# VENTILATION AND AIR-CONDITIONING SYSTEMS - INVESTIGATIONS TO THE ODOUR AND POSSIBILITIES OF CLEANING

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## ABSTRACT

For many years there has been an increasing rate of complaints on the air quality in non-industrial buildings. The occupants suffer from many diseases especially problems of breathing. Besides other reasons the air-conditioning systems themselves pollute the indoor air because dust, aerosols and other substances deposit inside the system. Therefore an air-conditioning system, which has been operating 26 years was investigated. The aim was to find the main pollution sources of the system and possibilities to eliminate them. Some conclusions to problems of odour, cleaning and design of ventilation and air-conditioning systems are made.

## INTRODUCTION

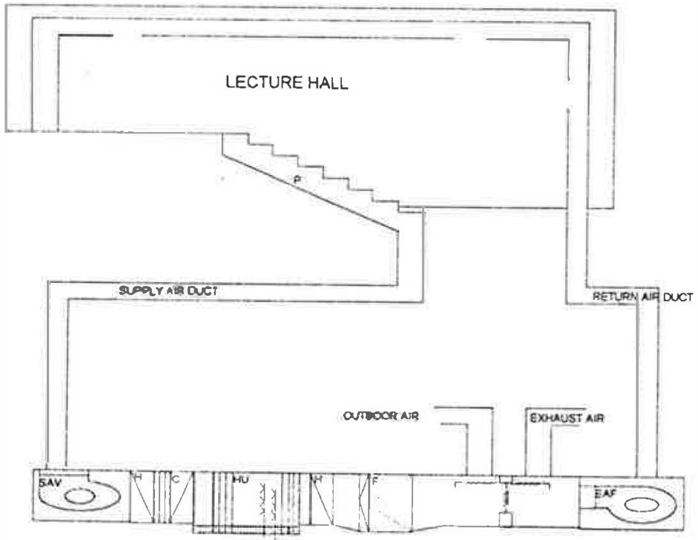
In recent years there is a growing interest in saving energy. This is the reason why the air exchange rates in air-conditioned buildings are reduced. As a result there were increasing rates of occupants who are dissatisfied with the indoor air quality in air-conditioned non-industrial buildings. They are suffering from symtomes like headache, eye and throat irritation which were classified by the World Health Organisation as the 'Sick Building Syndrome' (SBS). This increased research activities concerning 'Indoor Air Quality' (IAQ).

The IAQ in rooms depends on a number of factors like outdoor air quality, fresh air rate of the ventilation system and different pollutants. The pollutants are divided into three main groups - pollutants from occupants, from materials used in the building and the room, and from the air-conditioning system. Recent publications point out that 40 % of all pollutants are originated by the air-conditioning system (1). Deposits of dust or various aerosols and chemical and biological contaminants pollute the air. The pollutions have many reasons as uncleanliness of the production of components, of the installation, of the operation and finally of the maintenance of the system.

Therefore pollution sources in a 26 years old air-conditioning system were investigated. After determining the present working conditions the components were inspected in respect to dust deposits, hygienic conditions and perceived air quality (method from Fanger (2)). Finally some suggestions for cleaning and proper system design are made.

## THE AIR-CONDITIONING SYSTEM - ACTUAL CONDITION

The air-conditioning system run since 1966 (construction see Figure 1) supplies air to a lecture hall with 120 places. The system was designed for a total air flow rate of 8000 $m^3/h$ including recirculating air. The operating hours have been determined by the daily running time (12 h/d) during the lecture weeks of the university (32 weeks/a). This resulted in an anual operating time of 1920 h/a and a total time of 50000 h. For the first years of operation a maintenance contract existed, but during the laster years the maintenance has been irregular. Only filter material was exchanged and defect parts of the system were replaced.




| | | |
|---|---|---|
| SAF | = SUPPLY AIR FAN | H = HEATER |
| C | = COOLER | F = FILTER |
| HU | = HUMIDIFIER | P = PLENUM |
| EAF | = EXHAUST AIR FAN | |

Fig. 1. Design of the air-conditioning system

## CHANGES IN THE DEVELOPMENT OF TECHNOLOGY

There are some differences in technology between the time of designing the system 1963/64 and today. For example the outdoor air intake would not be placed at ground level nowadays but 3 m above (3).

Furthermore no electric filters would be used with filterelectrodes sprayed by an special oil after cleaning with water. The oil is used to fixe the particles at the electrodes spoilen the air quality simultaneously. This type of filter is not used severly today.

The air flow check of the system showed that the air quality decreased by the recircultaing air. Without recirculated air the indoor air quality is much better and the air flow rate may be reduced to 40 %.



A further contribution is the surface structure inside the ducts and the components. They are not abrasionproof and flat. Therefore the surfaces favour dust deposition are very good and the dust on the surfaces is polluting the air quallity in the rooms.

## DUST DEPOSIT AND HYGIENIC CONDITIONS OF THE SYSTEM COMPONENTS

Dust and particle deposits are one reason for reduction of air quality.
There are different kinds of dust deposits in air-conditioning systems depending on the air velocity and the distance from the intake. Bigger amounts of deposits are found in wakes. Thin layers are deposited on the lower duct surfaces where a uniform velocity distribution across the duct is given. Larger particles are found closer to the intake. But there were also some middle sized stones, material from the installation work and even a newspaper dated 1971. This shows that the system was not cleaned before going into operation. The newspaper came into the system through a defect air outlet in the lecture hall.

An estimation of the amount of dust deposited in the system during operating time was done under the following assumptions. For the given operating time, the designed air flow rate, an average outdoor air dust concentration of 100 $\mu g/m^3$ in Berlin and the filter efficiency of 90 % the dust deposit will be 3,2 kg in the entire plant. Same samples taken from the lower horizontal duct surfaces were weighted. Assuming the same dust concentration on all similar surfaces result in a total amount of 4,6 kg of dust. There is rather good agreement in the estimated and the weighted amount of dust. The higher weight may be explained by dust which entered the system during the shut off time when the air moves backwards by natural convection and transports dust from the hall into the plenum.

The hygienic investigation of the components began with the spray humidifier. First there is a malfunction during shut off time. The heater is ran with an increased water temperature of almost 90 °C to prevent freezing. Simultaneously the water in the humidifier is heated up to 38 °C, pretty conditions for the growth of bacteria. A water test showed 10 legionella/ml. Inspite there were not more then totally 1000 CfU/ml (CfU - Colony forming Units) in the water.

## INFLUENCE OF THE AIR HANDLING ROOM TO THE AIR QUALITY

An inspection of the air handling unit showed that air is sucked from the air handling room into the unit by leakages. The supply fan motor is outside the unit driving the fan by an V-belt. The opening is not airtight and an air flow of 880 $m^3/h$, more then 1/10 of the desinged air flow rate flowing from the machine room into unit.

Furthermore an air flow moved by buoyancy against the normal flow direction takes place, when the system is not in operation. The main reason for the buoyancy is the vertical exhaust air duct, the temperature difference between the machine room and the lecture hall and the malfunktion of the dampers. The air flows from the lecture hall passed plenum to the unit. By this air movement dust is transported to the plenum and the unit. Both effects spoil the air quality in the lecture hall.

## PERCEIVED AIR QUALITY

Some first efforts have been done to estimate evaluations of the perceived air quality. Each component of the air-conditioning system is judged by a method proposed by Fanger (2). The perceived air quality is estimated by an untrained panel of about 18 persons. The set up for the investigation is shown in Figure 2.

The dampers are closed and sealed. An auxiliary fan supplies a reduced outdoor air flow rate into the unit. Therefore a small overpressure exits between the unit and the machine room and no additional fan is nessesary for the sniffing cones placed at the different components. For the comparision of the estimated Dezipol-values with the known "milestones" a box which is connected to the outdoor air is provided. Outdoor air is sucked through the box by underpressure in the machine room by running the exhaust air fan and opening the unit to the machnie room. After each component sniffing openings enable to estimate the air quality. By this procedure it is possible to determine the Dezipol-values in the parts of the system.

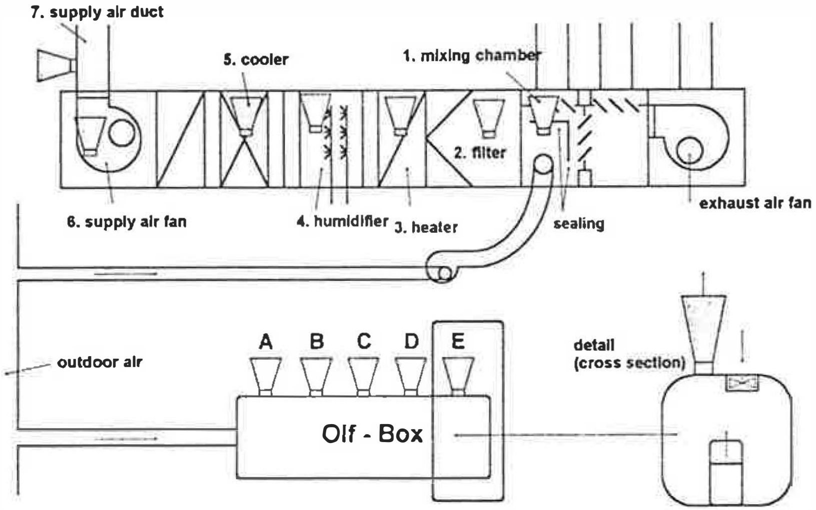
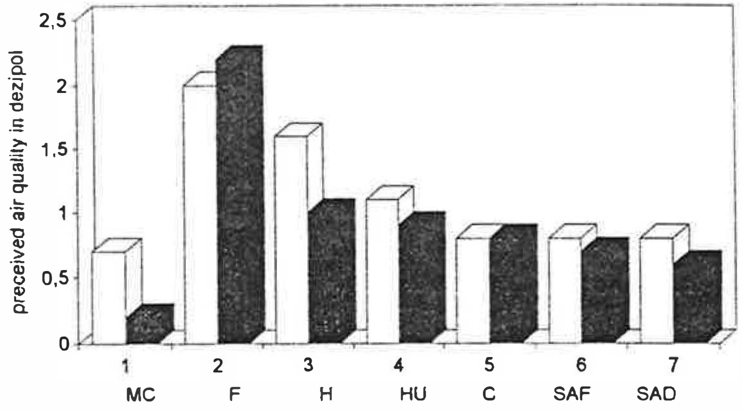



Fig. 2. Set up of the investigation of pollution sources in air-conditioning systems.

First results of this measurements are shown in Figure 3. The figure shows two estimations of preceived air quality on the components of the air-conditioning system. The measurements were done on different days with a panel of 18 and 12. The main pollution source of the system is the filter. This is a equal result compared to Clausen (6). The humidifier was during that measurements not in operation.

Explaining the result there is an decay of perceived air quality over the system after the filter. A similar result was discribed by Bluyssen (5). To verify this further work has to be done especially about the decay of perceived air quality after the pollution source.



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|---|---|---|---|---|---|
| MC | MIXING CHAMBER | HU | HUMIDIFIER | SAD | SUPPLY AIR DUCT |
| F | FILTER | C | COOLER | | |
| H | HEATER | SAF | SUPPLY AIR FAN | | |

Fig. 3. Perceived air quality of the air-conditioning system, 2 series

## CLEANING THE SYSTEM

The air duct surfaces are still in a good conditions. Only some dust and installation material is found. There was no corrosion at the inner surface of the ducts.
The system is cleanable by using an vacuum cleaner or a shred. With the help of these simple techniques a good cleaning quality can be achieved.

The plenum under the lecture hall has to be cleaned basicly and the surfaces have to be equiped with an abrasionproof covering. The same procedure is nessesary for the inner surfaces of the unit. They have to be abrasionproof and the cleaning conditions will be improved.

## CONCLUSIONS

To improve the air quality in rooms it is nessesary to know the pollution sources in the system. One pollution source is the dust sedimenting in the unit components. It was found that there are 4,6 kg of dust in the investigated air-conditioning system. This amount of dust deposited during an operating time of totally 50000 h. This pollution source was eliminated by using an vacuum cleaner or a shred.

First investigations on perseived air quality showed a good agreement with the results of Clausen (6). In result the filter is qualitativly the main pollution source in the view of air quality. In the components after the filter there is a decay of perceived air quality. Some further efforts should be done to explain this phenomena.

The knowlegde of the present system conditiones is important for the retrofitting of the unit. The following measures should be carried out to improve the air quality. At first there is the reducing of the amount of air by using only outdoor air. The recirculating air should not be set in because of air quality problems. Furthermore the plenum and the inner surfaces of the units needs a abrasionproof surface to prevent dust deposits and improve the cleaning possibilities. The humidifier and the filter has to be changed, because of the conditions in the components. If the leakages are closed and the dampers are in good conditions the main problems of the system

## ACKNOWLEDGEMENTS

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# STUDY ON CONTAMINATION CONTROL OF AIRBORNE PARTICLE FROM AIR CONDITIONING SYSTEMS IN JAPANESE BUILDINGS

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## ABSTRACT

Field studies were carried out on air contamination by dust particles from air conditioning systems in four buildings in Tokyo area.

We tried to investigate contamination of airborne particle and surface contamination by sedimentary dust in air duct, and considered a matter in all its aspects that caused indoor air pollution.

1. Time variations of airborne particle concentrations at supply outlet were influenced by the operation of air conditioning system.
2. Specially, maximum concentration was showed at the first one of the day.
3. The test on the opening of the service port door showed most significant in crease of the particulate generation.

## INTRODUCTION

Seventy percent of modern buildings in Japan completed in and after 1970 are equipped with air conditioning systems.

It is, therfore, necessary from the standpoint of controlling indoor air pollution to examine the quality of air supplied through air ducts to rooms of buildings equipped with air conditioning systems with a view to determining the degree of contamination and its possible causes and developing effective countermeasures.

Taking a stand on the prevention of indoor air pollution, researchers such as Yoshizawa, Fujii, and Irie pointed out contamination within air conditioning systems including air ducts.(1)(2) But only a small number of researches seem to have been made in Japan on contamination in air transmission lines from air conditioning systems to individual rooms. A few reports have been published on in-duct contamination by dust particles; Sato(3), Fujii(4) and others identified sedimentary dust in air ducts, and studied dust within a duct line by location and influences of start-ups and stoppages of air conditioning systems. More recently, Kuroda, Yamaoka and others examined sedimentary dust in air ducts, and compiled a comprehensive report(5) on acarian, allergen and metals based on the investigation of selected subjects ranging from organisms, biological activity and constituents.

However, there are still few reports leading to indoor air pollution control measures or

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