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Sensing and detoxification devices in public building spaces

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SUMMARY:
This paper describes commonly used ventilation principles and where sensing and detoxification devices could be integrated in public buildings in an effort to warn and protect citizens against surprise attacks by toxic agents. The release of toxic agents may be outdoors, in a single indoor spot or their origin may be diffuse.

It is common to classify ventilation systems by their functions, distribution strategies, ventilation principles or a combination of them all. As this paper is meant as a guide to developers and manufacturers of sensing and de-toxification devices, focus will be on ventilation principles and where to integrate these devices. Two principles will be discussed, namely the displacement principle and the mixed principle. These ventilation principles are widely used in public buildings. The differences in air distribution using the displacement or the mixed principle are discussed in three different scenarios.

The scenarios exemplified are: A very densely populated space (Theatres and Cinemas), A large airtight space with dominant air change by mechanical ventilation (Airport Terminal) and an Underground space (Subway or metro station).

For sensing and detoxification devices to be effective and preferably ahead of situation, this paper will point out strategic areas where to integrate these devices into the building space and in its immediate surroundings.

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1. Introduction

For sensing and detoxification devices to be effective and preferably ahead of situation, this paper will point out typical ventilation principles used and strategic areas where to integrate sensing and detoxification devices into the building space and in its immediate surroundings. Examples of deployment of sensing devises may be in exhaust and inlet openings of ventilation systems, in openings as windows and doors and along conveyer belts. The paper will also list typical figures for ventilation rates, The following scenarios will be looked at: Very densely populated space (Cinemas and Theatres), Large airtight space with dominant air change by mechanical ventilation (Airport Terminal) and an Underground space (Subway or Metro station).

1.1 Classification of Ventilation systems

It is common to classify ventilation systems by their functions, distribution strategies, ventilation principles or by combinations of them all. This paper will not go into a discussion on functions or distribution strategies. Focus will be on ventilation principles. Within the mentioned distribution strategies two different principles are in use, namely displacement airflow and mixed airflow. In both principles air can be distributed through the room as a constant air volume CAV or as a variable air volume VAV.

1.1.1 Displacement principle

With the displacement principle heat and pollution from people and equipment are transferred from the residence zone near the floor, up to the ceiling where it is evacuated through the outlet system. Make up air is supplied to the room within the residence zone at low speed. The displacement principle is illustrated in figure 1.

With displacement ventilation the outlet pollution concentration is higher than the pollution concentration in the residence zone. The ventilation efficiency can be higher than one.

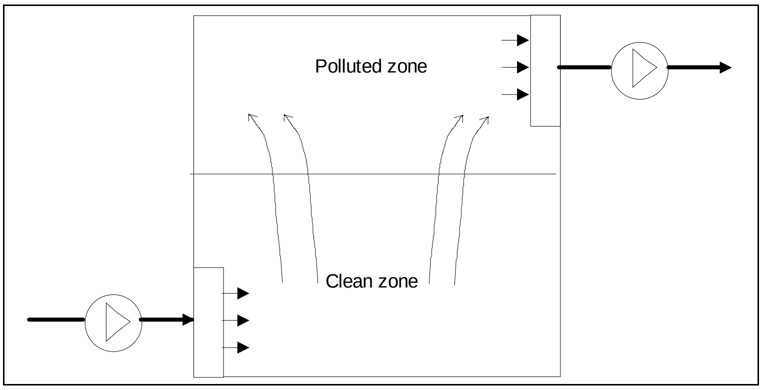

FIG. 1. Ventilation system using displacement principle.

1.1.2 Mixed principle

In a ventilation system utilising the mixed principle, make up air is supplied to the room above the residence zone at high speed. The mixed principle is illustrated in figure 2.

With mixed ventilation the outlet pollution concentration is close to the pollution concentration in the residential zone and the ventilation efficiency will approach to one.

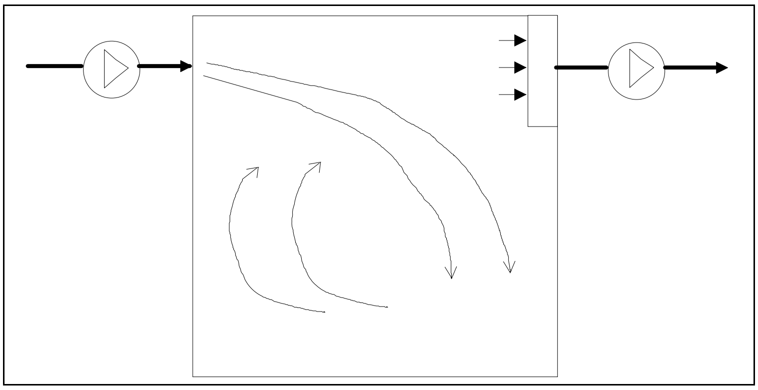

FIG. 2. Ventilation system using the mixed principle.

1.1.3 Ventilation rates

When dimensioning a ventilation system the determining factor is the amount of air to be conditioned and distributed by the system. Fresh air is an important part of this air. The room air has to be exchanged several times per hour to clear the air from odours, dust and eventually toxic agents. The air exchange rate varies with a lot of factors; the number of people present in the room, the desired comfort level, etc. Therefore it is not possible to state a specific air exchange rate. Various sources on designing HVAC systems will provide rules of thumb for air exchange rates. Commonly recommended air exchange rates (The Engineering ToolBox. 2005) are shown in table 1.

TABLE 1. Commonly recommended air exchange rates in some rooms and buildings.

Building/room	Air exchange rate n, [1/h]
Auditoriums, Cinemas, Theatres	8 - 15
Cocktail Lounges , Bars	20 - 30
Cafeterias	12 - 15
Department Stores, Malls, Supermarkets	4 - 10
Municipal Buildings	4 - 10
Restaurants	8 - 12

In many cases local regulations and building codes will govern the ventilation requirements.

Typically the fresh air supply to a room can be calculated as:

$$Q = n\,V \qquad (1)$$

Where

Q = *fresh air supply* $[m^3/h]$

n = *air exchange rate* $[1/h]$

V = *Volume of room* $[m^3]$

As an example, the fresh air supply to a cinema/theatre with a volume of 2000 m^3 and an air exchange rate of 10 can be calculated as:

$$Q = 10[1/h]\ 2000\ [m^3]$$

$$= 20000\ [m^3/h]$$

2. Sensing and detoxification devices

In NANOSECURE, research laboratories and manufacturers are developing sensing and detoxification devices. The first prototypes are about to be tested in small scale.

In this project a sensing device is a device developed to be able to sense and recognise a specific toxic agent. This means, you have to use a different sensing device for every toxic agent you want to trace.

A detoxification device is a device able to decompose a specific toxic agent into non-toxic components. Again, this means you have to use a different detoxification device for every toxic agent you want to detoxify.

Right now it is not possible to have one device being able to sense or detoxify every known toxic agent. As mentioned, the first prototypes are about to be tested in the laboratory. Therefore it has not yet been possible to do a full-scale testing of the equipment. Nano-technology is used in the development of these devices, so the new sensing devices will be far more sensitive than similar known devices, if any. They will be able to react on quite small air samples, whereas detoxification devices have to be able to process really large air volumes to be effective in real life.

This could lead to a discussion on which device type to give the highest priority. Should it be the sensing or the detoxification device? For reasons of public safety, the sensing devices are most important. The newly developed sensing devices will be able to react very fast, which means that connected monitoring and alarm systems will be able to alert people immediately for evacuation. Detoxification devices on the other hand has to process thousands of cubic meters of air before a toxic contamination comes below a given threshold level.

How many different sensing devices to apply in a building is related both to how many different toxic agents you want to be able to detect and to how high the security level should be in the building.

In chapter 1 normally used ventilation principles were introduced. To be able to relate these principles to real life buildings, the following chapter will introduce three scenarios using different ventilation principles. Although describing typical ventilation systems and principles in scenarios without being specific on ventilation rates, air volumes processed etc., it could be important to developers and manufacturers to know, which systems and principles are used. Normally they don't deal with ventilation systems at all.

3. Scenarios

The following paragraphs show three target areas or scenarios, which could be of interest to terrorists, namely theatres and cinemas, airport terminals and subway stations. The gathering of many people is common to all of them and it is indoor spaces. In indoor spaces people are highly vulnerable to exposure from for example toxic agents as seen in the Tokyo Subway on March 20, 1995, where terrorists exposed innocent people to Sarin.

Focus will be on ventilation principles normally used in these places. A brief discussion on where to integrate sensing and detoxification devices into the building space and in its immediate surroundings will follow.

Not knowing the exact design of the buildings, their ventilation and security systems etc. makes it difficult to point out exact solutions on where to integrate sensing and detoxification devices and how many to use.

3.1 Theatres and Cinemas

Typically many people are gathered in theatres and cinemas for two or three hours during a performance. This makes it very important to be able to maintain a suitable indoor climate. Three ventilation principles will be shown.

3.1.1 Upwards ventilation principle

The upwards ventilation principle is shown in figure 3. This ventilation principle is widely used in large theatres and cinemas. Typically conditioned inlet air is coming from a plenum beneath the floor. The inlet air is then leaving the plenum through inlet openings in the floor or through integrated openings in the bottom of the chairs. Contaminated air is let out through openings in the ceiling.

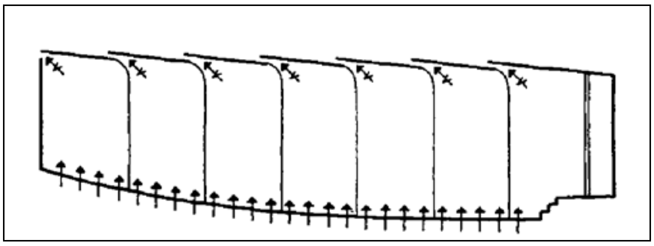

FIG. 3. Upwards ventilation principle used in theatres or cinemas.

3.1.2 Downwards ventilation principle

Different downwards ventilation principles are shown in figure 4. These ventilation principles are also widely used in large theatres and cinemas. Typically conditioned air is let into the room through openings or fans in the ceiling. Contaminated air is let out through openings in the floor or through openings integrated in the bottom of the chairs.

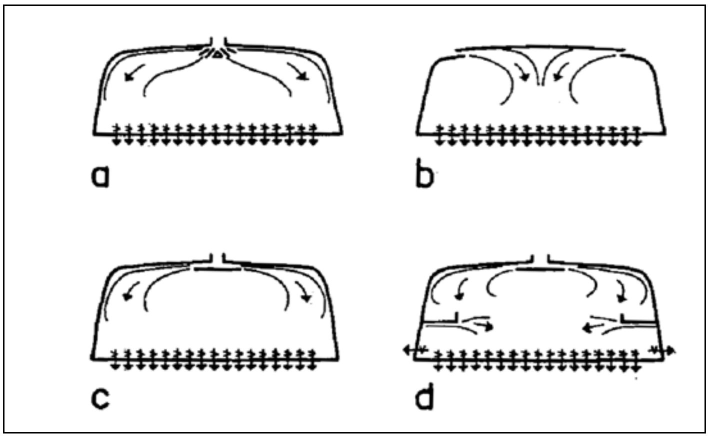

FIG. 4. Downwards ventilation principle used in theatres and cinemas.

3.1.3 Horizontal ventilation principle

The horizontal ventilation principle is shown in figure 5. Conditioned air is let into the room at high speed through jets. Hereby conditioned air is mixed with contaminated air. Mixed contaminated air is then let out through openings in for example a balcony or through openings in the back wall.

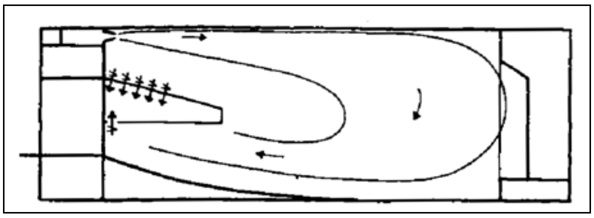

FIG. 5. Horizontal ventilation principle as used in theatres and cinemas.

3.2 Airport Terminal

Often people are queuing from the very moment they enter the terminal. In the first place they are queuing in front of the check-in counter and then at the security gate. Before boarding the flight, people may go to the shopping or waiting areas and finally they often have to wait at the gate before entering the flight. At peak hours all these areas, where people are gathered in long queues, are potential target areas, which could be of interest to terrorists (Edwards B. 2005).

Mostly airport terminals are very complex buildings often integrated with a subway station. This also makes ventilation systems very complex. Normally several sub-systems have to be used to maintain a suitable indoor climate for the staff at work and for the passengers. Airport terminal buildings can normally be characterised as long wide-spanned buildings with ceiling heights of maybe 20 – 25 m. To be able to maintain a suitable indoor climate in very large spaces, ventilation systems are to be considered global and local within the building site.

The global part of the ventilation system may consist of air diffusers that push conditioned air down toward floor level, as shown in figure 4a, b and c. Diffusers would normally be placed just beneath the ceiling. Contaminated air would then be returned through outlet openings placed in the floor, at columns or in the walls. A ventilation system with wall-mounted diffusers could also be used. Here diffusers would also push conditioned air down toward the floor. Contaminated air would be returned as before.

The local part of the ventilation system would typically be placed in a shopping area, behind ticketing desks, at service desks in cafeterias etc. Here conditioned low-velocity air would be supplied from outlet openings at floor level. Contaminated air would be returned through outlet openings in walls or ceilings.

As stated before, airport terminals normally are large open buildings. Therefore, to prevent toxic agents from spreading throughout the whole building, techniques used in fire fighting could be used. During a fire the building would normally be parted into airtight sections. Horizontal and vertical firewalls will isolate part of the building until fire is under control (Cui E. and Chow W. K., 2001). Similar precautions could come into use if toxic agents were released in very large spaces.

3.3 Subway or Metro Station

Subway stations are typically crowded with people at rush hours. Besides the subway station the building also could have a shopping mall as seen in many places. Two, three or maybe four stories on top of each other often centered around an atria.

Without knowing the exact layout of the subway station, it is not possible to describe how a ventilation system should be designed and which ventilation principle to be used. Today, the complex design of a modern subway ventilation system would be carried out using computer simulation (Tabarra M., Abi-Zadeh D. and Saadokierski S., 2004). Figure 6 show the layout of a modern subway ventilation system. Abbreviations in figure 6 are; OTE duct *Over Train Exhaust duct*, UPE duct *Under Platform duct*.

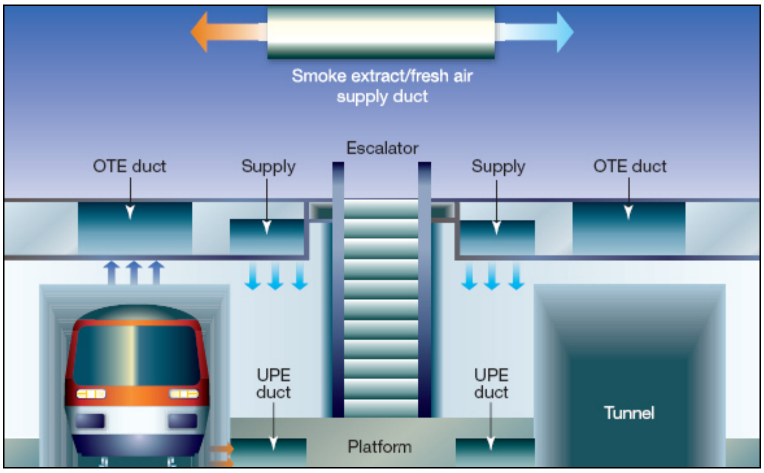

FIG. 6. Layout of modern subway ventilation system. Source: Arup (London).

4. Integrating sensing and detoxification devices

Until now the most common sensing devices integrated in ventilation systems are sensors for inlet and outlet air temperatures, humidity and CO_2. Temperature sensors are integrated in inlet and outlet openings. Humidity sensors could be integrated in the same openings or within the room itself. CO_2 sensors would be integrated in outlet openings. All these sensors are normally used for maintaining a suitable indoor climate.

How and where to integrate sensing and detoxification devices into building spaces as the ones described in the scenarios is not obvious. These sensors and devices are used strictly for preventive purposes, and the use of them is new.

Detoxification devices could be integrated as part of the central ventilation unit. This is where the very large air volumes are processed. In case of Subway and Metro stations and adjacent platforms and tunnels detoxification devices could be integrated locally.

To prevent people from carrying toxic agents into (public) buildings would of course be the best solution. But this is not always possible. Therefore sensing devices have to be integrated both into rooms and into ventilation systems. Most places will be common to all the scenarios, and some will be specific in relation to the purpose of the building. Obvious places to integrate sensing devices would be:

- In fresh air inlet openings
- In outlet openings
- Numerous places throughout entrance, lounge and check-in areas
- Numerous places throughout a theatre or cinema room near the floor

- Numerous places throughout platform areas near the floor in Subway and Metro stations
- Numerous places within security gate areas
- Throughout baggage handling systems, conveyer belts etc.
- In smoking areas, toilets and nursery rooms
- In front of ticket offices near the floor or at places nearby where people will put their bags or luggage
- Any other well-ventilated area within the building
- Inside-ventilated equipment such as vending machines for soft drinks, candies, popcorn etc
- Inside self-service check-in computers
- Inside self-service ticket machines
- In tunnel ducts adjacent to Subway and Metro stations
- In subway trains, specially around entrance areas

Some of the suggestions state that sensors have to be placed near the floor. The reason is, that some toxic agents, when in the gas phase, is heavier than air and therefore will sink to floor level when released. Then again some toxic agent will stick to for example clothing and other surfaces for a period. This means that, although sensors have detected a toxic agent and people are getting evacuated, the exposed surfaces (and peoples clothing) still are a source of contamination.

As mentioned before, until now none of these sensing and detoxification devices have been used in real life. Therefore the above mentioned places to integrate sensing devices have to be a “best guess”.

5. Conclusion

For sensing and detoxification devices to be effective and preferably ahead of situation, this paper focuses on typical ventilation principles used and strategic areas where to integrate sensing and detoxification devices into the building space and in its immediate surroundings. Manufacturers of sensing and detoxification devices need to know where to integrate their devices into the ventilation systems and into the building space itself. This paper therefore outlines two commonly used ventilation principles, namely the displacement and the mixed principle. To maintain a certain comfort level in a room or space, it is necessary to know the air exchange rate and to know the amount of fresh air to supply. In table 1 a list of commonly recommended air exchange rates is shown. An example of calculating the amount of fresh air needed in a cinema/theatre is also shown.

The following scenarios are looked at:

- Very densely populated space (Cinemas and theatres)
- Large airtight space with dominant air change by mechanical ventilation (airport terminal)
- Under-ground space (Subway or Metro station)

Ventilation principles for the scenarios are looked at. Obvious places to integrate sensing and detoxification devices are also looked at. Due to the complexity of the buildings in the scenarios and the complexity of the ventilation systems, only the most obvious solutions are suggested.

Prevention of attacks with toxic gases is still a new discipline. An obvious way to find preventive solutions would be the use of computer simulations. In recent years these techniques have been widely used for simulating fire hazards. Simulating an attack with toxic gases is not the same as simulating a fire, producing heavy heat and smoke loads on the environment. Research on how and where contaminated air moves in a densely populated space and knowing how various toxic gases blends with air, water and surfaces are still to be carried out.

6. References

Cui E. and Chow W. K. (2001). Numerical studies on smoke filling process in an airport terminal, *Journal of Architectural Engineering*, September 2001

Edwards B. (2005). The Modern Airport Terminal, New approaches to airport architecture, *Taylor & Francis*

Facts about Sarin, (2005). Centers for Disease Control and Prevention, CDC, http://www.bt.cdc.gov/agent/sarin/basics/facts.asp (Accessed 2008-01-31)

Tabarra M., Abi-Zadeh D. and Saadokierski S. (2004). Design of a modern subway ventilation system, http://www.arup.com/_assets/_download/download265.pdf (Accessed 2008-31-01)

The Engineering ToolBox. (2005). Air Change Rates in some typical Rooms and Buildings, http://www.engineeringtoolbox.com/air-change-rate-room-d_867.html (Accessed 2008-01-31)