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Pollution and Energy in Air Handling Units
Some Results of the European Project Airless

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POLLUTION AND ENERGY IN AIR HANDLING UNITS
SOME RESULTS OF THE EUROPEAN PROJECT AIRLESS

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ABSTRACT

The purpose of air handling units is to provide clean air into the buildings. Measurements have however shown that this was not always the case. Therefore, the European AIRLESS programme was started to identify the pollution sources in air handling units, to characterise these sources using measurement protocols developed on purpose, to propose measures to avoid or eliminate this pollution, and to assess the effect of such measures on the energy use.

It was shown that main pollution sources are the filters, oil residues in ducts, poorly maintained air humidifiers, and poorly installed rotating heat exchangers. In most cases, increasing the airflow rate does not improve the air quality downwind the polluting components, as if the pollution source intensity increases with the airflow rate.

Cooling energy may be important in office buildings, even in temperate climate. An efficient and cheap cooling strategy is to combine a mechanical ventilation system designed for the minimum hygienic airflow rate with night passive cooling using natural ventilation.

RESUME

L'objectif des installations de traitement d'air est de délivrer de l'air propre dans les bâtiments. Des campagnes de mesures ayant montré que ce n'était pas toujours le cas, le programme européen AIRLESS a été mis sur pied pour localiser les sources de pollution dans les installations de ventilation mécaniques, pour caractériser ces sources à l'aide de protocoles de mesures développés à cet effet, de proposer des mesures propres à éviter cette pollution et d'examiner les impacts énergétiques de ces mesures.

On a montré que les principales sources de pollution sont les filtres, les résidus d'huile dans les conduites, les humidificateurs mal entretenus et les échangeurs de chaleur rotatifs mal installés. Dans la plupart des cas, une augmentation du débit d'air n'améliore pas la qualité de l'air en aval des composants, comme si l'intensité de la source de pollution augmentait avec le débit.

Les besoins en refroidissement peuvent être importants dans les bâtiments administratifs, même en climat tempéré. La combinaison d'une ventilation mécanique minimal hygiénique avec le refroidissement nocturne passif par ventilation naturelle semble être une méthode de refroidissement efficace et économique.

INTRODUCTION

The European AIRLESS project started in 1997 and ended in March 2001 [1]. Six academic institutions, two national research laboratories and four industrial partners collaborated to this project. The project AIRLESS focused on developing strategies, principles and protocols to

improve and control the performance of HVAC-systems and its components for incorporation in codes and guidelines.

Former experiments have shown that the air is polluted when passing through air handling units (AHU). The first step in this project was then to define this pollution and to investigate ways to prevent this pollution. In the second step, protocols were defined to keep this pollution away. Strategies to decrease the pollution caused by a total HVAC-system together with strategies to lower the energy consumption were defined. And finally, dissemination and exploitation activities were executed.

There is not enough place here to present all results. Some of them, in particular the DAHU diagnosis methodology to characterise air handling units were already presented at CISBAT [2]. We will therefore focus this presentation on pollution sources in air handling units and on energy effect of some of the investigated options.

SOURCES AND CAUSES OF POLLUTION IN HVAC-SYSTEMS

In normal comfort ventilation systems the filters and the ducts seem to be the most common sources of pollution, especially for odours. Humidifiers and rotating heat exchangers may be remarkable pollution sources if not constructed and maintained properly. The pollution load caused by the heating and cooling coils seems to be less notable.

The effect of airflow on the pollution effect of HVAC-system components seems to be less important: doubling the airflow rate does not change much the pollutant concentration downwind the components. It can be deduced that the pollutant source strength increases in proportion with the airflow rate.

Filters

Filters are one of the main sources of sensory pollution in ventilation systems. Some new filters generate disturbing odours (Figure 1). The pollution of new filters decreases after some time of use but, when filters are in use for some time, the pollution increases again. The reason for this is still unclear. Environmental conditions such as airflow (amount or intermittent/continuous) and temperature did not have an influence on the pollution effect.

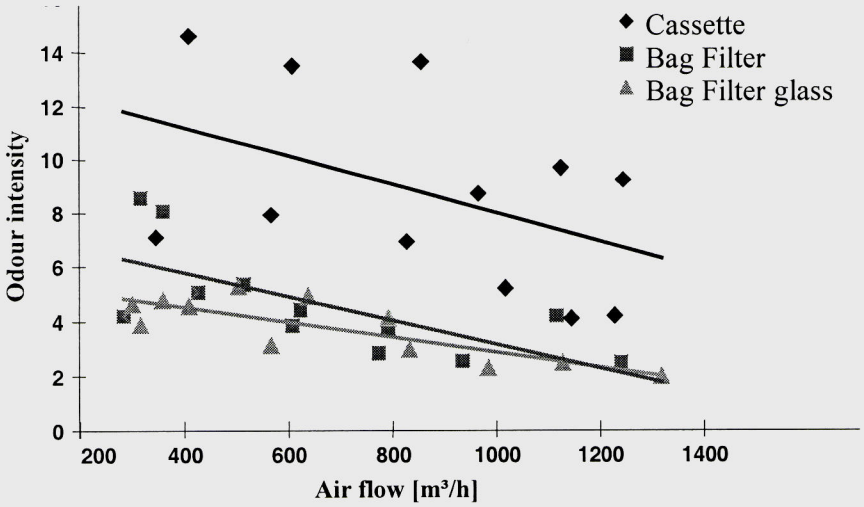

Figure 1: Comparison of different new filters (filter class F7).

Ducts

The duct material and the manufacturing process had the biggest effect on the perceived air quality. Depending on the machinery used in the manufacturing process, new spiral wound ducts; flexible ducts and other components of the ductwork might contain small amounts of

processing oil residuals. The oil layer is very thin and invisible, but it emits an annoying odour. The sensory assessments showed a clear correlation between the total mass of oil residuals (average surface density × surface area) and the odour intensity (Figure 2)[3].

Emissions from dust/debris accumulated in the ducts during construction (mostly inorganic substances) seem to be less important. The effect of airflow on the perceived air quality from ducts was relatively small and is probably insignificant in normal applications.

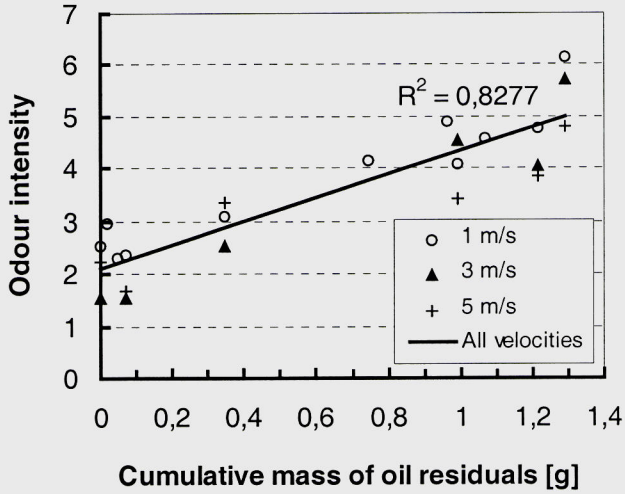

Figure 2: Correlation between the odour intensity and the mass of oil residuals in the tested ducts.

Humidifiers

The main reasons of pollution from humidifiers are: Disinfecting additions, old water in tanks and/or dirty tanks, microbiological growth, stagnant water in the tank, and desalinisation and demineralisation devices/agents (if used).

Humidifiers only pollute the air significantly if the humidifier is not used in the prescribed way and/or if it is not properly maintained. Periodical cleaning of humidifiers is an absolute must, as is the use of fresh water. Under normal conditions, it was found for all humidifiers that the airflow has no influence on the odour intensity caused by humidifiers.

A relation was found between the perceived air quality and the concentration of bacteria on the inside of the humidifier[4]. The odour intensity increases with increasing number of bacteria. This was not the case for other locations in an HVAC-system. A similar correlation could not be found for fungi.

Rotating heat exchangers

Rotating heat exchangers may transfer contaminants from exhaust to supply with entrained air, through possible leakage around the wheel at the separation wall, and by adsorption-desorption on the inner surfaces of the exchanger's wheel.

Leakage from exhaust to supply was measured in several units, and found negligible in most cases. Leakage and pollutant transfer can be avoided or at least strongly reduced through a proper installation of the wheel, good maintenance of the gasket, proper installation of a purging sector, and by maintaining a positive pressure differential from supply to exhaust duct at wheel level.

Significant amounts of VOCs are transferred when the purging sector is not well used. Even when it is well installed, certain categories of VOCs are easily transferred by a sorption transfer mechanism. Among the tested VOCs, those having the highest boiling point were best transferred.

Coils

The results showed that heating and cooling coils without condense water or stagnating water in the pans, are components that have small contributions to the overall odour intensity of the air. On the contrary, cooling coils with condense water in the pans are microbial reservoirs and amplification sites that may be major sources of odours to the inlet air.

INFLUENCE OF VARIOUS OPTIONS ON ENERGY USE

The main objective of the energy part of the study was to assess the impact on energy consumption of the use of natural and mechanical ventilation in administrative buildings, and to develop general recommendations.

The TRNSYS simulation environments, including purpose developed modules, was used to perform that study.

First, representative parts of a modern administrative building have been modelled with TRNSYS. The three-storey building, has offices facing south, and an atrium at the North (Figure 3).

In order to be able to assess natural as well and mechanical ventilation, complementary approaches have been used. A specific natural ventilation module (Figure 4) as well as a specific mechanical ventilation module (Figure 5) have been developed respectively by EMPA and by SORANE.

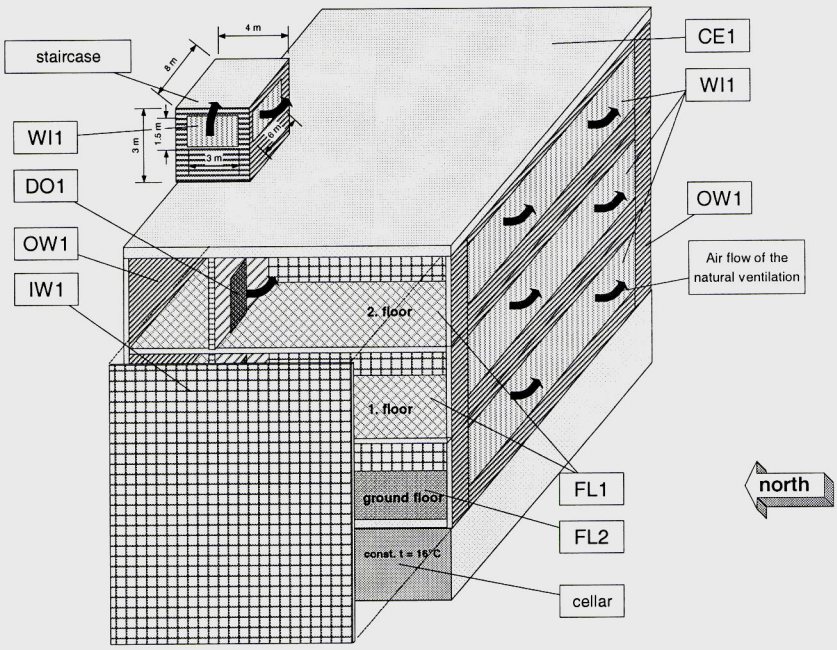

Figure 3: Representation of the simulated building

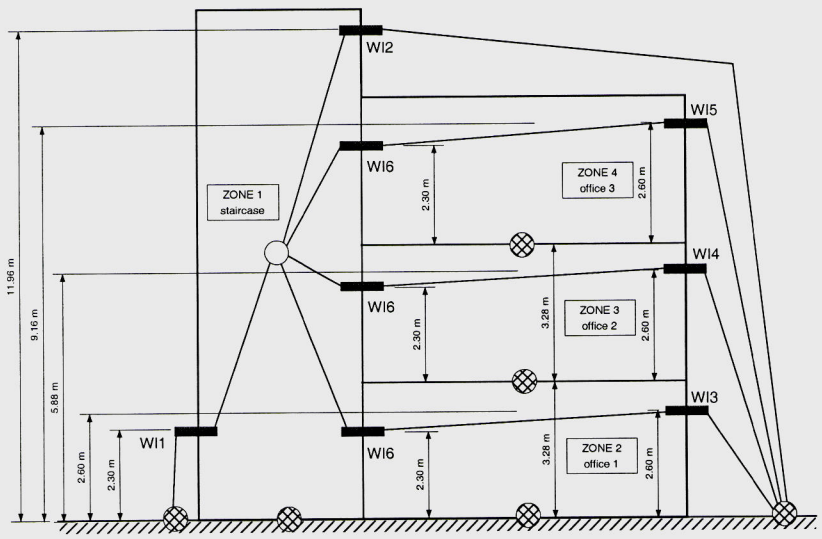

Figure 4: Natural ventilation network simulated with COMIS coupled with TRNSYS building model

The developed configuration allows to compare in a systematic manner mechanical and natural ventilation strategies in various climates, and various conditions.

For the mechanical ventilation systems, the main parameters studied were: air flow rates, humidity, heating and cooling energy, use of heat recovery, losses by infiltration. For natural ventilation, night ventilation cooling was added. The building structure characteristics were also taken into account by simulating with and without false ceiling.

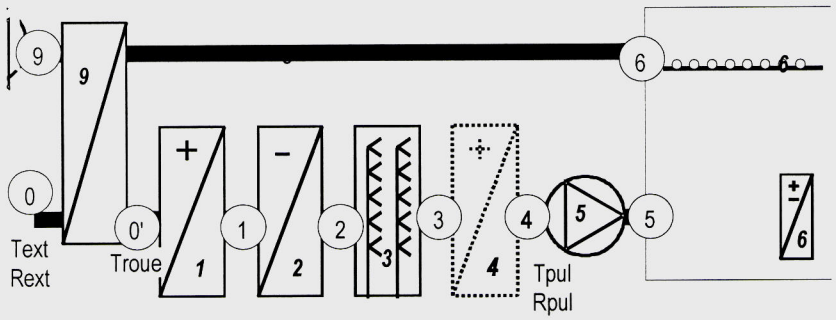

Figure 5: Schematics of the HVAC unit developed for TRNSYS and coupled with TRNSYS building model

For building with high performance envelope, and low air flow rate for high energy efficiency, it is not possible to remove the heat accumulated during the day when the ventilation does not operate at night. Hybrid solutions allowing to cool the building naturally at night are therefore recommended. (see for instance case 1) against case 7), and 8) on figure 6). Under northern climate, a naturally ventilated building (at least at night) shows lower temperature distribution than a low flow mechanically ventilated building. It is also important to notice that, since the gains during the occupation are sufficient to heat the building, the heating energy consumption is not higher for the naturally ventilated building.

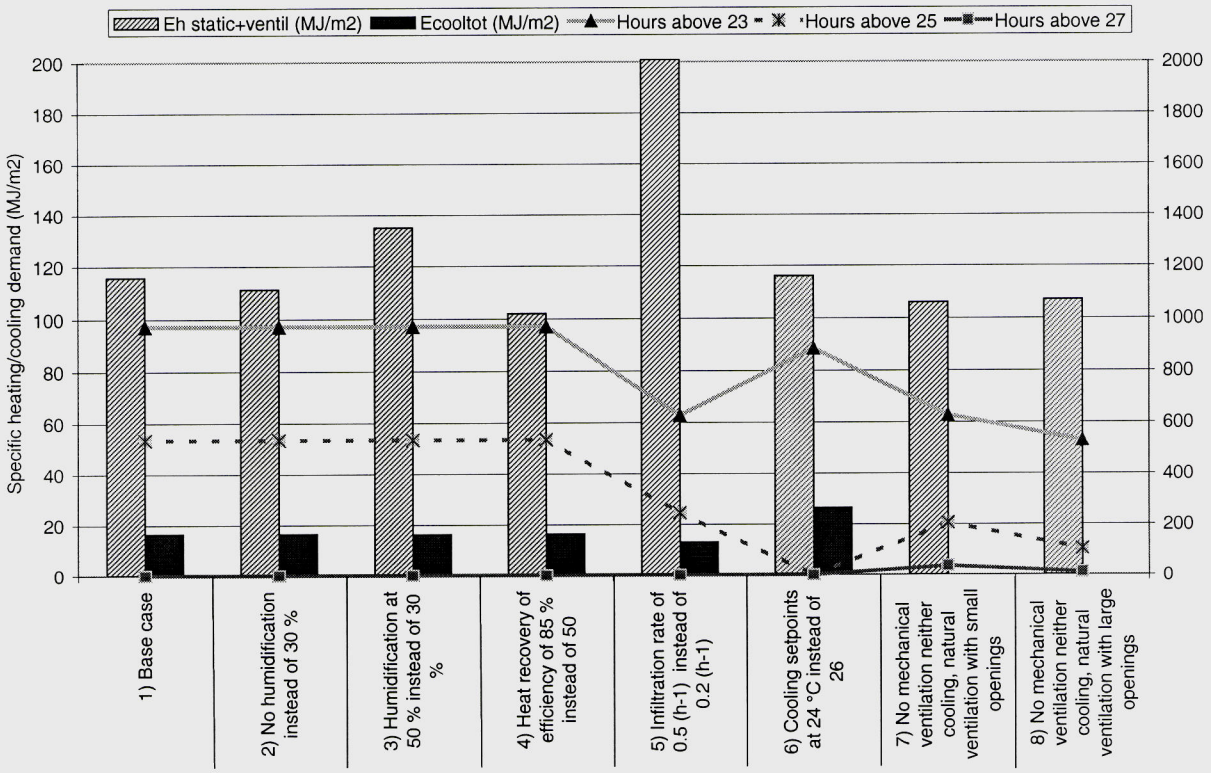

Figure 6: Energy use and comfort conditions for several ventilation strategies (1) Base case: Mechanical ventilation during occupation of 25 m^3/h-pers, humidification to 30%, heat recovery efficiency of 50%, infiltration rate of 0.2 (h-1), cooling to 26 °C, other are variations of the base case.

Other important findings are:

- Humidification is an significant energy consumer. Humidifying to 50% instead of no humidification may increase the heat demand by more than 30% (see for instance case 3) against case 1), and 2) on figure 6).

- Another very important parameter for actively cooled buildings is the cooling set point, which, when reduced from 26°C to 24 °C increases the cooling energy by a factor 3 (see for instance case 6) against case 1) on figure 6).
- Thermal inertia can only be used when the night natural ventilation helps in cooling the building structure.
- Building envelope tightness is the most important parameter. A leaky envelope can more than double the heating energy use (see for instance case 5) against case 1) on figure 6).

CONCLUSIONS

The results of the AIRLESS project were not just meant to be of a scientific character but were thought, and most of them also planned, to become tools for the intervention in the real world of the design, commissioning and maintenance of HVAC-systems for better IAQ.

From the point of view of **source control**, the first aim was to characterise the HVAC-components as potential pollution sources, and to understand why and how some components are more important as pollution sources than others. Protocols to assess the degree of cleanliness of the different components and to define a strategy for clean HVAC-systems are published. Then, the final aim was to be able to give relevant inputs to better design, better commissioning and better maintain air-handling units, under the IAQ perspective.

From the **ventilation** point of view, the issue was to evaluate what is the contribution of the HVAC-systems for the pollution load in a given space, in parallel with the occupants and the materials, and to determine what is the appropriate level of ventilation to cope with that load in order to keep the levels of indoor pollutants below a certain threshold. This requires the knowledge of the nature of the pollutants and the quantification of the pollutants emitted.

From the **energy aspect,** it was found that envelope air tightness is paramount for achieving good ventilation at low cost. Humidification and mechanical cooling are significant energy users. Mechanical ventilation, when used in conjunction with night natural ventilation for night cooling, can ensure a low flow hygienic air change, without the necessary high intensity cooling. In many cases, when applicable, naturally ventilated buildings do present similar heating demand than low flow mechanically ventilated systems and smaller electricity consumption.

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