

Energy-conservation and Optimization Study of SPF Laboratory Animal Room Air System in Air Conditioning

— Discussion on the Best Air Change Rates

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Abstract: This paper simulated and analyzed the concrete project of laboratory animal room by CFD software, studies the best air change rate in laboratory room, and analyzed the energy-conservation potential of the air system of air conditioning. the studies indicated the best air changes of laboratory animal room is 14 times/h which take the air distribution of supplying in ceiling diffuser and exhausting air in underside. compare air change rates of 20 times/h which taken in old system, The 30% energy of the air system of the air conditioning can be saved.

Key words: Energy-conservation, Laboratory Animal Room, the Best Air Change Rates

1. FOREWORD

To the comfort air conditioning system, the clean air conditioning system of SPF laboratory animal room have many difference, such as air conditioning system mode, basic circuit of air handling, the control of indoor positive pressure and air distribution, another important difference is the air change rates of clean air conditioning is much big than comfort air conditioning. The air change rates of the laboratory animal room have a coupling relation among indoor contamination distribution and conservation of energy.

A best coupling point was exist among the air change rates, indoor contamination distribution and conservation of energy, based on this point, and analyzed indoor contamination distribution of laboratory animal room, found the corresponding rule, then can draw the best air change rates. In typical air distribution, ceiling diffuser are installed for supplying air, and return intakes are designed in the corners for exhausted air, in this kind of air distribution, putting animal's cage along width direction is more rational than putting along length direction^[1], now can study the relation among the air change rate, energy conservation and cleanliness.

2. DISCUSS ON AIR CHANGE RATE

The physical model and mathematics model of this simulation can refer to reference 1, put the animal's cage along width direction. All the parameter did not changed except the air change rates in this research. The air change rates changed 2 times/h to 40 by change the supply air outlet velocity.

Eight data points were establish base on the contamination distribution in different air change rates.

See as fig.1, the coordinate of data points are: data point 1 is (1.625, 3.110, 1.025), 2 is (2.025, 3.110, 1.025), 3 is (1.650, 2.500, 1.025), 4 is (2.025, 2.500, 1.025), 5 is (1.650, 0.500, 1.165), 6 is (1.650, 2.000, 1.165), return air intake is (0.000, 0.300, 0.125), 8 is (1.650, 3.750, 1.165). Point 1 is on the right of the middle cage of the second row, the distance from the cages is 10cm, the corresponding point is point 3, it is on the left of the same cage, the distance from the cages is 0cm, Point 2 is on the right of the second cage of the second row, the distance from the cages is 10cm, the corresponding point is point 4, it is on the left of the same cage, the distance from the cages is 0cm. Point 5 is in the middle of the cage and wall. Point 6 is in the middle of the supply air outlet, ground and two cages; point 7 is in the middle of return air intake; point 8 is in the middle of two cages.

Base on the particular numerical value of the data point, some curve can be drawn by excel. The following figures are the curves of the data points.

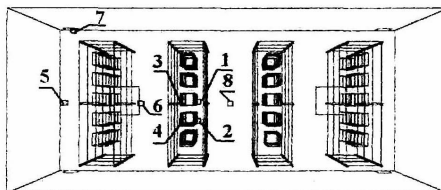


Figure 1: the particular position of the data point
1 - point 1 2 - point 2 3 - point 3 4 - point 4
5 - point 5 6 - point 6 7 - return air intake
8 - point 8

2.1 confirm the high-point of the air change rates

The red point in these figures mean that after this point, the curves become flatness, it imply means after passing through this point, increase the air change rate is vainness to improve the cleanness, so for this special air distribution, this inflexion is the high-point for it, the corresponding air change rate is the high-point air change rate for this kind of air distribution.

Analyzed the figures above, for point 1, the contamination distribution increase with the air change rates, because with the increasing of the air change rate, the indoor turbulent fluctuation has been strengthened, the contamination from the animals has been strengthened with the diffusion of the air current, it is more favorable to the diffusion of the indoor contamination. When the air change rates reached 24 times/h, there are certain fluctuations in the diffusion of the contamination, but the range of rising has been already relatively small, so can confirm that 24 times/h is the high-point of the air change rates of point 1. in the same way, 20 times/h is the high-point of the air change rates of point 2; 20 times/h is the high-point of the air change rates of point 3; 18 times/h is the high-point of the air change rates of point 4; 12 times/h is the high-point of the air change rates of point 5; 12 times/h is the high-point of the air change rates of point 6, 12 times/h is the high-point of the air change rates of return air intake; 10 times/h is of point 8.

Table 1 the high-point of the air change rates of data points

Data point	1	2	3	4	5	6	Return air intake	8
Air change rate	24	20	20	18	12	12	12	10

The high-point of the air change rates of the different data point in this air distribution can be learn from chart 1, base on its position in the laboratory animal room, the effect for animals can be judged. The contamination concentration of return air intake is stand for the average concentration in the room, if take the average concentration as the evaluation criterion, the air change rate of this air distribution is 12 times/h, increase the air change rates have nothing for the indoor cleanness. Data point 1 and 2 are the most unfavorably point in all those data points, so need the most air change rates. The position of data point 1 and 2 are near the animal, the concentration influence is greater, to ensure the quantity of animals, take these air change rates as the high-point of the air change rates of this air distribution, it is 24 times/h.

2.2 Discuss laboratory animal room air change rate by taking the ammonia as contamination guideline

In preceding analysis, the high-point of the air change rates of this air distribution has been confirmed, it can provide certain reference for normal formulation, but for actual project, confirm the optimization air change rate, will offer a best reference for the design and operation.

As to the general ventilation that contamination

distributes in the room, the Calculate formula of air change rate as below:

$$n = \frac{K_s M}{V(c - c_0)} \quad (1)$$

Among them, n is air change rate; M is contamination distribution concentration; V is the room volume; c is indoor contamination average concentration, c_0 is the contamination concentration in the supply air, for the fresh air, it is 0; K_s is safety coefficient, according to the actual conditions, it is 3~10.

To confirm the best air change rate, need to know M , V , c , K_s . In the check and accept standard of the laboratory animal room confirms the laboratory animal room, only a ammonia concentration standard, so took the ammonia as contamination standard, but it is a value most difficult to confirm, there are no reference in this respect at home, can not searches correlative reference in VIP information and CNKI, only search some relevant information in US National Library of Medicine^{[47]~[50]}, but has not provided the ammonia distribution amount of the animal directly, just offer some information in the following in the experiment, in the ventilating cage of 230mm×450mm×165mm, have raised two little mice, the supply air amount is 56L/min, the ammonia concentration kept 0.3ppm in the cage at last, so the ammonia concentration is 0.7764kg/m³, the ammonia concentration distributed by a mice is: cage volume:

$$V_1 = 0.23 \times 0.45 \times 0.165 = 0.017078 \text{m}^3 \quad (2)$$

ammonia concentration:

$$c_1 = 0.3 \times 10^{-6} \times 0.7764 \times 10^3 \times 10^3 = 0.2329 \text{mg/m}^3 \quad (3)$$

distributed by a mice:

$$M_1 = \frac{1}{2} L \times c_1 \\ = 0.2329 \times 56 \times 10^{-3} / 60 / 2 = 0.0001 \text{mg/s} \quad (4)$$

the room been simulated have 4 rows of cages, two or three animals can be raised in a cage generally, so 70 animals can be raise in a row cages. The amount of mouse raised in whole room is 280, can calculate the whole indoor distributing amount of contamination is 0.028mg/s. According to the standard above, because of non-uniformity of indoor air distribution in general ventilation room, the calculated air change rate must be multiplied by a safety coefficient, to ensure the safety of animals, fetched the greatest safety coefficient here, Calculate the average contamination concentration under different air change rates in laboratory animal room.

According to the formula (1), can draw the rule between indoor contamination distributions to air change rates:

$$c = c_0 + \frac{KM}{nV} \quad (5)$$

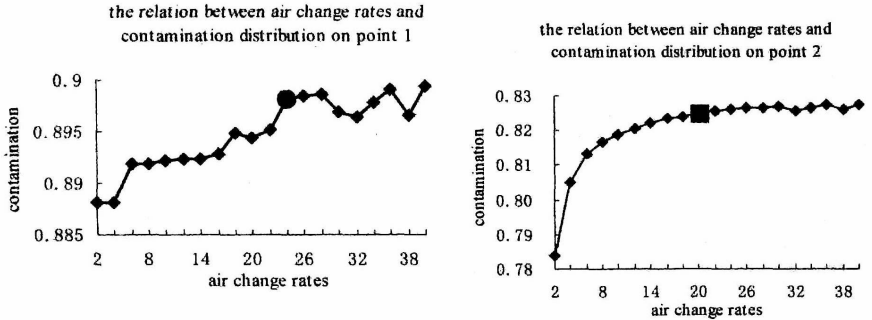


Figure 2: the relation between air change rates and contamination distribution on point 1 and 2

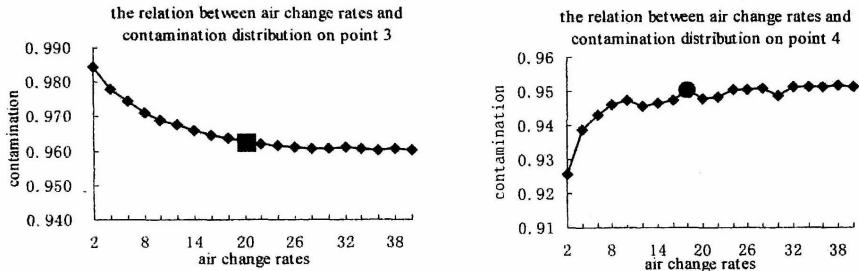


Figure 3: the relation between air change rates and contamination distribution on point 3 and 4

For the clean air conditioning, the contamination in the supply air is 0, so the above formula can change to:

$$c = \frac{KM}{nV} \quad (6)$$

Take K , M , V into above formula, the relation between air change rate and indoor contamination distribution can be drawn. In nation standard, the upper limit of ammonia concentration is $14\text{mg}/\text{m}^3$, can see in the figures, even the air change rate is 2 times/h, the indoor ammonia concentration will not exceed $1.2\text{mg}/\text{m}^3$, if increase the air change rate, the indoor ammonia concentration will be more smaller.

For the best air change rate, it will less than the high-point of the air change rate, for the Fig.1 to Fig.5, when check the best air change rate, the reference point is not always the point when the curve become flatness, if in certain air change rate, the indoor contamination concentration under the nation standard, can take this air change rate as the suitable one, and need not increase the air change rate. From the analysis above, the ammonia concentration in laboratory animal room did not exceed the standard when the air change rate is 2 times/h, it is to say, as long as the air change rate is more than 2 times/h, it is the air change rate can be accepted one, combined the high-point air change rate of this air distribution in preceding analysis, the contamination concentration of

return air intake is stand for the average concentration of laboratory animal room, the high-point air change rate of this point is 12 times/h, and it is minimal one in all air change rate, the standard regulated the air change rate range of the SPF laboratory animal room is 10~20times/h. Synthesized all fact above, take the 12 times/h as the best air change rate.

3. CONSERVATION-ENERGY ANALYSIS

In preceding analysis, a best coupling point was exist among the air change rates, indoor contamination distribution and conservation of energy, the relation between air change rate and cleanness was analysis in preceding, thus drawn a suitable air change rate. The relation between conservation-energy and air change rate will be calculated detailed in this section. To predigest the calculation, only the fresh air load will be calculated, the wall load, light load and equipment load will not be calculated.

There are five laboratories in Nanhua university laboratory animal room, and the clean corridor, filth corridor and quarantine room also needs general ventilation. General volume is:

$$V=455.2\text{m}^3 \quad (7)$$

So increase a air change rate need add air volume is:

$$V' = 455.2\text{m}^3/\text{h} = 0.1264\text{m}^3/\text{s} \quad (8)$$

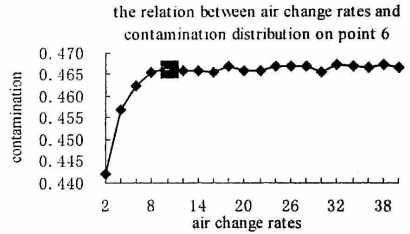
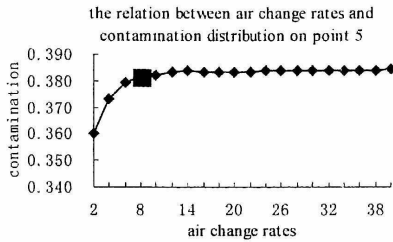


Figure 4: the relation between air change rates and contamination distribution on point 5 and 6

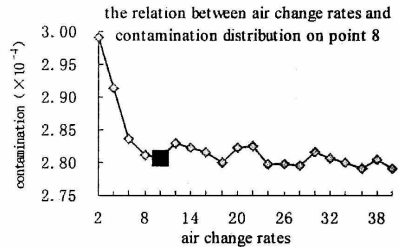
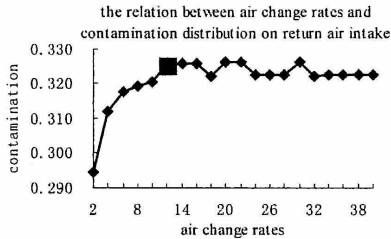


Figure 5 : the relation between air change rates and contamination distribution on return air intake and point 8

The summer meteorological parameter outdoors of Hengyang can be checked as follow: $t=36^{\circ}\text{C}$, $t_w=27.4^{\circ}\text{C}$, the enthalpy in this situation can be drawn in the psychrometric chart: $i_w=86.84\text{kJ/kg}$, the indoor design variables as follow: $t=25^{\circ}\text{C}$, $\phi=60\%$, the enthalpy is: $i_w=55.48\text{kJ/kg}$, so increase an air change rate will consume energy:

$$\begin{aligned} Q &= (i_w - i_N) V' \rho \\ &= (86.84 - 55.48) \times 0.1264 \times 1.2 \\ &= 4.73 \text{ kJ/s} = 4.73 \text{ kW} \end{aligned} \quad (9)$$

can learn from the above calculation, increased an air change rate in this laboratory animal room in summer, collectivity energy increased 4.73kW.

The winter meteorological parameter outdoors of Hengyang can be checked as follow: $t=-2^{\circ}\text{C}$, $\phi=80\%$, he enthalpy in this situation can be drawn in the psychrometric chart: $i_w=4.34\text{kJ/kg}$, the indoor design variables as follow: $t=20^{\circ}\text{C}$, $\phi=65\%$, the enthalpy is: $i_w=44.18\text{kJ/kg}$ so increase an air change rate will consume energy:

$$\begin{aligned} Q &= (i_w - i_N) V' \rho \\ &= 6.04 \text{ kJ/s} = 6.04 \text{ kW} \end{aligned} \quad (10)$$

can learn from the above calculation, increased an air change rate in this laboratory animal room in summer, collectivity energy increased 6.04kW.

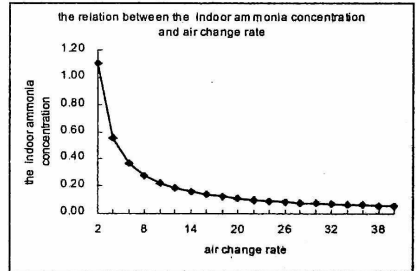


Figure6: the relation between indoor ammonia concentration and air change rates

The above calculated data are only the are only the cold and hot load of fresh air, if increase the air change rate, unavoidable need to increase the fan load, The air conditioner of high-load is more expensive than the small load one. Increase the operation expenses and first cost at the same time, so seeking the optimized air change rate has very real meanings. The building area of Nanhua university SPF laboratory animal room is relative small, for the large area laboratory animal room, the effect of the energy-conservation will be more obvious.

Through the Comparison above, consider such factor as the cleanliness and energy-conservation etc. synthetically, the air change rates of 12 times/h is the suitable one.

The design air change rate of Nanhua university SPF laboratory animal room is 18 times/h, the supply air is $8193.6\text{m}^3/\text{h}$, if the supply air change rate is 12

times/h, the best supply air amount is 5462.4m³/h, the energy-conservation rate of ventilation system is:

$$\eta = \frac{8193.6 - 5462.4}{8193.6} = 33.3 \% \quad (11)$$

4. CONCLUSION

The air distribution of this simulation is ceiling diffuser are installed for supplying air and return intakes are designed in the corners, for the other kind of the air distribution did not detailed study yet, the study will be done the future work.

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