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ARTICLE

Best Determined Position of Vents Based on Jet Cooling Model

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ABSTRACT

In some data centers, cold air is required to act on the cabinet to achieve cooling requirements, and the mixing of cold air and hot air reduces the utilization efficiency of cold air. In order to solve this problem, a jet cooling model is established to solve the optimal position of the outlet through the movement of cold air.

1. Introduction

The high-intensitive data processing of the data center is accompanied by a great quantity heat set free.For the sake of pledge the normal operation of the computer, the data center provides cold air in the open computer cabinet.Whereas,the combination of hot and cold air causes vast cold air to stay in the gap corridors and cracks of the cabinet, the utilization rate of cold air is very low, augment energy loss and resource squander.

2. Problem Analysis and Preparation

2.1 Dynamic Analysis of Cold Air and Cabinet System

In order to solve the problem that the temperature of the data center room lacks the data of airflow movement under the action of airflow, a central hypothermia cooling model is established to simulate the temperature change of the cabinet on the premise that the cold air directly acts on the cabinet and drives the hot air[1]. It reflects the direct utilization of cold air, As shown in

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Figure 1.

*Analyze the now available size, shape and thermal power of the computer equipment in the data center cabinet, and determine the size of the cabinet type.

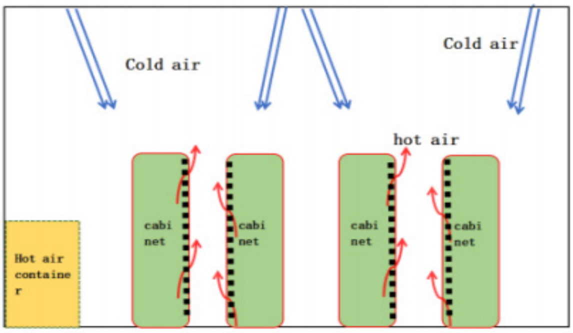

Figure 1. Schematic diagram of hot and cold air flow

2.2 Formulation of the Best Strategy

Four rows of cabinets are required as mentioned in the title.According to code for design of data center (GB 500174-2017), the specification of cabinet is 6000mm in and 600mm in width length. On the basis of different models, the cabinet is h = 42U, 36U and 24u, and ceiling height.

H= 3.2m, In order to maximize the use of cold air and reduce the loss of cold air, the direct contact between cold air and cabinet shall be increased as much as possible, and the cold air shall not be directly blown into the corridor or gap. Therefore, we set the position of the air outlet[2]. The ventilation angle requires the cold air to reach the top and bottom edge of the cabinet, so that the cold air drives the hot air flow and contacts the maximum area of the cabinet. For solving exact location the exit, the coordinate system is established with the length and width of the ceiling as the x-axis and y-axis. Then, on the basis of the geometric relationship of the room, we can calculated the position from the cabinet to the air outlet. This is the horizontal distance of the exit from the edge of the cabinet. The length of the room is determined by the distance between the four cabinets and the distance from the air outlet. To ensure that the maximum area of cold air acts on the cabinet, on basis of the actual situation, each branch pipe needs several outlets. In this way, the width of the room is determined, and the exact coordinates of the exit are finally given.

3. Establish Jet cooling Model

3.1 Hypothesis

(1) hypothesis leave out the effect of humidity of the air,water coolant,which on the internal system of air conditioning.

(2) assuming that the main computer is normal, that emit heat. And no fault heating.

(3) presume outdoor temperature doesn't affect indoor,that indoor temperature.

(4) suppose gas flow ,that the only effect factors is its own nature. have no connection with liquid level and solid wall.

3.2 Energy Analysis of Air and Cabinet

3.2.1 Conservation of Momentum of Cold Air

The cold air is entered into the motor room by means of the shower nozzle, diffusion in the motor room.Without the effect of liquid level and solid wall, free flow, forming free jet. Under this precondition, cold air knock against with ambient air, swop momentum, delivery some momentum to the swop air, and promote then to diffuse. It goes on and on, jet cross section is always increasing, the gaseous fluid moving around is escalation. So as to achieve the effect of hypothermia. Although, in the process, cold air loses its energy motion. Cold air and ambient air, the sun of momentum is a constant value. It can be represented by the following formula[3] .

$$q \times v = cons\tan t \tag{1}$$

3.2.2 Regular of Velocity Decay

Free jet effect of cold air, and only it happened. In turn, change the blast of cold air. Focus on center speed, diminishing up and down boundary layer. Also, ambient air acquisition energy, enlargement flow rate, has been increasing. In case fix x-axis orientation, which direction of cold air expulsion. So under the premise of free jet, the blast of cold air is from center to both sides, little by little lessen. Among them, center blast attenuation has a pattern follow. As shown in figure 2.

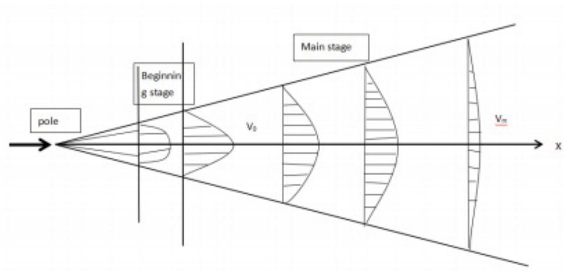

Figure 2. Free jet diagram

In the light of boundary layer theorem, law of conser-

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vation, you can get, when free jet occurs, the pattern of cold air center blast. As shown in Figure 3 and formula (2).

$$v_m = \frac{0.96 v_0 r_0}{ay + 0.29 r_0} \tag{2}$$

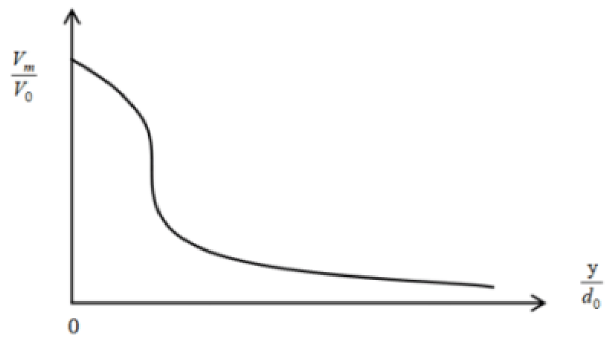

Figure 3. Diagram of center velocity curve of free jet

3.2.3 Air Solid Heat Conduction

The heat transfer between air and cabinet is convection heat transfer, and Fourier's law shows that all problems related to heat conduction can be solved by the following formula.

$$q = q_x j + q_y j + q_z k \tag{3}$$

According to Fourier's law and differential equation[4] of heat conduction, if the temperature of the medium around the object and the convective heat transfer coefficient between the object and the boundary are given, the expressions are as follows.

$$\lambda = \frac{-q \cdot \delta n}{\delta t \cdot n} = \frac{-a \Delta t \cdot an}{\delta t} \cdot K \tag{4}$$

That is, the temperature of the object medium and the surface thermal conductivity on the boundary surface are given, and the heat flux of convective heat transfer can be calculated.

3.3 The Foundation of Model

3.3.1 Model Basic Parameters

Basic parameters of the model: First, take ordinary cabinet as an example, which6.0m long, 0.6m wide, 42U high (1.867m). In data center, there are four rows of cabinets and air conditioning system. Combined with *Data Center Design Specification*, (GB 50174-2017). We are set to the length, width, and height of the room, L = 12.4m, W = 8.0m and H = 3.2m. At this point, distance between cabinet top and ceiling, H=1.333 meters, as shown in Figure 4.

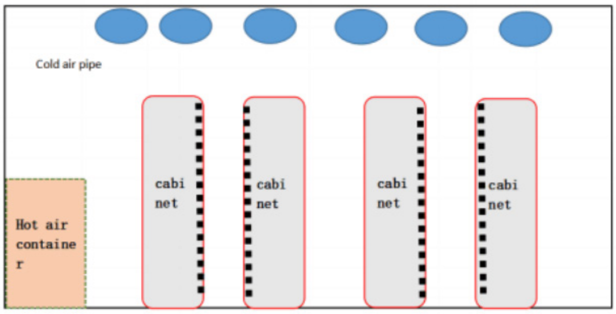

Figure 4. Plane elevation of cabinet room

3.3.2 Model Establishment

Model establishment: According to the flow law of jet, as shown in Figure 5, velocity of jet center in the initial section, equal to the initial speed, the velocity distribution curve of jet is changed. On the dimensionless coordinate system, draw velocity distribution curve. The empirical formula of central velocity is obtained[5] , that's formula (5).

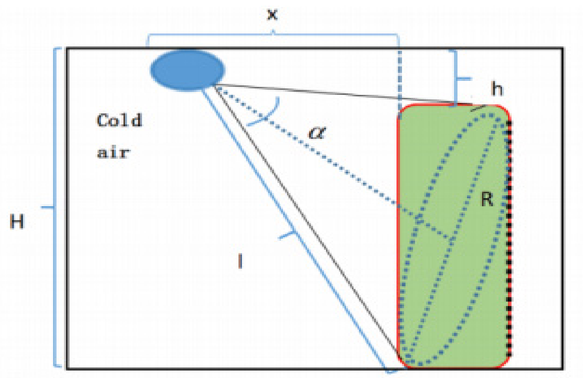

Figure 5. Diagram of the area of cold air acting on the cabinet (Mainview)

$$v = v_m [1 - (\frac{y}{R})^{\frac{3}{2}}]^2 \tag{5}$$

The injected fluid is spatially conical. As shown in Figure 5、6, when the cold air flow is brought into contact with the cabinet area when it is shot on the cabinet, the diagonal diagonal of the cabinet can be made to be the diameter of the jet cross section.

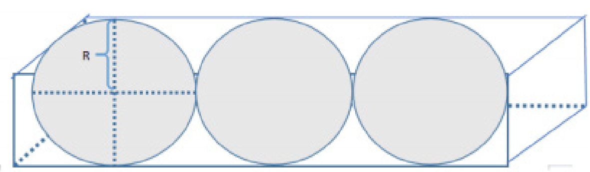

Figure 6. Diagram of the area of cold air acting on the cabinet (left view)

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$$\begin{cases} v = v_m[1-(\frac{y}{R})^{\frac{3}{2}}]^2 \\ \lambda = \frac{-q\cdot\delta n}{\delta t\cdot n} = \frac{-a\Delta t\cdot an}{\delta t}\cdot K \\ v_{average} = \frac{(\int_0^y v_m[1-(\frac{y}{R})^{\frac{3}{2}}]^2\cdot 2\Pi y dy)}{\Pi R^2} \\ v_{average} = Kv_m = 0.257v_m \end{cases} \quad (6)$$

3.3.3 Conclusion

As can be seen from the above formula, When the speed v = 0, r = 1.9m, That is y=1.9m. It can be obtained by Fourier law and jet transfer formula. At the same time, According to the geometric relationship shown in (Figure 6), and the following four formulas, find out H = 1.333m, x = 2.333m.

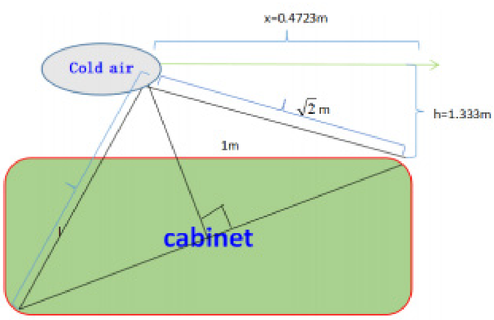

Figure 7. Schematic diagram of the relationship between x and h

As shown in figure 8, the length of the room is 8.4 m, because the cabinet is 6 m long, so to arrange a three exports, the cabinet to ensure sufficient to cool cabinet, can be designed as the width of the room is 8 m,(1.1277 m, 2 m) (1.1277 m, 4 m) (1.1277 m, 6 m), the same can be concluded that the coordinates of other nozzle respectively (3.0723 m, 2 m), (3.0723 m, 4 m) (3.0723 m, 6 m) (5.3277 m, 2 m) (5.3277 m, 4 m) (5.3277 m, 6 m) (7.2723 m, 2m) (7.2723m, 4m) (7.2723m, 6m).

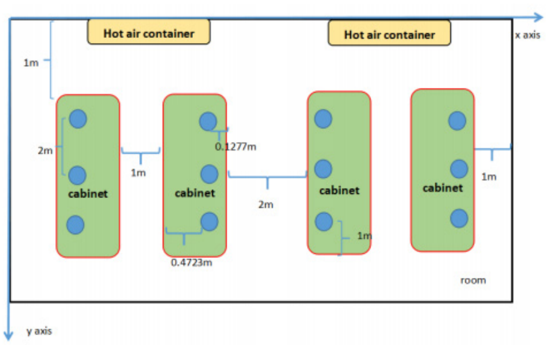

Figure 8. Large cabinet room layout top view

3.3.4 Analyze the Other Two Cabinet Types

The 36U cabinet(6m * 0.6m * 1.6m), is different in height, and the position of the exit should be re-established, taking v' = 0, then R' = 0.85m, then y' = 0.85m, h' = 1.6m > 1.3212m.Therefore, its best position is below the ceiling, and the length of the two edges of the airflow is taken. If the mixing degree of cold air and hot air increases, which reduces the utilization efficiency of cold air. If the contact area, between the cold[6].

$$\sum_{k=1}^{n} a_k^2 \sum_{k=1}^{n} b_k^2 \geq (\sum_{k=1}^{n} a_k b_k)^2$$

Deduced only at the time, established the equal sign, so can a bit of along to the ceiling, as shown in figure 9 the best position for export level, can be calculated according to the geometrical relationship, because in the process of solving large cabinets to determine[7] the room L = 8.4 m, W = 8 m, so not reality, so as shown in figure 10, set the leftmost export at the edge of the room, in the middle of the exports and the first type is the same. Then the export coordinates of the second model are respectively[8] (0, 2m) (0, 4m) (0, 6m) (3.0723m, 2m) (3.0723m, 4m)(3.0723m, 6m) (5.3277m, 2m) (5.3277m, 4m) (5.3277m, 2m) (8.4m, 2m) (8.4m, 4m) (8.4m, 6m).

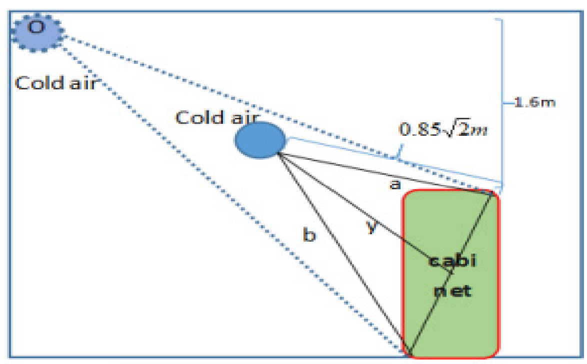

Figure 9. Schematic diagram of the area of cold air acting on a medium cabinet

Analyze the third kind of cabinet (6m * 0.6m * 1.068m), at this time, then, can be found, so the third kind of cabinet and the first kind of cabinet situation is the same, can be calculated according to the geometric relationship. Since the room size is D=1.7m, R=0.85m, the required coordinates should be the same as the design of the second cabinet outlet, the coordinates are respectively (0, 2m) (0, 4m)(0,6m) (3.0723m, 2m) (3.0723m, 4m) (3.0723m, 6m) (5.3277m, 2m) (5.3277m, 4m) (5.3277m, 6m)(8.4m, 2m) (8.4m, 4m) (8.4m, 6m).

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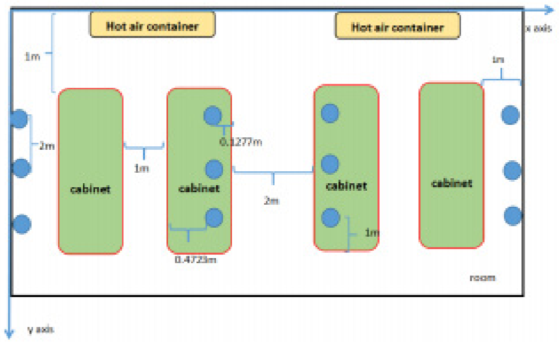

Figure 10. Top view of medium cabinet room layout

4. Conclusions

4.1 Distribution of Ventilation Outlet of Large Cabinet 42U

(1) The first column: (1.1277m, 2m) (1.1277m, 4m) (1.1277m, 6m)

(2) The second column: (3.0723m, 2m) (3.0723m, 4m) (3.0723m, 6m)

(3) The third column: (5.3277m, 2m) (5.3277m, 4m) (5.3277m, 6m)

(4) The fourth column: (7.2723m, 2m) (7.2723m, 4m) (7.2723m, 6m)

4.2 Distribution of 36U Ventilation Outlet of Medium Cabinet

(1) The first column: (0, 2m) (0, 4m) (0, 6m)

(2) The second column: (3.0723m, 2m) (3.0723m, 4m) (3.0723m, 6m)

(3) The third column: (5.3277m, 2m) (5.3277m, 4m) (5.3277m, 6m)

(4) The fourth column: (8.4m, 2m) (8.4m, 4m) (8.4m, 6m)

4.3 Small Cabinet 24U Ventilation Outlet Distribution

(1) The first column: (0, 2m) (0, 4m) (0, 6m)

(2) The second column: (3.0723m, 2m) (3.0723m, 4m) (3.0723m, 6m)

(3) The third column: (5.3277m, 2m) (5.3277m, 4m) (5.3277m, 6m)

(4) The fourth column: (8.4m, 2m) (8.4m, 4m) (8.4m, 6m)

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