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THE OVERFLOW-SYSTEM, A NEW VENTILATING LAYOUT FOR A SURGICAL DEPARTMENT *)

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1. INTRODUCTION

In the last decennia, it has repeatedly been suggested to apply laminar flow for the ventilation of operating theatres. This type of flow originates from the clean room technique and many firms working in this field aim at introducing this technique also in operating theatres. It has already often been emphasized that the name "laminar flow" is misleading, because it is not a laminar flow but only a non-mixing low-turbulent or displacement flow. The clean displacement flow may be disturbed by temperature differences in the operating theatre. To attain a reliable operation, the air velocity in the down flow may not be lower than 0.3 m/s and in the cross flow the horizontal air velocity may not be lower than about 0.5 m/s. An important difference between conventional ventilation and displacement flow in the operating theatre is the difference in air change rate. In conventional systems the air change rate is often 20 times an hour and for displacement flow this rate may be 50 to some hundreds.
Above the operating table the air change rate is in the order of several hundreds. In spite of many efforts to prove the effectiveness of such high air change rates for the operating room there are many leading authors, e.g. Laufman in the U.S.A., who are still of the opinion that

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an actual decrease in post operative infections by using laminar flow has not yet definitely been proved.

Yet the displacement flow has certain advantages. Therefore, efforts have been made to moderate the disadvantages, i.e. the higher investment costs and the higher energy need by certain measures. One of these measures is the choice of down flow because, compared to cross flow, this is also effective at lower air velocities and the diameter of the air stream can further be decreased by down flow, namely to less than 2 x 3 m2. This means that for down flow 6500 m3/h suffices, whereas for cross flow 15000 m3/h is required.

Besides, using cross flow, no objects or persons may be present between the air supply jet and the operating table, because they would disturb the effect and contaminate the cross flow. Whyte [1] in Great Britain also concluded, based on many germ measurements and considerations, that the germ numbers in the wound area for down flow are so low and the accessibility of the operating table is so much better from all sides, that he prefers the down flow system. Bossers [2] has developed the system in the Netherlands. In the Netherlands, the Dutch Health Council in principle supports down flow as a standard system for most operating theatres.

Owing to the cost only a few suitable down flow systems were installed till now. However, by combining the down flow principle with the overflow system the total cost (investment and operating costs) can be decreased considerably, because the air duct system can be largely simplified, the air quantities needed are smaller and, consequently, the energy costs will be lower. The major principles of the overflow system are:

1. The clean air for the whole surgical department is supplied to the operating theatres only. This air flow is about 2400 m3/h per operating theatre.
2. The operating theatres should all be ventilated by down flow. Each operating theatre is provided with a recirculating fan supplying about 6500 m3/h of recirculation air through a filter to the

operating table.

3. The air flow of 2400 m3/h to each operating theatre flows over to the adjacent spaces through a kind of grills in openings in the walls. In this way the spaces of the department are ventilated.

Thus, a very reliable pressure hierarchy is achieved in the department. By pressure hierarchy is meant the pressure differentiation intended for the different spaces. For cleaner spaces, higher pressures are required than for less clean spaces. In the overflow system this pressure hierarchy is maintained without automatic controls and is not affected by the number of operating theatre recirculation fans in full operation. Now, there are two important questions:

- Is the pressure hierarchy adversely affected by open doors?
- What numbers of germs may be expected in the air of the operating theatre and in the other spaces and are these numbers acceptable?

2. THE RELIABILITY OF THE PRESSURE HIERARCHY

As a study object, a large surgery department as designed for the new building project of the university hospitals in the Netherlands was chosen. In these projects, a department with twenty operating theatres is planned.

By the present guidelines in the Netherlands, if a conventional ventilating system would be chosen, an air flow of 200 000 m3/h would be required for the air change of all spaces of this department. An amount of 60 000 m3/h of these should be fresh air.

If the overflow system is chosen, only those 60 000 m3/h of fresh air have to be supplied to the twenty operating theatres. The air in the operating theatres is constantly purified by the recirculation fans of the operating theatres, which recirculate 6500 m3/h through filters (see Figure 1).

In Figure 2, the two possibilities - the conventional and the overflow system - are set against one another.

The conventional system operates with 200 000 m3/h, the overflow system with 60 000 m3/h.

In the conventional system, each space is connected to the air supply system and the air exhaust system. In the overflow system the air supply duct system only supplies air to the operating theatres; only the unclean spaces and the space farthest from the operating theatres are connected to the exhaust system. In the conventional system, the pressure hierarchy can only be maintained - that is, be made independent of the number of operating theatres in operation - if controls are used in the air duct system.
The basic principle of the overflow system implies, however, that the pressure hierarchy is maintained "by itself" i.e. without the help of controls, and, without being effected by the number of operating theatre recirculation fans in operation.

To find out if the pressure hierarchy is affected by the opening of doors a pneumatic analogue was used (Figure 3).
The analogue represents the department which was simplified to 69 spaces and gives all air flows and pressure relationships in the right ratio to reality.
In this model, 37 doors could be opened independently of each other. Each space had its own fluid tube manometer. In this way, the pressures in all spaces could be read simultaneously. It appeared that only in exceptional cases the pressure gradient direction will reverse owing to the opening of a door.

A reverse of the pressure difference direction in one or more places occurs more frequently if two doors situated directly one after the other are opened. In such cases, the reverse of the pressure difference can be prevented, if desired, by interlocking of critical door pairs. While automatic doors are often used today, mutual locking of door pairs will be possible without high costs.
The Dutch Committee on the control of cross infection (the Committee) did not consider this interlocking as necessary, however, because it only concerns short periods of reversing of pressure differences. The experiments on the model are treated in detail [3].

3. THE GERM NUMBERS TO BE EXPECTED

The germ numbers were calculated using the numbers of shed germs found by Whyte [5] and those found by May and Pomeroy [6]. Whyte has made examinations with men and women while they made movements, dressed in different types of operating dress, in experimental rooms ventilated in different ways.
As might be expected, rather different numbers were found. On the ground of Whyte's results, we chose a number of 25 000 germs (colony forming particles) per hour for the patients and the staff in operating theatres ventilated with vertical displacement flow.

For the staff outside the operating theatre we chose 100 000 germs/h. May and Pomeroy's numbers are of the same order of magnitude as Whyte's.

We emphasize that these numbers must not be considered as absolute numbers, they only give the order of magnitude. They are near the median values and are used for calculating the average germ number ratio's in the different spaces.

The following assumptions were made: there are 47 patients and 246 staffmembers in total in the department. In the operating theatre there are 0.8 patients and five members of the surgical team. Together these people spread 5.8 x 25 000 = 145 000 germs/h. In the original work [4], still 20 000 germs/h were added, coming from elsewhere with 90 m3/h. Then the total amount is 165 000 germs/h. These are picked up by 2520 + 6500 = 9020 m3/h of air, so the average concentration in the operating theatre is 165 000/9020 = 18,3 germs/m3, of which 2,2 germs/m3 originate from the patient.
The concentration in the air in the wound area is much lower because clean air is directed vertically from the ceiling to the table.
In the same way, the germ numbers for the other spaces can be calculated from the known air flows and germ numbers.
In Table 1 the main results are given in round figures.

Table 1: Germ numbers in different spaces.

	germs from patients in the operating theatre and clean corridor	germs from staff
operating theatre, wound area	much less than 2/m3	much less than 16/m3
overflowing air	2/m3	16/m3
clean corridor	6/m3	150/m3
reception{supply air	6/m3	150/m3
reception{overflow	6/m3	190/m3
recovery{supply air	6/m3	200/m3
recovery{overflow	6/m3	250/m3

It is once more emphasized that the ratios found are more important than the absolute values.

In the Netherlands the Committee rejected the old habit of switching over to underpressure in the operating room in the case of septic operations. The germs in the pus do not enter the air as airborne particles.

Germs originating from other spaces must be prevented from entering the operating theatre. This is attained by maintaining overpressure in the operating room.

From Table 1, it is seen that the germ number at the clean corridor is much higher than in the operating theatre. The figures in Table 1 support the present rule that in the operating theatre overpressure should always be maintained. The calculations are treated in detail in publication [4].

4. FURTHER CONSEQUENCES

The overflow openings in the walls should be of such a size that the air flow desired will be achieved at a pressure difference of 5 to 10 Pa. The accompanying overflow velocity is then about 3 m/s, with which a sufficient ventilation of the spaces can be achieved without stagnant zones.

The pressures at the doors remain moderate; the doors can be opened against the pressure difference without effort. If sliding-doors are used they can be opened without any difficulty.
The temperatures of spaces which are situated downstream can be controlled by using air coolers with a low air resistance such as the coolers used in induction units, which often are applied at a resistance in the order of 3 to 4 Pa.
If cooling water of about 17°C is used, no surface condensation occurs in the cooler. The higher the temperature of the passing air, the stronger the cooling effect.
Control of every cooler therefore, is perhaps unnecessary.
Generally, the air humidity will hardly increase by more than one percent. If the absolute humidity of the air in the department increases by 1 g/m3, the 60 000 m3/h of air can already absorb 60 l/h of water.
Sound transmission between adjacent spaces is only possible where these spaces are connected functionally. It must therefore be noted that also without measures a decrease in sound level in the order of 10 to 15 dB may be expected.
If door interlocking is applied it must remain possible to open them by hand in case of emergency.
The pressure hierarchy in the overflow system is much less affected by leaks in the building construction than in the conventional system, because the volumes of air flowing over are much larger. This is evident from the experiments in the model: many doors could be opened without affecting the pressure hierarchy provided they are not situated directly in succession.
In the overflow system pressure hierarchy is far less impaired by wind influence than in a conventional installation.
In the operating theatre an overpressure must always be maintained. Switching over to underpressure during so-called septic operations is rejected in the Netherlands. So, the overflow principle can be maintained without exceptions. If the air flow flowing over to a small space is large, the air velocities in the small space may be too high. This can be avoided by an air duct partly shortcircuiting this space.

5. CONCLUSIONS

Compared to a conventional system the overflow system has the following advantages:

1. Conditions in the operating room and above the operating table are better.
2. The duct system is far simpler.
3. The air volume flow needed, is much smaller.
4. Pressure hierarchy is maintained without automatic control ("by itself").
5. Pressure hierarchy is much more reliable.
6. Pressure hierarchy is far less affected by leaks in the building construction or by wind influence.
7. With a good design adjustment of the pressure hierarchy will be hardly necessary. Once right, always right.

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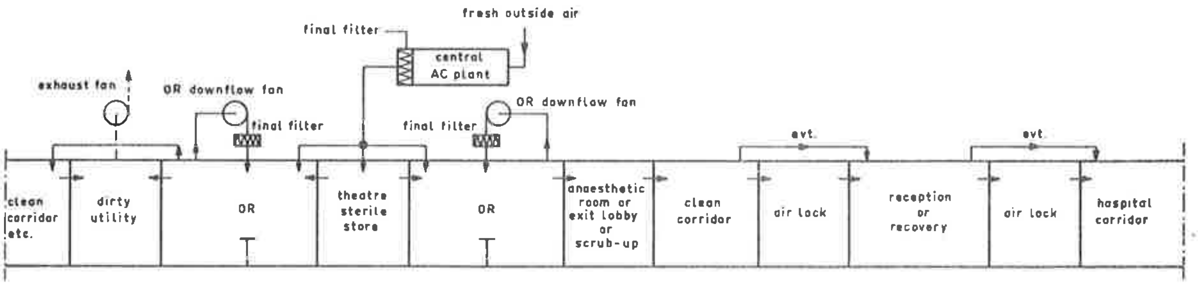
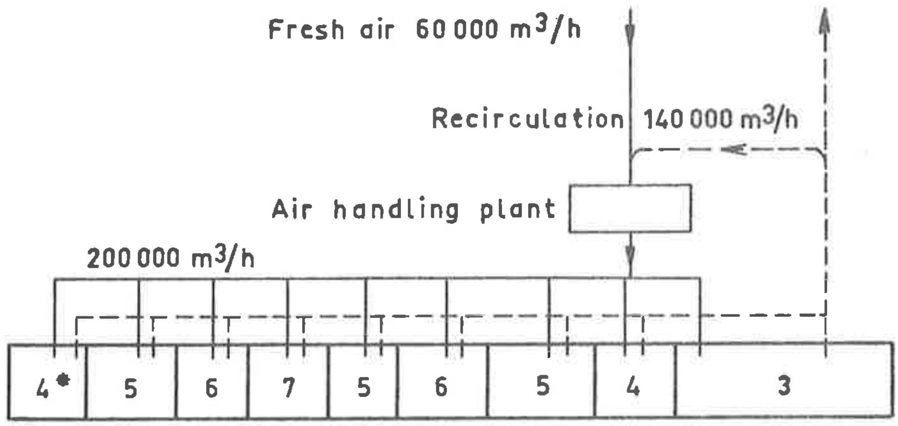


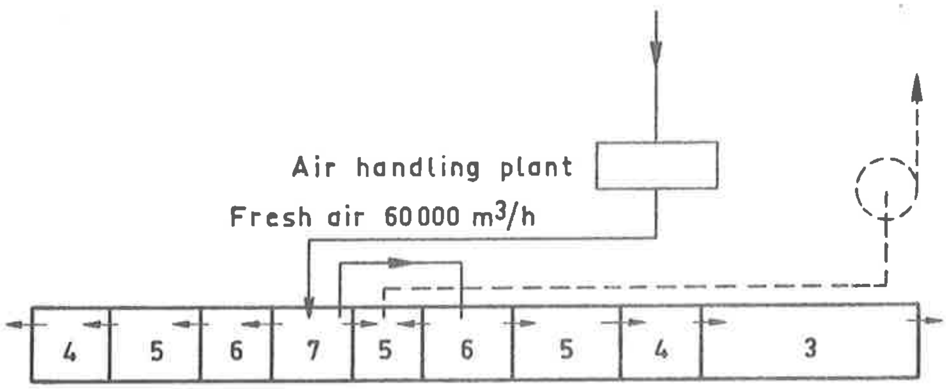
Fig. 1

Principle of the overflow system for a surgical department



Conventional ventilating system

* 7-6-5-4-3 = decreasing pressure levels



„Overflow" ventilating system

Fig. 3

The pneumatic analogue.

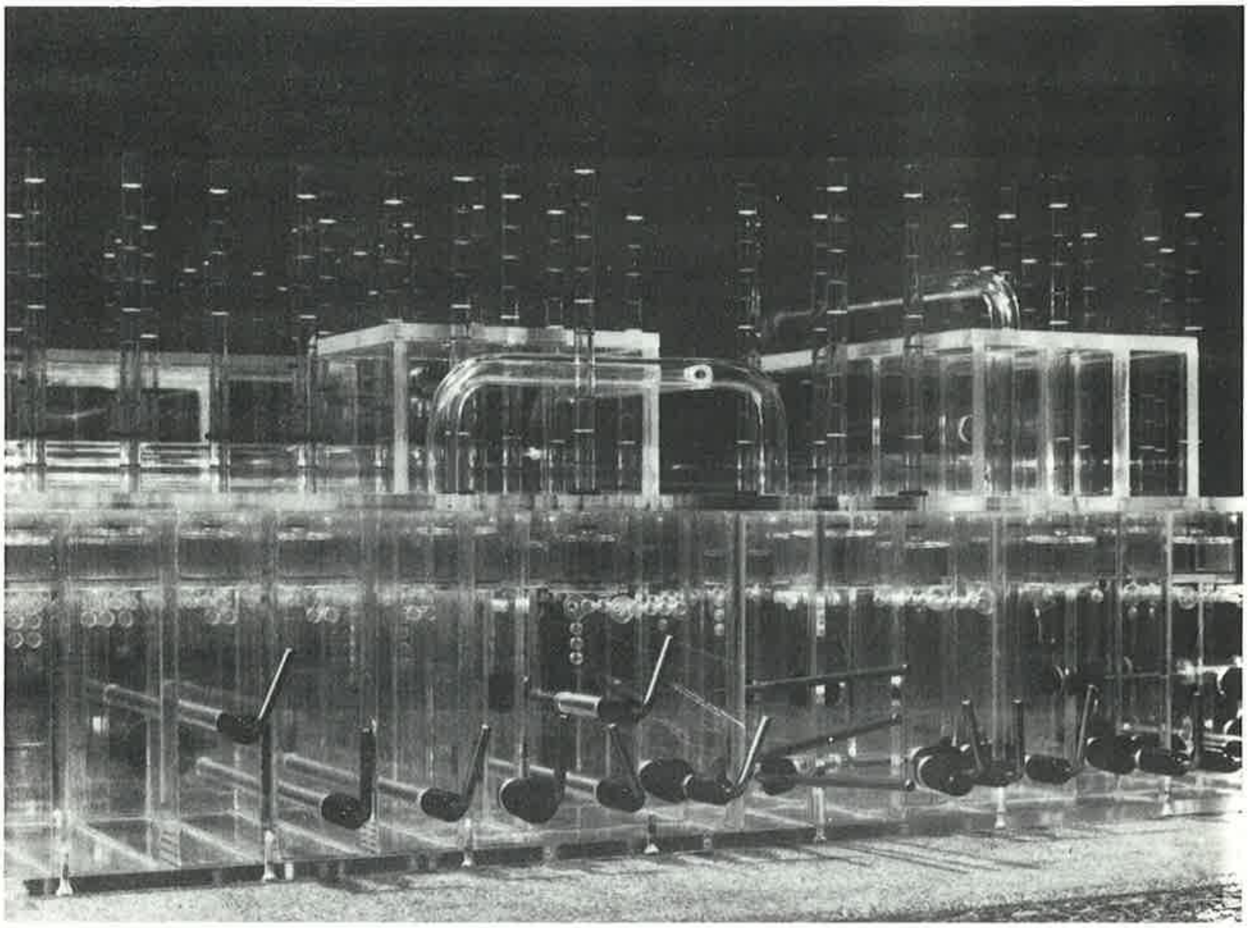


fig. 2

Comparison of conventional system and overflow system