An Experimental Investigation on Indoor Air Pressure Performance of Multi-compartment Pharmacy Cleanroom under Local Fume Hood Operating Scenario

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Abstract. The control of indoor air pressure is very important in cleanroom operation, because of its sensitiveness of the risks from contaminants dispersion. Especially in pharmaceutical cleanrooms, since there always exist multiple compartments, the parametric stability of indoor air pressure is the key-point of operation control. When a fume hood in cleanroom running, the exhaust air volume changes greatly and then cause indoor pressure oscillating. Meanwhile, this scenario of fume hood running is often occurred because of manufacturing process need. However, the performance pattern of pressure is not clear when fume hood switches on or off. Therefore, the control strategy might be inefficient and even invalid. In this paper, the performance of indoor air pressure of multi-compartment cleanrooms under fume hood operating scenario is measured and analysed by experimental investigation method. The works of this paper might help understanding the performance of pressure variation in cleanrooms when disturbances occur and change. And the conclusions of this paper could be references for the design and operation strategies of multi-compartment cleanrooms.

1 Introduction

In recent years, a large number of pharmaceutical plant buildings have appeared all over the world. In order to ensure the safety and quality of manufacturing, the indoor environment of pharmaceutical workshop has to follow very strict standards, such as Good Manufacturing Practice (GMP) standard [1]. Generally, the control of indoor air pressure is very important in cleanroom operation, because of its sensitiveness of the risks from contaminants dispersion. In pharmaceutical cleanrooms, due to the needs of manufacture process, there always have multiple compartments, which is not a large single space like electronic clean workshop. Because the coupling relationship between the pressure fluctuations in each compartment, it is difficult to keep indoor air pressure steadily of each compartment with the same air-conditioning system [2]. If the pressure gradient would not meet the requirements or even reverses, it would bring risks to manufacture. Therefore, the parametric stability of indoor air pressure is very important and is the key-point of operation control.

There are several kinds of disturbances could influence the undulation of indoor pressure in cleanroom, such as door's open-and-close, change of supply or exhaust air volume [3]. The door open-and-close caused by personnel access, or the change of air supply volume caused by the switching of different manufacturing scenarios have already researched by some scholars [4-7]. However, there are few studies on the performances of pressure variation caused by local exhaust fume hood, which occurs more often in pharmaceutical factories. Because pharmaceutical factories are mostly consisted by small compartments, local exhaust air has a greater impact on the indoor pressure of clean room. When a fume hood in cleanroom switches on, the exhaust air volume changes greatly and then causes indoor pressure oscillating. Meanwhile, this scenario of fume hood running often occurred because of manufacturing process need.

In order to keep pressure steady, the control strategies are employed during cleanroom operation period, such as the common-used residual air volume control. However, the performance pattern of pressure is not clear when fume hood switches on or off. Therefore, the control strategy might be inefficient and even invalid.

In this paper, the performance of indoor air pressure of multi-compartment cleanrooms under fume hood operating scenario is measured and analysed by an experimental investigation. Based on results analysis, the performance of pressure variation under fume hood operating scenario is addressed briefly. The works of this paper might help controlling indoor pressure with appropriate control strategy in cleanrooms when disturbances occur or change.

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2 Method

2.1 Description of experiment

The experiment was conducted in the clean environmental laboratory of Beijing Union University. The experiment platform includes test chamber, air handling unit and the corresponding control-monitoring system. The test chamber has 5 compartments with a total clean area of 32 m2, including one 4 m × 4 m large room (Room E); four small rooms of 2 m ×2 m (Room A-D), the indoor clear height is about 3.1 m. The cleanliness grade of the chamber can be grade B (Fig. 1).

The maximum air supply volume of the air handling unit is 5000 m^3/h, and the motor frequency converter is used to control the air volume. All of the supply air and return air of each compartment can be adjusted by variable air volume damper. The maximum air supply volume of small compartment (Room A-D) is 650 m3/h, and of large compartment (Room E) is 1300 m^3/h. The air supply outlets are all equipped with H13 high efficiency filter. A local independent exhaust fume hood is set in Room E to simulate the processing scenario of pharmaceutical workshop. The maximum exhaust air volume of fume hood is 1200 m^3/h, where the volume can be adjusted by motor frequency converter. The exhaust Fume hood is located in Room E, which is shown as Figure 1.

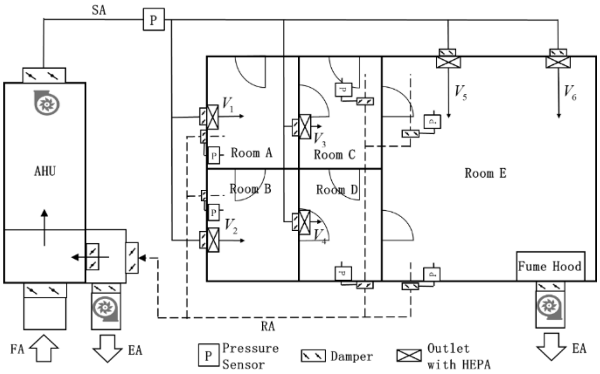

Fig. 1. Diagrammatic map of the experiment platform

2.2 Experiment scenarios

In order to reveal the real manufacturing environment of pharmaceutical plant, Room A and B are set as buffer rooms, C and D are airlocks, and E is the main cleaning room. Set Room E as the highest cleanliness level. Under the initial case (case0), the air conditioning system operates but the exhaust fume hood does not, the pressure and ventilation rate setting values are shown in Table 1.

The purpose of this experiment, is to investigate the influence of local fume hood on the pressure fluctuation of each compartment under different exhaust air volume. 6 cases of exhaust air volume are designed in this experiment, which can be set by controlling the motor frequency converter of the fume hood. The exhaust air volume and corresponding motor frequency of all cases are shown as Table 2.

Table 1. Initial values of indoor pressures (Case 0).

	Pressure (Pa)	Air Change Rate (h^{-1})
Room A	10	20
Room B	10	20
Room C	20	20
Room D	15	20
Room E	40	30

Table 2. Exhaust air volume and corresponding motor frequency of experiments.

	Exhaust air volume (m^3/h)	Motor frequency (Hz)
Case 1	1200	50
Case 2	1100	48
Case 3	1000	46
Case 4	900	44
Case 5	750	42
Case 6	600	40

3 Results

With air conditioning system, maintain the indoor pressures to the initial values (Case 0). Then switch on the fume hood to adjust to the frequencies of Case 1-6, and keep running the fume hood till steady state of indoor pressures, witch duration is about 8 minutes. The fluctuate patterns of indoor air pressure of each compartment are shown as Fig.2-7.

When the exhaust air volume of fume hood is 1200 m^3/h (case 1), shown as Fig.2, the pressure of Room E instantly decreases from about 40 Pa to less than 20 Pa. And then decreases to about 3 Pa in about 1 minute and to about zero in about 100 minutes. The pressure of adjacent Room C rapidly decreases from about 20 Pa to about 15 Pa. Another adjacent room D decreases from about 12 Pa to 5 Pa, and then gradually to about zero. The pressure of Room A decreases to a lesser extent, and Room B gradually decreases to 0 Pa.

It can be seen that opening the fume hood can impact at different degrees on the pressure of each compartment at the same time. The Room E, where the fume hood is located, has the greatest impact. The impacts on adjacent compartments (Room C and D) are great as well, which cause pressure reversal to the Room E. With the decrease of the exhaust air volume of fume hood, the influence on each compartment decreases (case 2-5), which are shown as Fig.3-6. When the exhaust air volume is 600 m^3/h (case 6), the pressure of the Room E reduced to about 10 Pa, the reduction range is narrowed, and the pressure reduction degree of other rooms shows the similar performance (Fig.7). When the exhaust fume hood stops, the pressure in each room rises rapidly. With the exhaust air volumes of most cases, the pressure recovery in Room E takes about 1 minute.

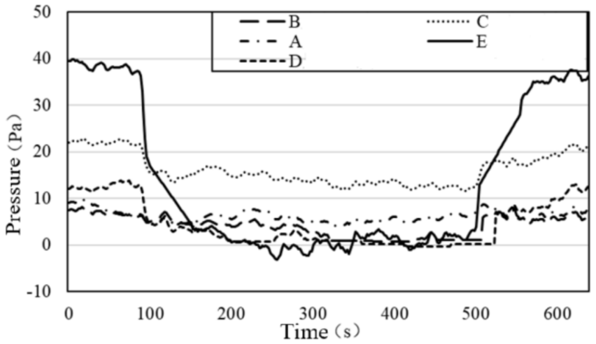

Fig. 2. Indoor air pressures of Case 1.

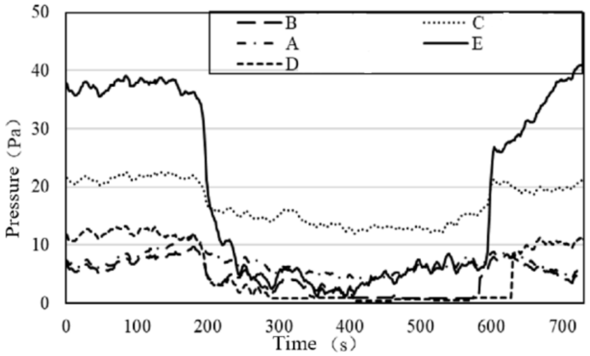

Fig. 3. Indoor air pressures of Case 2.

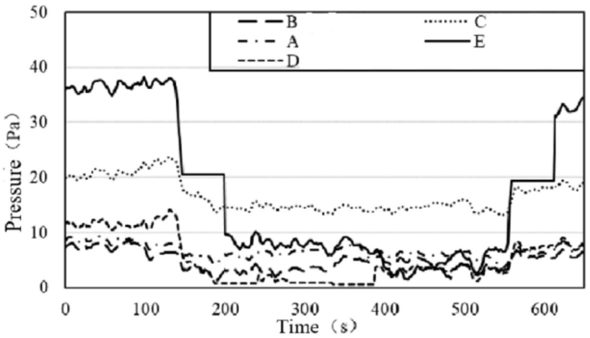

Fig. 4. Indoor air pressures of Case 3.

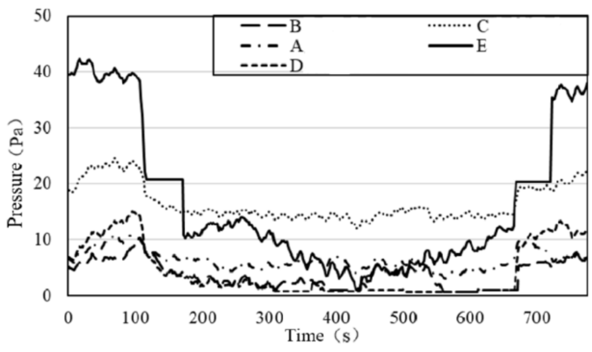

Fig. 5. Indoor air pressures of Case 4.

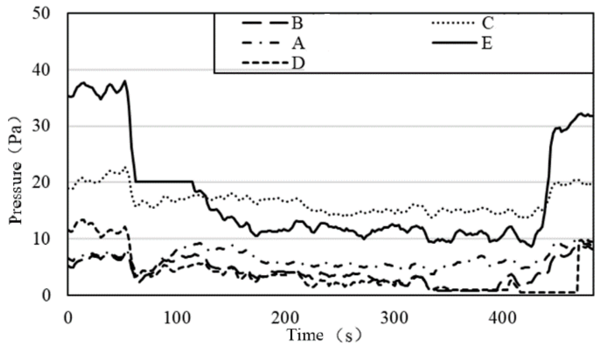

Fig. 6. Indoor air pressures of Case 5.

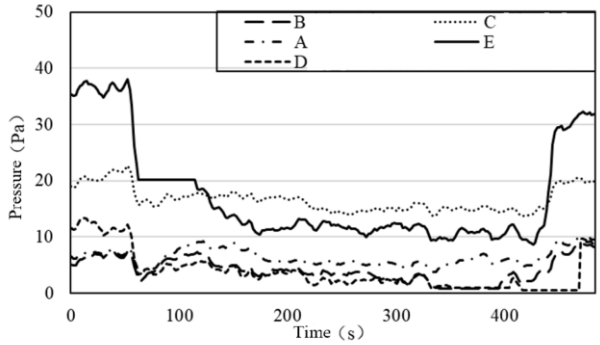

Fig. 7. Indoor air pressures of Case 6.

4 Discussion

When the fume hood starts, it will cause pressures change and take some time to restore after stops. Frequent switching on and off may cause complex fluctuation of pressure of each room. Therefore, it is necessary to discuss the influence of frequent switch on and off in the same time on pressure variation.

Through experimental investigation, when the fume hood is started and stopped once, the pressures of Room E, C and D are reduced by 15 Pa, 3 Pa and 5 Pa respectively. The pressures of Room A and B, which are not directly adjacent to Room E, are reduced by about 1 Pa. There is no reversal of the pressure gradient, and all pressures recovered rapidly after fume hood stopped. When fume hood shifted on and off 4 times within 2 minutes, the pressures decreases and recovers rapidly, and the pressure fluctuation caused by the two adjacent shift processes has no superimposed effect. When the shift process is 5 times within 2 minutes, there occurs the superimposed effect of pressure fluctuation, where resulting in irregular pressure variations. Therefore, these influencing factors and effects of superimposed effect need to be studied in the future.

5 Conclusion

The performance of indoor air pressure of multi-compartment cleanrooms under fume hood operating scenario is measured and analysed by experimental investigation method in this paper. Finally, the main conclusions based on analysis results are addressed as follow.

According to the experimental data, the pressure variation of each room under different exhaust air volume of fume hood are analysed. When fume hood is operating, the indoor air pressures of all compartments are greatly reduced. The fluctuation of pressure has a great impact on the main cleaning room and the two adjacent rooms, which can be easy to cause negative pressure and then pollute the air of clean room. When the exhaust air volume of fume hood decreases, the change degree of the room pressure gets narrow, and the risk of pollution in the clean room will be reduced. If the fume hood switches off after a short start-up time, the resulting differential pressure fluctuation will recover soon. Even if it switches on and off several times continuously, it will not aggravate the fluctuation of differential pressure. When the frequency of switch increases, the two adjacent pressure fluctuations will produce a superposition effect, and result in irregular pressure variation, which will increase the risk of pollution in the clean room.

The works of this paper might help understanding the performance of pressure variation in cleanrooms when disturbances occur and change. And the conclusions of this paper could be references for the design and operation strategies of multi-compartment cleanrooms.

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