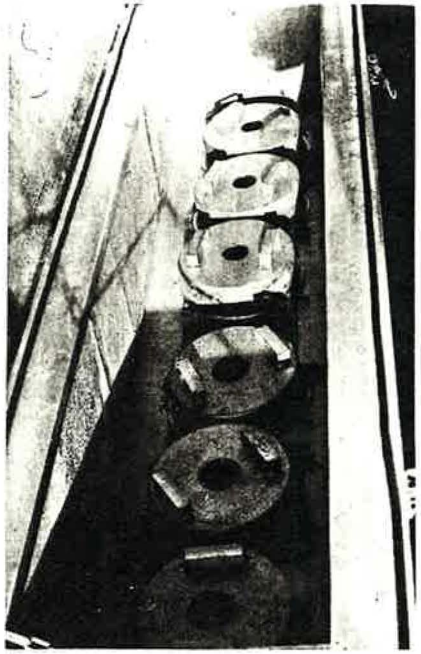

Fig. 4: The restrictors are easily removable for cleaning the ducts. There are two diameters: one for kitchen ducts (15 l/s at Δp 50 Pa) and one for bathrooms (12 l/s).

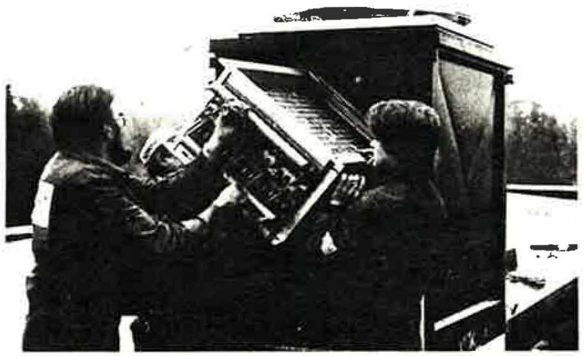

Fig. 5: The cooling coil is placed in the exhaust air unit.

INCREASED VENTILATION EFFICIENCY IN ROOMS

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Abstract

The ventilation efficiency in a room can be improved by means not used much so far. For a couple of years the author has made studies and tests of a new efficient method for lowering the contamination level in a room. The method is based on the fact that a supply air stream with high induction characteristics will draw secondary air to the outlet. The secondary air containing a maximum amount of contaminants and having a higher temperature than the primary air has, is the most desirable to exhaust in a room. In any type of ventilation system in a room, the supply-exhaust air diffuser or register will considerably increase the ventilation efficiency in the room.

The Background

The author's interest in the efficiency of ventilation in rooms, started 20 years ago when he worked with laminar flow benches and systems, and other equipment used to maintain clean room conditions. He realized that there is often more than one combination of air distribution for obtaining the same level of cleanliness. From laminar flow to single outlet systems. He soon discovered that some advantages of laminar flow could to a certain extent be met by a combination of outlets/inlets. In laminar flow systems one may have stagnant, turbulent air movements caused by machines, people, etc, which may be eliminated by directed air streams. And in ceiling outlet/inlet systems one may have unwanted contamination caused by secondary air movement, which may be eliminated by supplying primary air at floor level or by location of exhaust air inlets where secondary air contains a maximum of contaminants.

The aforementioned is primarily a consequence of one of the fundamental principles in all air distribution, namely: It is the supply air outlet that practically alone creates the ventilation efficiency in a room. One can almost regard the supply air outlet as a fan with inlet and outlet, where the inlet of the fan is the flow of primary air, and the outlet of the fan is the flow of the total air stream. It may also be said that usually more room air is returned to the primary air stream than to the exhaust air inlet, in a balanced conventional ventilation system.

Airborne Contaminants in Room Air

If you look at the settling velocities of particles you will find that particles larger than 10 μm settle, with some exceptions, fairly quick and become a cleaning problem. They are suspended only if there is a strong air current, stronger than the currents created by secondary air, exhaust air inlet or natural convection air. Particles smaller than 5 - 10 μm, however, may be suspended in the air for long periods by the air currents created by the secondary air and the natural convection air. So one can say that nature divides particles in roughly two kinds, the ones that settle on floors, etc, and the ones that are suspended by normal air currents in a room. The contamination of room air comes from both external and internal sources. However, the contamination level of room air is mostly a consequence of the occupants and the activities. The contribution from primary air is negligent with good filtering.

In order not to increase the average contamination level in a room the exhausted amount of contaminants must be at least equal to the amount created in or brought to the room. This can be desribed by the equation:

$$E = \frac{C_E}{C_R} \qquad (1)$$

where:

E is effectiveness factor

C_E is the average airborne contamination level in exhaust air, and

C_r is the average airborne contamination level in room air.

if:

$E > 1$, the ventilation efficiency is high, which means that the supply air outlets and exhaust air inlets are well located, decreasing the room air contamination level,

$E = 1$, the ventilation efficiency is neutral, which means that the room air is satisfactorily mixed, but any increase in the amount of room air contamination will negatively affect the efficiency,

$E < 1$, the ventilation efficiency is low which means that air supplied to the room is flowing through the room to the exhaust air inlet without being very useful, resulting in an increase of room air contamination level.

Effectiveness factors for different air distribution patterns were experimentally determined by John Rydberg at KTH, Stockholm, more than 30 years ago. (1). Three of the experiments are shown in Fig. 1.

A ventilation efficiency above 1 requires that most of the room air cotaminants are brought so close to the exhaust air inlet that they are removed from the room. This can be done, either by laminar flow systems or by properly combining supply air outlets and exhaust air inlets.

The New Approach

The idea of using the supply air stream to increase ventilation efficiency, started when the author studied the smudgings on and around supply air outlets. The smudgings on the ceiling around a diffuser are emanating from the room air and brought close to the diffuser by the secondary air motion.

Why Not Use This Natural Force To Remove Contaminants From The Room Air?!

This new approach for increasing ventilation efficiency is based on the fact that a primary air stream creates a secondary air motion that picks up air contaminants floating in the room air. In Fig. 2 is shown how the primary air streams from diffusers generates secondary air motions around the primary air. The contaminants picked up by the secondary air will move into the primary air by induction and most of them near the outlet, because of the higher induction rate there. Contaminants emanating from under the diffuser will also to some extent move through the air stream and smudge the ceiling. The rougher the ceiling surface is the easier the particles will settle. By lowering the diffusers the smudgings will move further away from the diffuser. The diffuser must be some 400 mm from the ceiling in order to eliminate smudgings on the ceiling.

The level of contamination at the ceiling and around the diffusers will be high and increase with the impulse of the primary air. If low returns are chosen to get some sort of non-laminar, conventional flow air distribution pattern for an increase in efficiency, the level of contamination increases in certain areas at ceiling and floor level. These areas of contamination are multiplied in deep rooms where there are several supply air outlets, but only low returns around the perimeter of the room. Ceiling supply air outlets and low returns will therefore not result in efficiencies above 1, as seen in Fig. 1.

The Supply-Exhaust Air Diffuser

The application of supply-exhaust air diffusers was first tested in a large room for computerized mail sorting machines five years ago. The contamination level in the room was relatively high before installation of the mail sorting machines, and was to be lowered as much as possible when altering the ventilation system. For the air distribution was selected the new supply-exhaust air diffuser shown in Fig. 3. The cylinder around the diffuser is of perforated sheet metal and is connected to the exhaust duct. The diffuser face is about 400 mm below the ceiling. By using the supply-exhaust air diffuser it was expected that more airborne contaminants would be exhausted than with a conventional type of air distribution.

The system has now been in operation more than five years and some tests have been made to prove the theories. It was realized soon after start-up that there was an increase in accumulation of dust in the exhaust air fan housing compared to before the alteration of the ventilation system. Also, when tests were made about 6 months after start-up, comparing the accumulation of dust on a) the exhaust air surface, b) the non-exhaust air surface and c) the ceiling surface, big differences were found. The tests, made simply by collecting the dust accumulated on the different surfaces with paper cloth, are shown on Fig. 4a - 4c. The tests showed that the diffuser with active exhaust in the perforated cylinder, accumulated very much more dust than the non-exhaust air surface or the ceiling surface. This proves that more contaminants are exhausted from the room air with this type of diffuser than with a conventional type, thereby increasing the ventilation efficiency of the system.

Reference:

1. John Rydberg, KTH (Royal Technical University), Stockholm. Handbook in Heating and Ventilation, Part III, 1955.

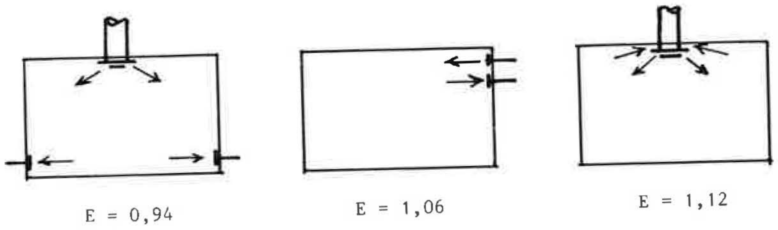

Fig. 1. Some of the air distribution patterns used in experiments by John Rydberg.

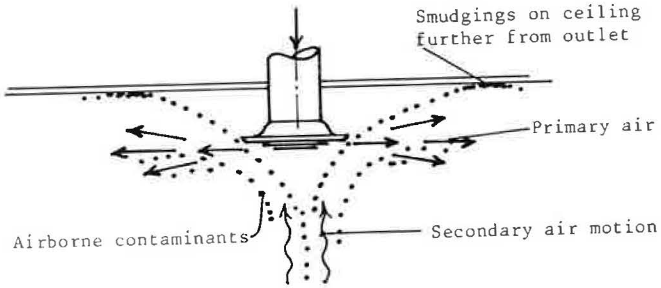

Fig. 2. Primary air streams generate secondary air motions.

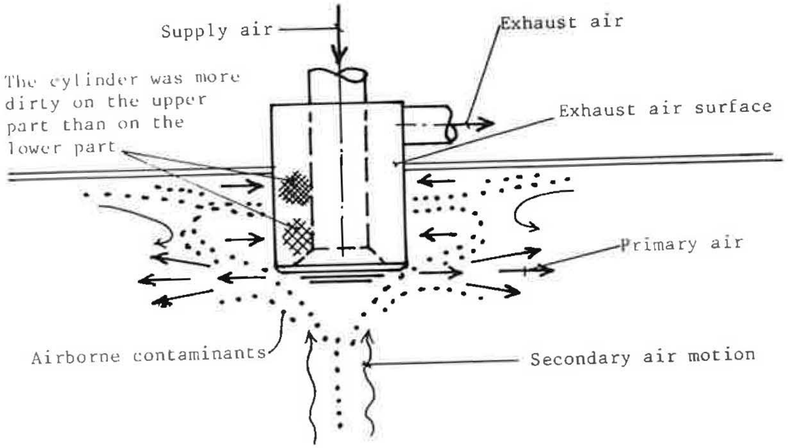

Fig. 3. The Supply-Exhaust Air Diffuser.

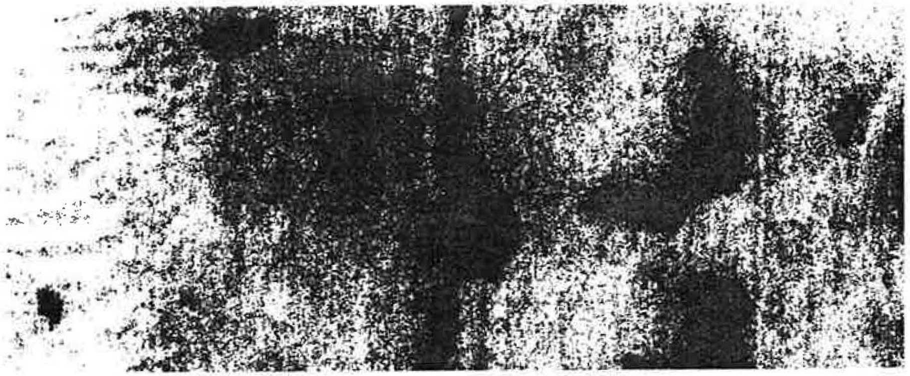

Fig. 4a. Dust accumulated on the exhaust air surface of the diffuser with open exhaust.

Fig. 4b. Dust accumulated on the exhaust air surface of the diffuser with closed exhaust.

Fig. 4c. Dust accumulated on the ceiling surface around the diffuser.