# Research on the influence of outdoor wind environment on the operation characteristics of outdoor units of air conditioners in winter

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**Abstract.** Variable Refrigerant Volume multi connected air conditioning system is widely used in high-rise and super high-rise buildings because of its convenient control, flexible layout and installation and energy saving. However, for high-rise and super high-rise buildings, the outdoor wind environment has a significant impact on the installation, layout and operation performance of Variable Refrigerant Volume multi connected air conditioning system outdoor units. In this paper, the numerical simulation method is used to study the variation characteristics of inlet and exhaust temperature and speed of outdoor unit under different outdoor wind speed and wind direction in winter when the inclination angle of outdoor unit shutter of Variable Refrigerant Volume multi connected air conditioning system is 0 °, ± 30 °, ± 45 ° and ± 60 ° respectively. The results show that in winter, the air inlet and exhaust outlet should avoid the outdoor wind direction as much as possible. When there is no wind outside or the wind speed is 4m/s, the shutter angle should be maintained between 30 ° and 45 °. When the outdoor wind speed is 2m/s, the shutter angle should be maintained at about 30 °.

**Keywords:** multi-splits air-conditioner, the outdoor unit, numerical simulation, inlet and outlet air temperature

## 1 Introduction

Variable refrigerant flow multi connected air conditioning system is widely used in high-rise and super high-rise buildings because of its convenient control, flexible layout and installation and energy saving. At present, domestic research on VRF has been carried out in different aspects[1] ~ [9], Tian Zhihua[10]and others conducted software simulation on the outdoor unit of a super high-rise building in Shenzhen. According to the simulation results, they found that the exhaust duct of the outdoor unit, the louver permeability of the facade curtain wall and the outdoor air environment will have an impact on the outdoor unit, and optimized it. Yang Yun [11] simulated the louvers of an outdoor machine room of a building in Shanghai. Through the simulation results and analysis, it can be concluded that the wind speed of the exhaust duct is not less than 6m/s, and the exhaust wind speed should be less than 9m/s. And, the tilt Angle of the louver baffle should not be too large. When the tilt Angle of the louver is too large, When the tilt angle of the louvers is too large, the flow guiding effect of the louver baffle will be significantly reduced, and a vortex area will be formed at the same time, which increases the vortex loss. Wei Xiaowen et al.[12] Simulated the outdoor thermal environment of multi on-line air-conditioning outdoor units under different horizontal array layout spacing. The results showed that the horizontal array layout spacing was affected by the outdoor unit size. The larger the outdoor unit size, the greater the spacing requirement to meet the same thermal environment. Combined with the thermal environment results under different horizontal array layout spacing, the layout area was comprehensively considered, The concepts of first installation distance and second installation distance are proposed. Chen Dahong [13] studied and simulated the influence of heat dissipation of outdoor unit of air conditioner on upper equipment through CFD software. The research results show that the heat release rate of outdoor unit and fan power will affect the upward flow of hot air. At the same time, the hot air discharged from the lower equipment will also have an adverse impact on the operation of the upper equipment, increasing the rising speed and temperature of the air at its inlet.

For high-rise and super high-rise buildings, the outdoor wind environment has a significant impact on the installation, layout and operation performance of multi on-line outdoor units. In this paper, CFD simulation software is used to simulate the air distribution around the multi online outdoor unit in high-rise buildings, and the results are analyzed and

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optimized, so as to determine the reasonable layout and design position of the multi online outdoor unit, so as to ensure the reasonable and efficient operation of the outdoor unit.

## 2 physical model

The establishment of calculation model is the basis of mesh generation and flow field simulation. The influence between the upper and lower layers of outdoor units and the influence between the levels of outdoor units will not be considered first. In order to fully develop the air flow discharged from the outdoor unit, the scale of the calculation domain is long × wide × Height: 6m × 5m × 5m, simulate and analyze the air flow in the calculation domain, and the established physical model is shown in Figure 1.

As shown in Figure 2, the louver in the machine room is ordinary aluminum alloy rainproof louver, the width × height of the louver is 1.74m×0.05m, the thickness is 2mm, and the spacing between the louvers is 60mm.The length × width of the exhaust outlet is 1.24m×0.5m, and the length × width of the air inlet is 1.24m×1.3m. Due to mesh and computing equipment, the thickness of the louver is ignored. The included angle between the louver and the horizontal axis is called the louver inclination. As shown in Figure 3,The specified shutter inclination is positive when it is upward and negative when it is downward.

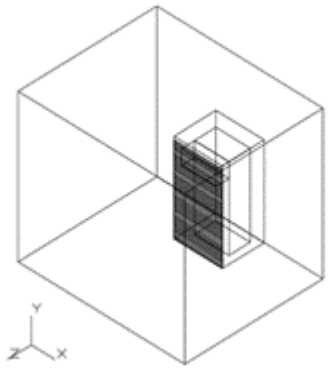

**Fig. 1** Model diagram of outdoor unit

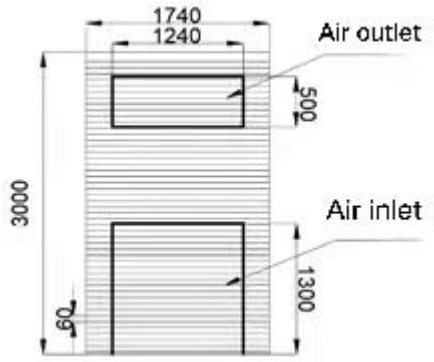


**Fig. 2** Schematic diagram of louver

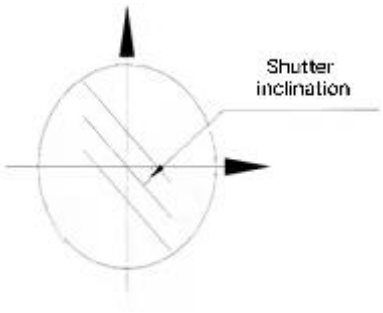


**Fig. 3** Schematic diagram of shutter inclination

## 3 Meshing and calculation conditions

### 3.1 Meshing

Unstructured grid is used in this simulation. In order to obtain high-quality grid and reduce the amount of calculation, the air inlet and exhaust outlet are locally densified, and after repeated division and calculation, the number of grids and nodes are finally obtained.

（1） Number of grids：536313

（2） Number of nodes：560924

The meshing quality is shown in Figures 4 and 5.

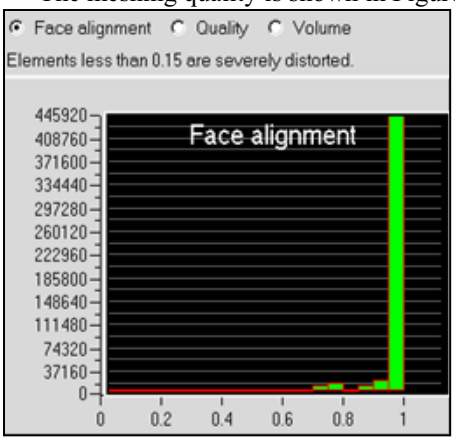


**Fig. 4** Face alignment

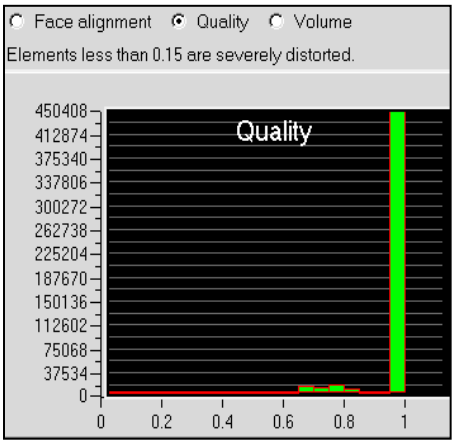


**Fig. 5** Quality

### 3.2 Calculation conditions

(1) This paper simplifies the internal structure of the outdoor unit, ignores the heat conduction between the components, and assumes that there is no interaction between the internal components, and the unit operates stably under the condition of full load. For the heat released by the radiator, the volume heat source simulation method is adopted.

(2) For air inlet and exhaust outlet, they shall be built on the same elevation, with lower air inlet and upper exhaust. The air inlet temperature of the outdoor unit is the outdoor atmospheric temperature, the air inlet volume is the rated air volume of the outdoor unit, and the parameters of the air outlet are calculated.

(3) The side and top of the outdoor unit are set as free outlets to connect them with the atmosphere

(4) The facade of the building is simplified and considered to be an adiabatic and flat wall; Solar radiation and wall radiation are ignored. The influence of many decorations on the outer wall of the building, such as windows, is also not considered.

(5) The outdoor wind speed and direction change from time to time, which is difficult to realize by numerical simulation. The outdoor wind speed and direction fluctuate little, so the outdoor wind speed and direction can be simplified in a steady-state way.

Location: Xi'an - cold area, east longitude 107 ° 40 ′ - 109 ° 49 ′ , north latitude 33 ° 42 ′ - 34 ° 45 ′ , altitude 396.9m. In winter, the outdoor atmospheric pressure is 913.8hpa, the average wind speed is 1.6m/ s, the outdoor calculated temperature is -5 ℃ , and the indoor calculated temperature is 20 ℃.

The simulated working conditions are shown in Table 1.

**Table 1.** Simulated working conditions

| | |
|---|---|
| Outdoor calculated temperature | -5℃ |
| Outdoor wind direction | Directly facing or perpendicular to the air inlet and exhaust outlet |
| Outdoor wind speed | 0m/s、2m/s、4m/s |
| Shutter inclination | 0°、±30°、±45°and±60° |

## 4 Simulation results and analysis of outdoor unit operation in winter

### 4.1 Simulation of no wind outside

The following is a broken line diagram of temperature and speed at x = 3m:

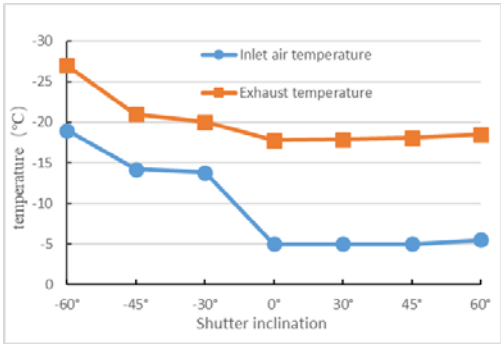


**Fig. 6** broken line diagram of inlet and exhaust air temperature

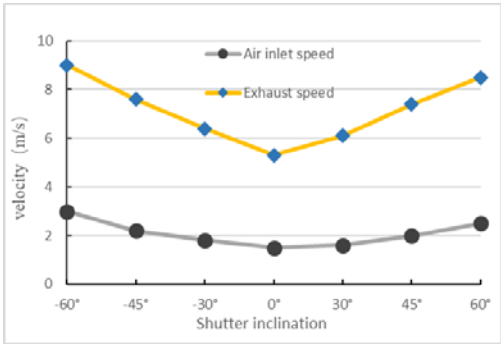


**Fig. 7** broken line diagram of air inlet and exhaust speed

In terms of temperature, when the shutter angle is downward, the inlet air temperature is too low and the temperature difference between inlet and exhaust air is too small, which is not conducive to the normal operation of outdoor unit; When the angle of the shutter is upward, the outdoor unit can operate normally.

In terms of speed, with the gradual increase of shutter inclination angle, the air inlet and exhaust speed increases gradually, and the air inlet and exhaust speed meets the working requirements of outdoor unit.

Therefore, when the inclination angle of the louver is 0 °, 30 °, 45 ° and 60 °, its air inlet and exhaust speed and temperature can meet the normal operation of the outdoor unit.

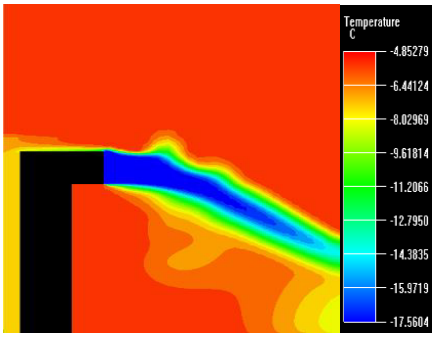


**Fig. 8** α = Temperature nephogram at 0 °

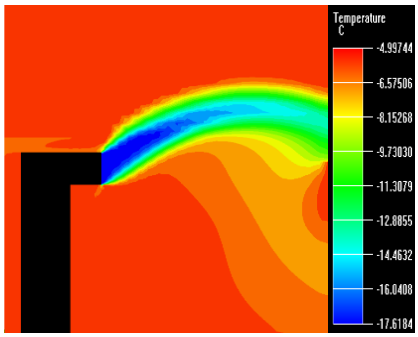


**Fig. 9** α = Temperature nephogram at 30 °

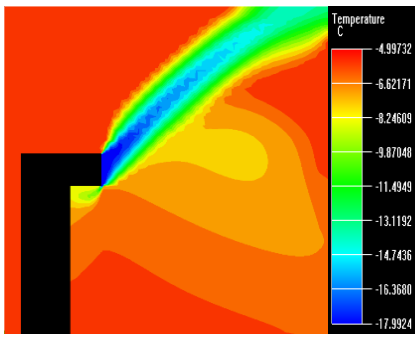


**Fig. 10** α = Temperature nephogram at 45 °

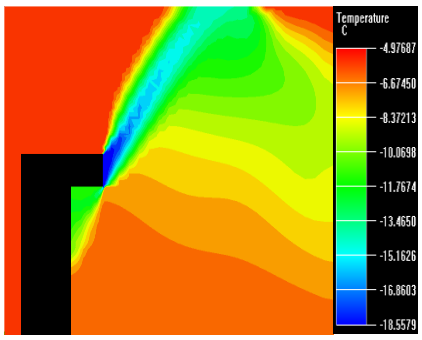


**Fig. 11** α = Temperature nephogram at 60 °

It can be seen from the figure that when the inclination angle of the shutter is 0 °, outdoor sundries are easy to enter the machine room. When the inclination angle of the louver is 60 °, the cold air basically rises in a straight line, making the inlet air temperature of the upper outdoor unit too low. Therefore, in order to maintain the normal operation of the outdoor unit, it is best to keep the shutter angle between 30 ° and 45 °.

To sum up, when there is no wind outside, in order to maintain the normal operation of the outdoor unit without affecting the upper equipment, the shutter angle should be maintained at about 30 ° to 45 °.

### 4.2 Simulation of outdoor wind speed of 2m/s

The following is a broken line diagram of temperature and speed at x = 3m:

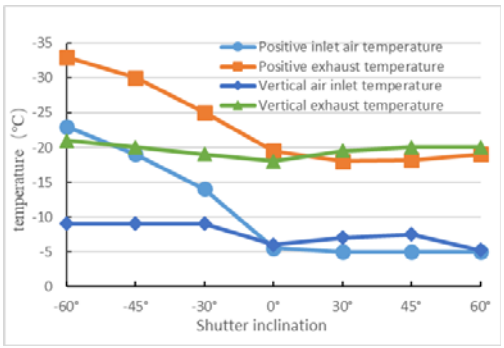


**Fig. 12** broken line diagram of inlet and exhaust air temperature

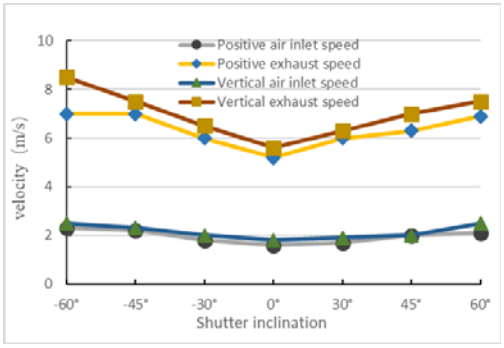


**Fig. 13** broken line diagram of air inlet and exhaust speed

In terms of temperature, the inlet and exhaust temperature when the shutter angle is downward is significantly lower than that when the shutter angle is upward.

When the inlet and outlet air are facing the outdoor wind direction and the inclination angle is -60 °, -30 °, -45 °, the inlet air temperature is still too low, which is not conducive to the normal operation of the outdoor unit.

For the air inlet and exhaust outlets perpendicular to the outdoor wind direction, when the shutter inclination is - 60 °, - 45 ° and - 30 °, although the air inlet and exhaust temperature is higher than that when the air inlet and exhaust outlets are facing the wind direction, the air inlet temperature is still too low, which is not conducive to the normal operation of the outdoor unit.

In terms of speed, there is little difference between the air inlet and exhaust speed when the air inlet and exhaust outlet are perpendicular to the outdoor wind direction and the air inlet and exhaust speed when the air inlet and exhaust outlet are facing the outdoor wind direction.

For the air inlet and outlet facing the outdoor wind direction, when the shutter inclination is 0 °, the air inlet and exhaust speeds are the same as the minimum value. When the inclination angle of the shutter is - 60 °, the air inlet and exhaust speed is the maximum. For the same inclination angle, the inlet and exhaust speeds when the inclination angle is upward are basically the same as those when the inclination angle is downward.

For the air inlet and exhaust outlets perpendicular to the outdoor wind direction, the change trend of air inlet and exhaust speed is basically the same as that of the outdoor wind direction facing the air inlet and exhaust outlet. When the inclination angle of the shutter is ± 60 °,

the air inlet and exhaust speed is too large, which is not conducive to the normal operation of the outdoor unit.

Therefore, when the inclination angle of the louver is 0 °, 30 ° and 45 °, its air inlet and exhaust speed and temperature can meet the normal operation of the outdoor unit.

The following is the temperature cloud diagram when the wind direction outside the room is facing the air inlet and exhaust outlet at x=3m:

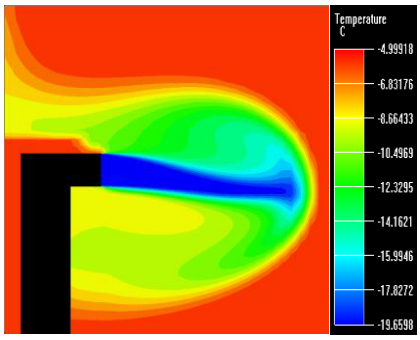


**Fig. 14** α= Temperature nephogram at 0 °

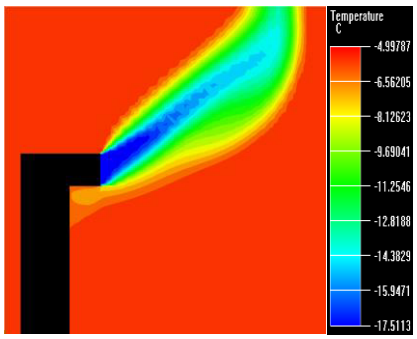


**Fig. 15** α= Temperature nephogram at 30 °

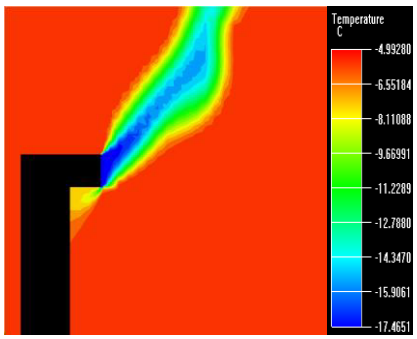


**Fig. 16** α= Temperature nephogram at 45 °

It can be seen from the figure that when the shutter inclination is 0 °, cold air accumulates on the upper part of the air inlet, and the exhaust range is too long. When the inclination angle of the louver is 30 ° and 45 °, the cold air rises in a straight line, reducing the inlet temperature of the upper outdoor unit. Therefore, it is not recommended that the air inlet and exhaust outlet of the outdoor unit face the outdoor wind direction.

The following is the temperature cloud diagram when the outdoor wind direction at x=3m is perpendicular to the air inlet and exhaust outlet:

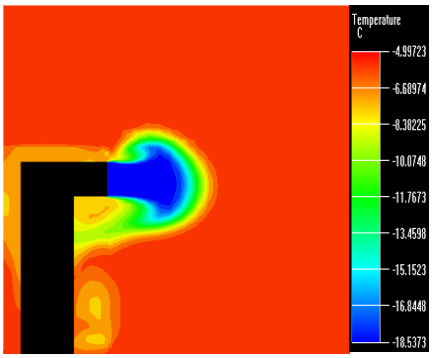


**Fig. 17** α = Temperature nephogram at 0 °

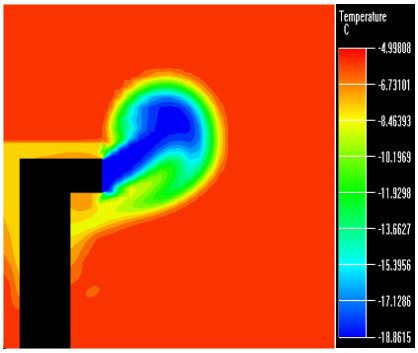


**Fig. 18** α= Temperature nephogram at 30 °

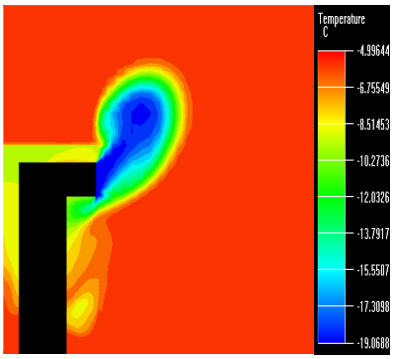


**Fig. 19** α= Temperature nephogram at 45 °

It can be seen from the figure that when the outdoor wind direction is perpendicular to the air inlet and exhaust outlet, the exhaust range is short and will not affect the upper outdoor unit. However, when the shutter inclination is 0 °, outdoor sundries are easy to enter the machine room. When the shutter angle is 45 °, the temperature in the upper part of the machine room is low due to the return of cold air, which is not conducive to the normal operation of the outdoor unit. Therefore, in order to maintain the normal operation of the outdoor unit, it is best to keep the shutter angle at about 30 °.

To sum up, when the outdoor wind speed is 2m / s, it is recommended that the air inlet and exhaust outlet of the outdoor unit should not face the outdoor wind direction as far as possible. At the same time, the inclination angle of the shutter shall be maintained at about 30 °. At this time, the temperature and speed of the air inlet and exhaust outlet can meet the normal operation of the outdoor unit, and will not have an adverse impact on the operation of the upper outdoor unit.

### 4.3 Simulation of outdoor wind speed of 4m/s

The following is a broken line diagram of temperature and speed at x = 3m:

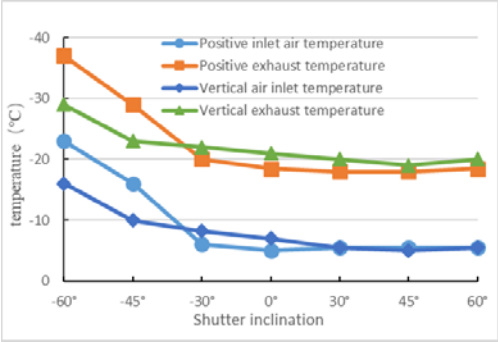


**Fig. 20** broken line diagram of inlet and exhaust air temperature

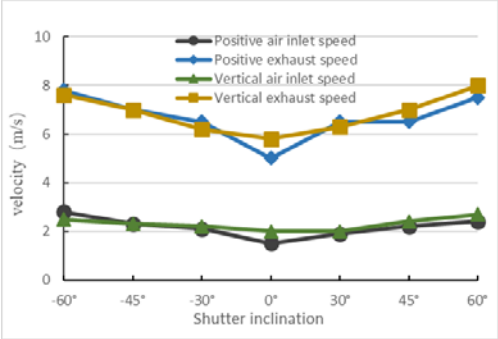


**Fig. 21** broken line diagram of air inlet and exhaust speed

In terms of temperature, when the outdoor wind direction is constant, the inlet and exhaust temperature of the outdoor unit when the shutter opening is upward is higher than that when the shutter opening is downward.

When the air inlet and outlet are facing the outdoor wind direction and the shutter inclination is - 60 ° and - 45 °, the air inlet and exhaust temperature is too low, which is not conducive to the normal operation of the outdoor unit. When the inclination angle of the louver is - 30 ° to 60 °, the inlet and exhaust temperatures remain basically unchanged.

For the air inlet and exhaust outlets perpendicular to the outdoor wind direction, when the shutter inclination is - 45 ° to - 60 °, although the air inlet and exhaust temperature increases compared with the air inlet and exhaust outlets facing the outdoor wind direction, the air inlet and exhaust temperature is still too low, which is not conducive to the normal operation of the outdoor unit.

In terms of speed, when the outdoor wind direction is constant, the inlet and exhaust speed increases with the gradual increase of the inclination angle of the shutter. The orientation of louver opening has little effect on the inlet and exhaust speed.

For the air inlet and exhaust outlets facing the outdoor wind direction, the air inlet and exhaust speed is the minimum when the shutter inclination is 0 °. With the increase of shutter inclination angle, the inlet and exhaust speed increases gradually; When the inclination angle of the shutter is - 60 °, the air inlet and exhaust speed reaches the maximum. Under the same inclination angle, the air inlet and exhaust speeds are basically the same when going up or down.

For the air inlet and exhaust outlets perpendicular to the outdoor wind direction, except that the air inlet and exhaust speed when the shutter inclination is 60 ° is slightly higher than that when the shutter inclination is - 60 °, the change trend is basically consistent with the speed change of the outdoor wind direction facing the air inlet and exhaust outlet.

Therefore, when the inclination angle of the louver is 0 °, ± 30 ° and 45 °, the air inlet and exhaust speed and temperature can meet the normal operation of the outdoor unit regardless of whether the air inlet and exhaust outlet are facing or perpendicular to the outdoor wind direction.

The following is the temperature cloud diagram when the wind direction outside the room is facing the air inlet and exhaust outlet at x = 3m:

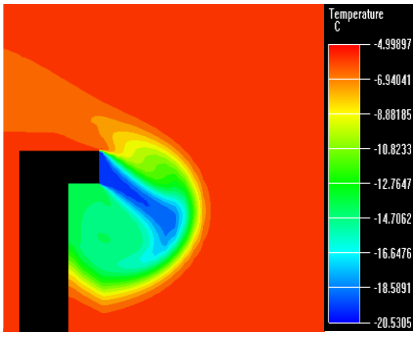


**Fig. 22** α=- Temperature nephogram at 30 °

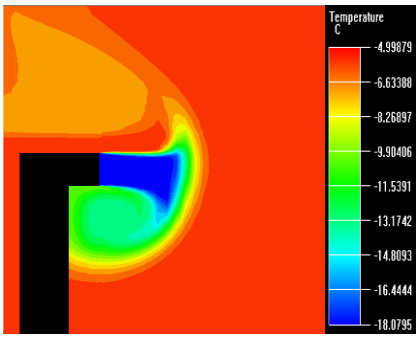


**Fig. 23** α = Temperature nephogram at 0 °

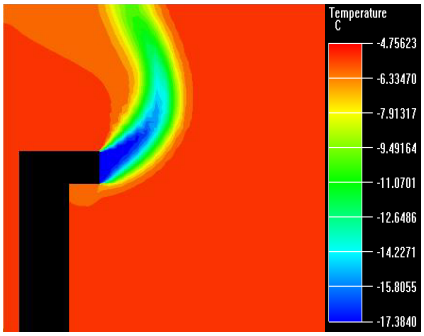


**Fig. 24** α = Temperature nephogram at 30 °

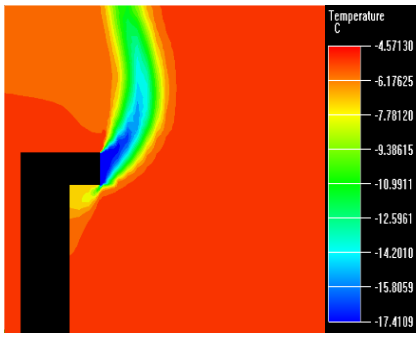


**Fig. 25** α = Temperature nephogram at 45 °

It can be seen from the figure that when the shutter inclination is - 30 ° and 0 °, although the exhaust range is short, a large amount of cold air accumulates on the upper part of the air inlet, which will adversely affect the operation of the outdoor unit. When the inclination angle of the louver is 30 ° and 45 °, the exhaust range is short, and the cold air basically rises in a straight line, which is not conducive to the operation of the upper outdoor unit. Therefore, it is not recommended that the air inlet and exhaust outlet of the outdoor unit face the outdoor wind direction.

The following is the temperature cloud diagram when the outdoor wind direction at x=3m is perpendicular to the air inlet and exhaust outlet:

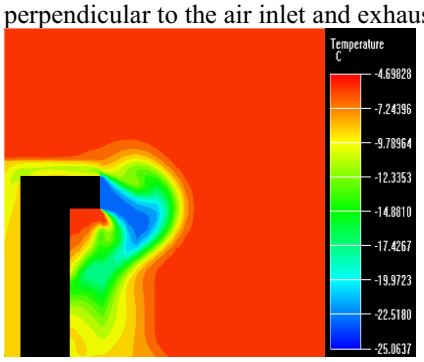


**Fig. 26** α=- Temperature nephogram at 30 °

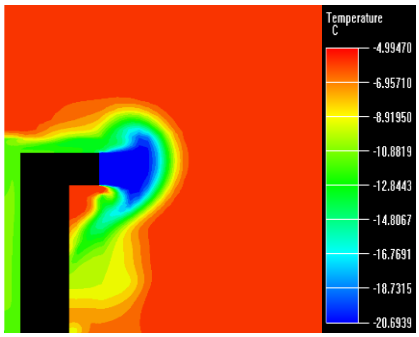


**Fig. 27** α = Temperature nephogram at 0 °

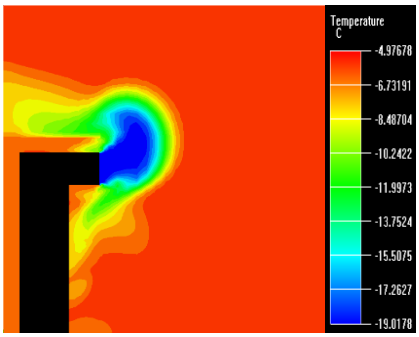


**Fig. 28** α =- Temperature nephogram at 30 °

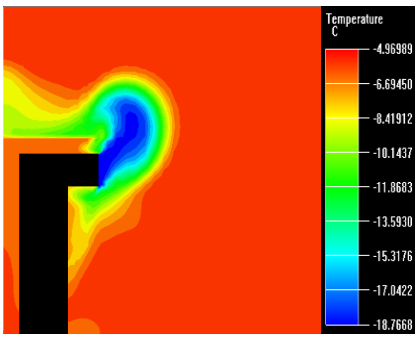


**Fig. 29** α= Temperature nephogram at 45 °

As can be seen from the above figure, the whole exhaust range is short. When the shutter inclination is - 30 ° and 0 °, a large amount of cold air accumulates on the upper part of the air inlet, which has an adverse impact on the operation of the outdoor unit. When the inclination angle of the shutter is 30 ° to 45 °, the rise height of the cold air is low, which will not affect the operation of the upper outdoor unit. Therefore, in order to maintain the normal operation of the outdoor unit, it is recommended that the air inlet and exhaust outlet should avoid facing the wind direction as far as possible, and the best angle of the shutter should be kept at 30 ° to 45 °.

To sum up, when the outdoor wind speed is 4m /s, it is recommended that the air inlet and exhaust outlet of the outdoor unit should not face the outdoor wind direction as far as possible, and the inclination angle of the shutter should be kept between 30 ° and 45 °.

## 5 Conclusion

The temperature and velocity distribution around the outdoor unit of VRV air conditioner with different shutter angles are simulated, compared and analyzed under different wind directions and wind speeds. The main conclusions are as follows:

(1) When the air inlet and outlet are facing the outdoor wind direction, no matter the outdoor wind speed is 2m/s or 4m/s, and the shutter inclination is 0 °, ± 30 °, ± 45 ° and ± 60 °, the air inlet temperature of the outdoor unit itself or the upper outdoor unit will be reduced. For the installation and layout of the outdoor unit of multi split air conditioner in high-rise buildings, the air inlet and outlet should avoid the outdoor wind direction as far as possible.

(2) When there is no wind outside or the wind speed is 4m/s, the inclination angle of the shutter shall be kept between 30 ° and 45 °; When the outdoor wind speed is 2m /s, the inclination angle of the shutter shall be maintained at about 30 °.

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