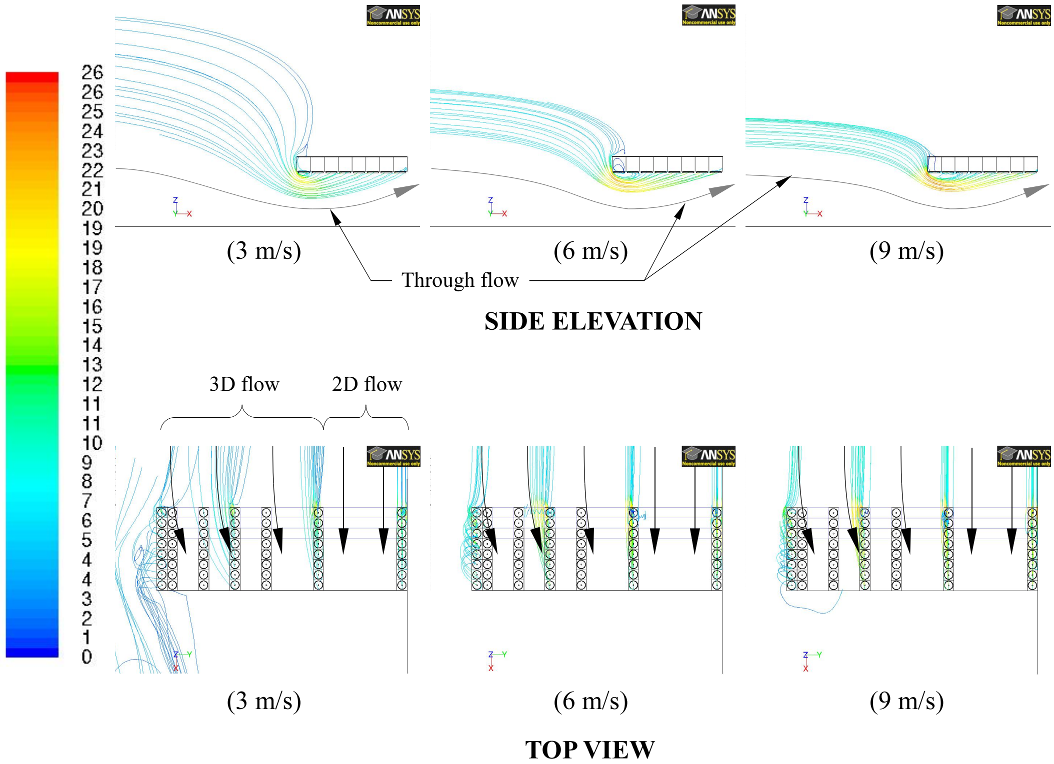


Figure 5.4: Flow line plots colored by velocity, m/s, of flow entering streets 1, 8, 16 and 24 of the ACSC for a 3 m/s, 6 m/s and 9 m/s positive x-direction wind

5.2.2 y-direction winds

The volumetric effectiveness of some fans in the ACSC subject to a y-direction wind are illustrated in figure 5.5.

The fan performance in street 1 of the ACSC is severely affected by an increase in positive y-direction wind speed. However the volumetric effectiveness of fans further downstream of street 1 remain above 90 % for the range

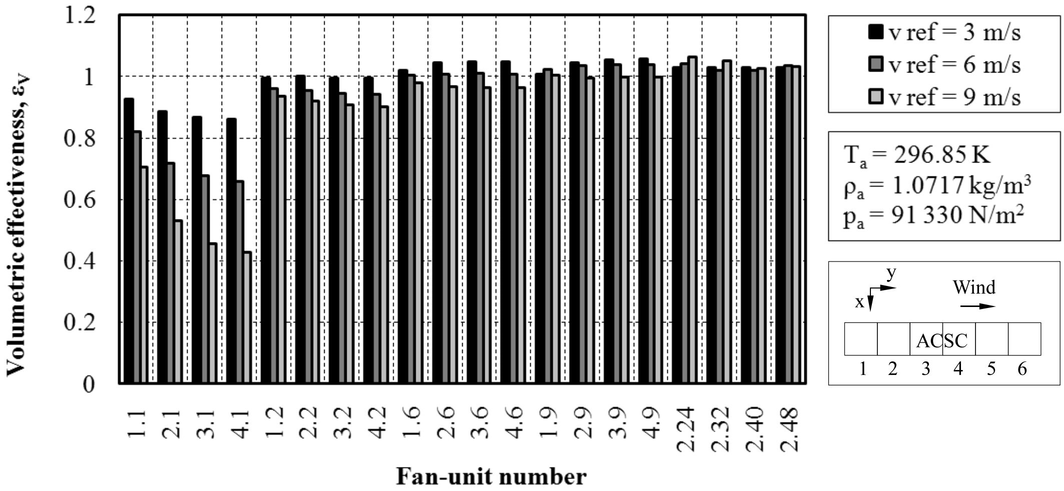


Figure 5.5: Change in fan performance of certain fans in the ACSC for positive y-direction winds

of wind speeds used in the present study. Little variation in results is seen for the volume flow through fans in the ACSC, placed further downstream of the wind. As shown in figure 5.5, the fans further downstream exploit the energy in the wind and a higher volumetric through-flow is observed compared to the ideal calculated volume flow for a single fan unit. This trend was also noted by Van Rooyen (2007), Joubert (2010) and Owen (2010).

Figure 5.6 shows the pressure contour plots beneath the fan platform for a positive y-direction wind. The separated flow region beneath the platform is seemingly smaller compared to the case of an x-direction wind (for the same wind speeds) and only extends over a portion of the fan inlets in street 1. This explains why only the fan performance in street 1 is severely affected.

The air flow into row 4 of the ACSC is shown in figure 5.7. By looking at the top view it can be seen that most of the flow entering the ACSC, enters from the sides parallel to the wind direction. Since the ACSC has the ability to draw in air three-dimensionally during this wind direction, lower air speeds cross the upstream periphery compared to the case of an x-direction wind. It should also be noted that through-flow beneath the ACSC platform is very small and the elevation from which air is drawn into the ACSC is lower compared to the case of an x-direction wind. Therefore the area and magnitude of separation beneath the fan platform is also reduced from the x- to y-direction wind and consequently fewer fans are affected by the separated flow region.

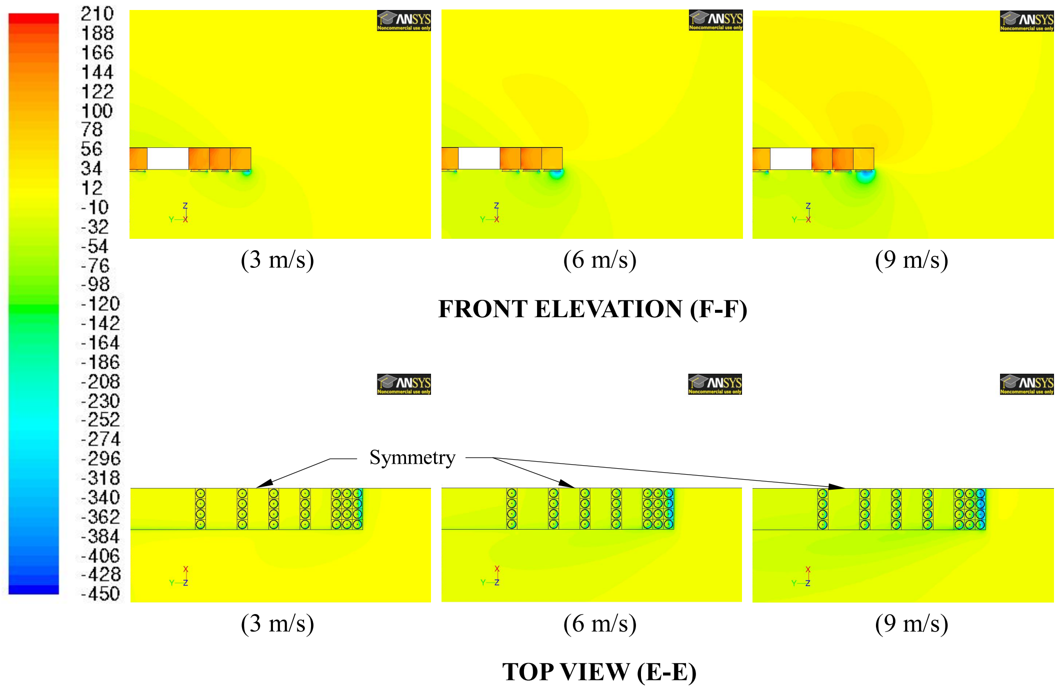


Figure 5.6: Contour plot of static pressure, N/m^2, on planes B-B and C-C respectively for a 3 m/s, 6 m/s and 9 m/s positive y-direction wind

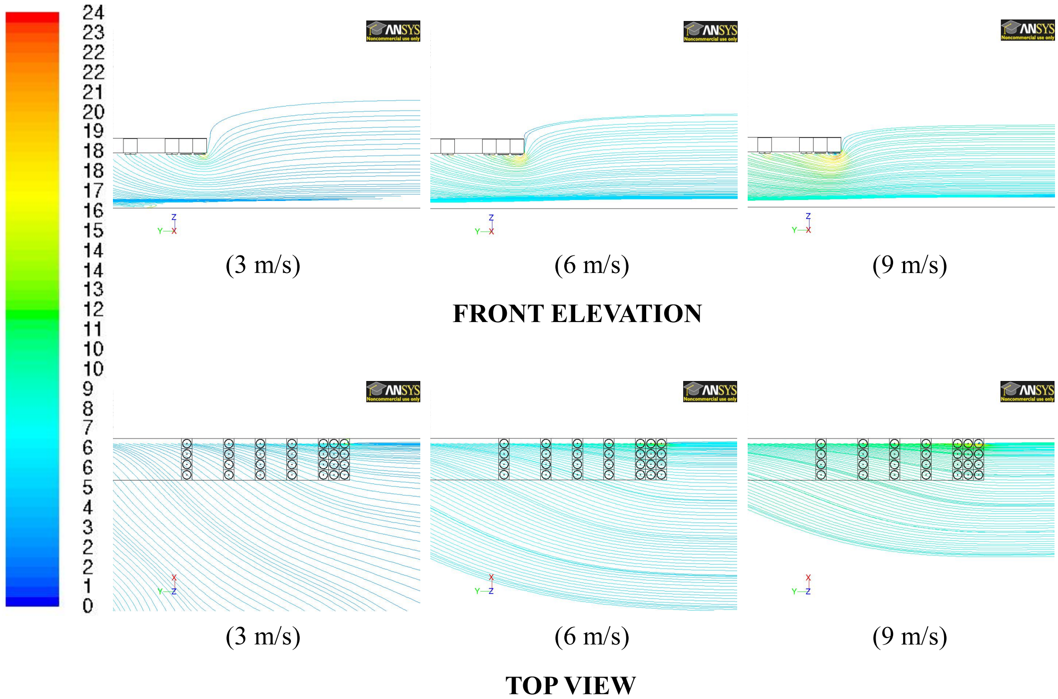


Figure 5.7: Flow line plots colored by velocity, m/s, of flow entering row 4 of the ACSC for a 3 m/s, 6 m/s and 9 m/s positive y-direction wind

5.3 Plume recirculation

A reduction in heat-exchanger performance is noticed when the inlet air temperature to the heat-exchanger bundles increases. During windy periods, hot plume air is drawn into the ACSC at certain locations along the ACSC periphery. The plume above the ACSC is illustrated by means of flow lines in figure 5.8 for the case of a positive (a) x- and (b) y-direction wind at the speed of 9 m/s, since plume recirculation is the worst for this case. The main reasons for plume recirculation is discussed hereafter.

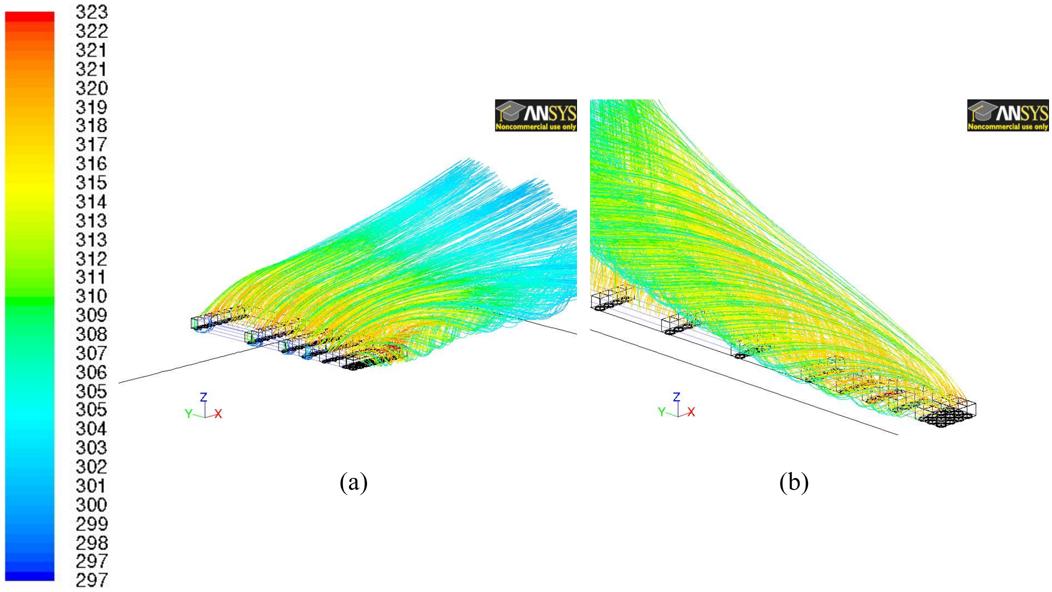


Figure 5.8: Flow lines colored by temperature, K, displaying the plume rising from the ACSC, subject to a positive (a) x- and (b) y-direction wind speed of 9 m/s

5.3.1 x-direction wind

The inlet temperatures to various fans in the ACSC, subject to a positive x-direction wind, is illustrated in figure 5.9.

The plume air, rising from the ACSC under the respective x-direction wind magnitudes, is illustrated in figure 5.10 through temperature contour plots along sections A-A, C-C and B-B. It can be seen that recirculation occurs on the upstream periphery as well as the along the side parallel to the wind direction.

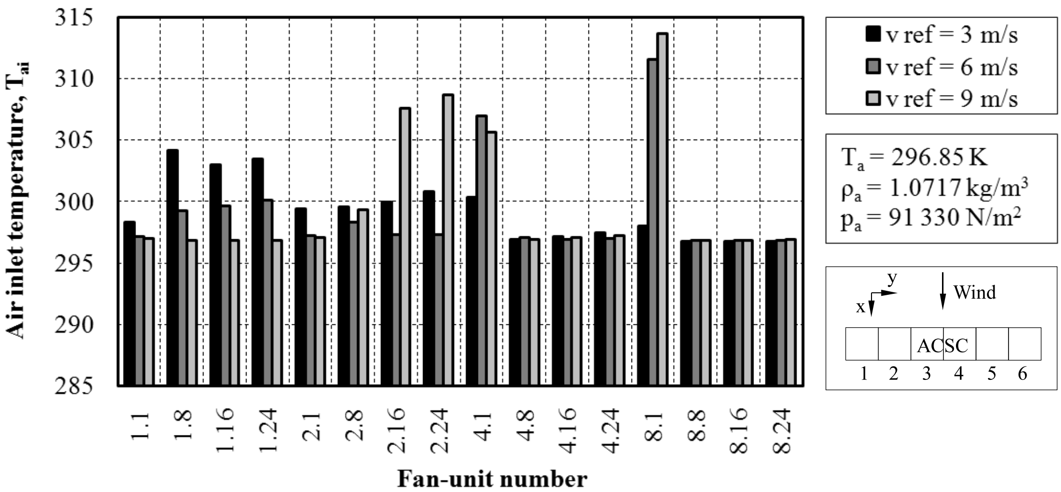


Figure 5.9: Air inlet temperature to certain fans in the ACSC for positive x-direction wind speeds of 3, 6 and 9 m/s

The answer to recirculation occurring on the upstream periphery of the ACSC is seen in the side elevations of figures 5.4 and 5.10. As discussed earlier, flow entering the ACSC towards the symmetry plane is drawn in from a higher elevation since it can only be drawn in two-dimensionally. This air entrains some of the plume on its way to the fans, causing the air inlet temperature to increase for certain fan units close to the upstream periphery. The plume entrainment decreases with an increase in wind speed, since less heated air is forced up into the atmosphere due to the decreased fan performance at the upstream periphery of the ACSC. At high wind speeds, such as 9 m/s, the simulation of back flow through some fan-units in row 1 causes the heat rejected from these units to be dispersed between the fan-units further downstream leading to an increase in air inlet temperature.

Vortexes forming on the side of the ACSC draw in hot plume air below the fan platform, as can be seen in the front elevation of figure 5.10. The vortex intensities increase with a progressive increase in wind speed and consequently more recirculation occurs on the parallel side of the ACSC.

5.3.2 y-direction wind

The inlet temperatures to certain fans in the ACSC is illustrated in figure 5.11. It can be seen that slight recirculation occurs at the upstream periphery. Furthermore, the fans in row 6 and 9 located on the side (parallel to the flow direction) of the ACSC, are also experiencing hot plume inflow due to the vortex shedding discussed earlier. This is also verified by the temperature contour plot in figure 5.12 for 3, 6 and 9 m/s wind speeds in the positive y-direction.

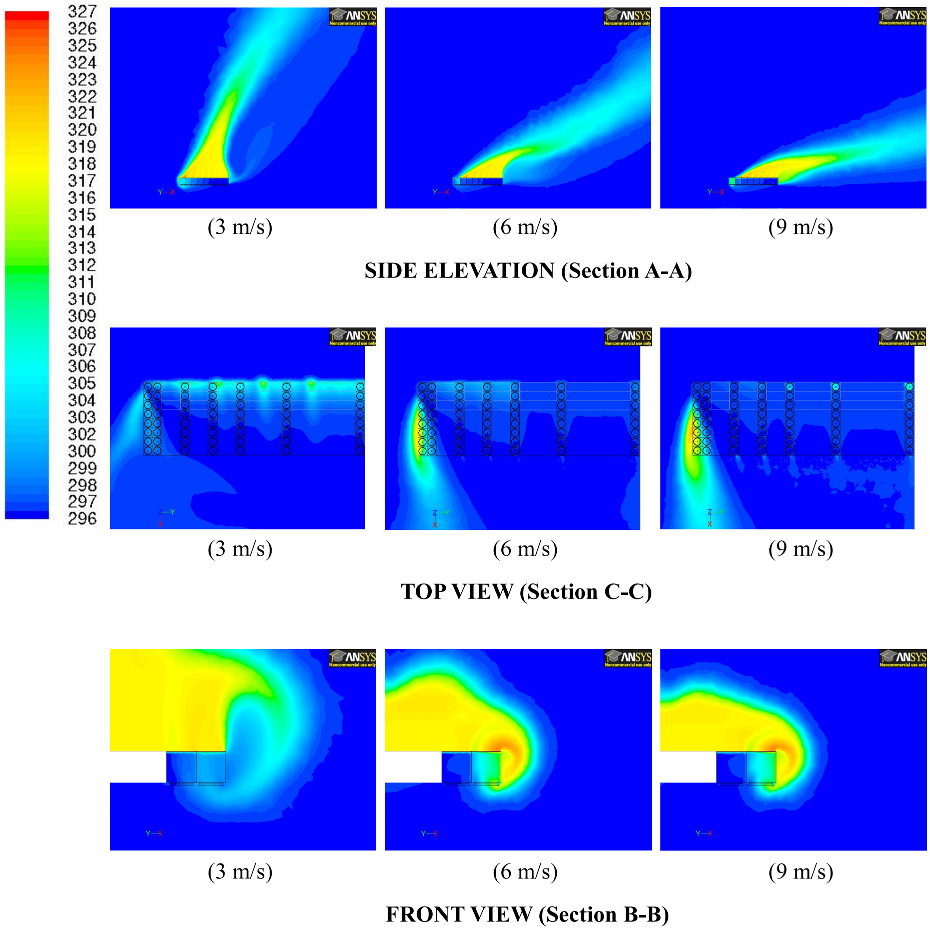


Figure 5.10: Contour plots of temperature, K, on planes A-A, C-C and B-B respectively for a 3 m/s, 6 m/s and 9 m/s positive x-direction wind

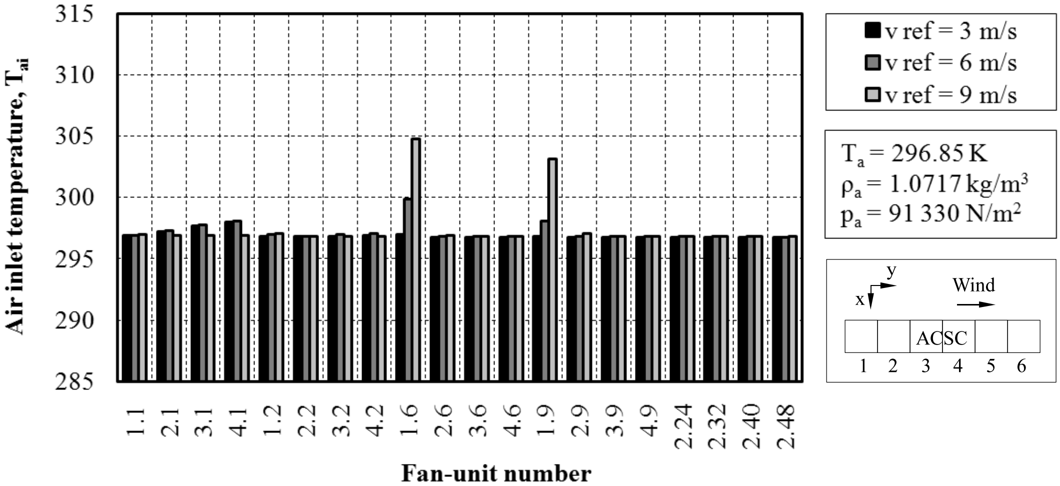


Figure 5.11: Air inlet temperature to certain fans in the ACSC for positive y-direction wind speeds of 3, 6 and 9 m/s

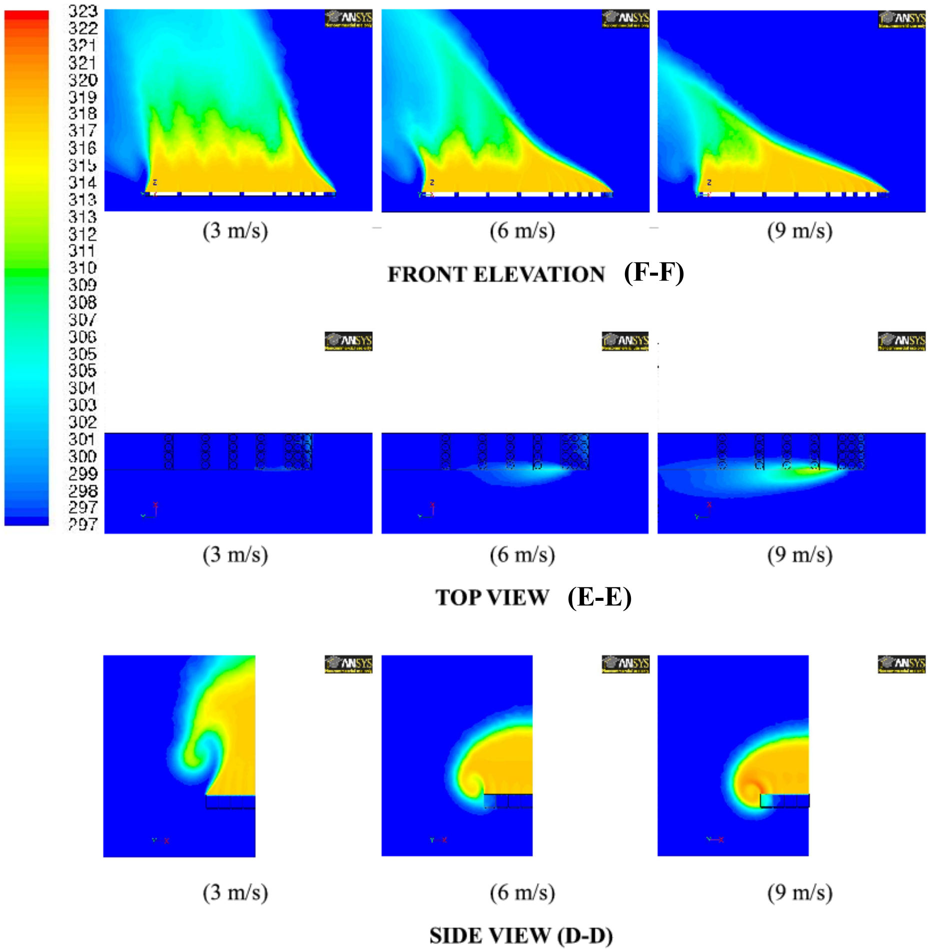


Figure 5.12: Contour plots of temperature, K, on planes B-B, C-C and D-D respectively for a 3 m/s, 6 m/s and 9 m/s positive y-direction wind

5.4 Comparison between the effect of fan performance and plume recirculation on overall ACSC performance

Experiments done on the flow through and around the current largest ACSC (288 fans) at Matimba power station, were presented by Goldschagg (1993). It showed that plume recirculation occurs during windy conditions, but no mention is made regarding the effect of fan performance. Owen (2010) presents a comparison between the effect of fan performance and plume recirculation and found that the former is the major contributer to the overall ACSC cooling performance. The system of Owen (2010) is however considerably smaller (30 fans) than the Large ACSC in the present study and therefore the effects of two-dimensional flow could not be seen. For this reason a similar comparison is done for the Large ACSC subject to a positive x- and y-direction wind.