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MEASUREMENT OF AIR FLOW RATES AND
VENTILATION EFFICIENCY IN AIR HANDLING UNITS

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ABSTRACT

Air handling units do not always function as planned: airflow rates are often larger than required, the recirculation rate is not at its set-point value and parasitic shortcuts sometimes decrease dramatically the ventilation efficiency. A dedicated diagnosis, based on the tracer gas dilution technique can easily detect such dysfunction, and help to cure the defects.

Within the framework of national and European projects, a measurement protocol, which includes the planning of measurement and the interpretation algorithms, was developed on the basis of years of practice in such measurements and implemented in a user-friendly computer program. The protocol was applied to several air handling units in various buildings. This contribution presents the method applied, the principles used in the test protocol, and some measurement results.

RÉSUMÉ

Les unités de traitement d'air ne fonctionnent pas toujours comme prévu. Les débits d'air sont souvent supérieurs au débit nécessaire, le taux de recirculation n'est pas à sa valeur de consigne et des court circuits parasites diminuent parfois dramatiquement l'efficacité de la ventilation. Une méthode de diagnostic utilisant la technique des gaz traceurs permet de détecter facilement ces défauts, et ainsi aider à y remédier.

Un protocole de mesure, basé sur des années d'expérience et comprenant la planification des mesures et les algorithmes d'interprétation, a été développé dans le cadre de programmes de recherches nationaux et européens. Ce protocole, traduit en un logiciel convivial, a été appliqué à plusieurs unités de traitement d'air dans différents bâtiments. Cette contribution présente la méthode, les principes de mesure et quelques résultats de mesures.

INTRODUCTION

It was found that air handling units seldom function as planned: airflow rates are not those required, recirculation rate is not at its set-point value and parasitic shortcuts sometimes dramatically decrease the ventilation efficiency [1][2].

Diagnosis tools would therefore be useful to detect dysfunction, preferably before or when commissioning the air handling unit. Velocity measurements using Pitot tubes are often used for that purpose. Such techniques, however, can be applied only in long straight ducts, seldom found in technical rooms. In addition, only main airflow rates are measured that way, while many other airflow paths may be found in an air handling unit, as shown in Figure 1.

The tracer gas dilution method is used since several years for diagnosis of air handling units [3][4]. It has the advantage of being applicable on any unit and to allow the detection and quantification of unexpected air flows, such as leaks or shortcuts. Practical application of this technique is however not straightforward, since each air handling unit has its own set-up and characteristics, and several precautions should be taken to avoid measurement or interpretation errors. Therefore, a measurement protocol, which includes the planning of measurement and the interpretation algorithms, was developed on the basis of years of practice in such measurements and implemented in a user-friendly computer program.

METHOD

Measurement technique

The technique is described in more detail elsewhere [3], [5]. Tracer gases are injected, most often at a constant flow rate, at carefully chosen locations in the air handling unit. Experience has shown that most practical and efficient injection locations are as indicated in Figure 1.
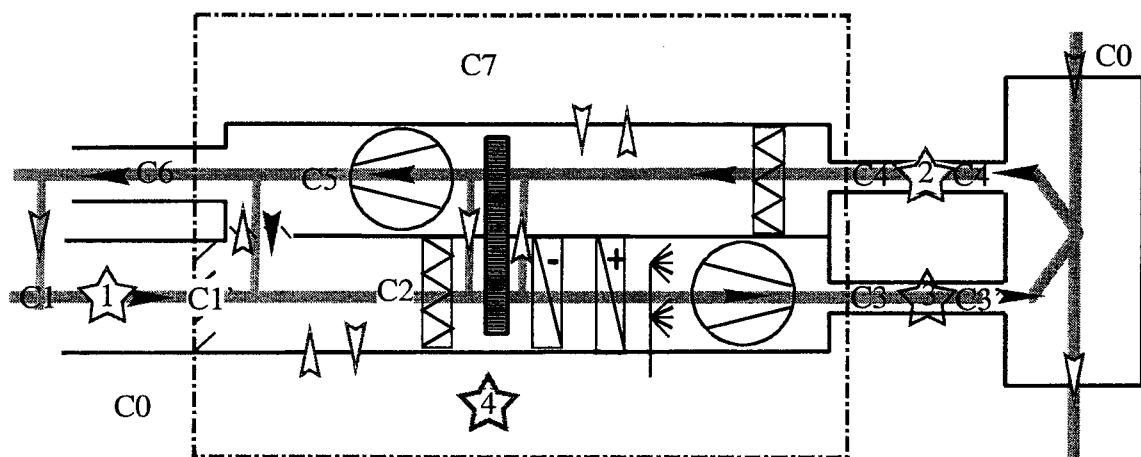

Figure 1: Schematics of an air handling unit showing main and secondary airflow paths (arrows), tracer gas injection (stars),and sampling points for concentration measurements (C_i). The equivalent network used to derive equations of system (1) is also shown.

Tracer gas concentrations are measured at various locations, in order to obtain enough equations from conservation of airflow and tracer gas flows to determine all required airflow rates. The practical procedure is as follows:

1. Analysis of the air handling unit, in order to define the list of airflow rates to assess and the non existent air flows. If some of the airflow rates, in particular the leakage and shortcut air flows, are known to be zero, the measurement can be greatly simplified.

2. Determine the number of tracer gases, the tracer injection points, and the air sampling locations. If less than three tracer gases are used, some of the airflow rates shown in Figure 1 will not be determined.

3. Inject the tracer gases and measure their concentration in air samples until reaching steady state. Check the tracer gas mixing by moving some sampling locations.

4. Interpret the measurements.

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INTERPRETATION

Conservation of air and tracer gas mass flows at each node shown in Figure 1 provides a system of linear equations, assuming steady state and perfect mixing of tracer gas at sampling locations [5]:

$$\vec{I} = C \cdot \vec{Q} \qquad\qquad 1$$

where:

C is a matrix, containing the tracer gas concentrations measured at the various locations

$\vec{I}$ is a vector containing the tracer gas injection rates;

$\vec{Q}$ is a vector of the airflow rates to be determined.

Depending on the number of tracer gases injected and on the number of sampling locations, this system may contain more equations than unknowns. Several possibilities to take advantage of this situation were tested. The most robust method, providing the most accurate results, was found to select the sub-set of N equations (N being the number of airflow rates to be determined) which provide the required airflow rates in the most direct way, that is using the smallest number of input variables in each equation.

Noting the injection starting time of tracer gas 1 and recording the evolution of tracer gas concentration in the exhaust duct versus time allows the assessment of the mean age of air and the air exchange efficiency in the ventilated space [3], [6].

RESULTS

Several air handling units were measured with this technique, and some results are given below to illustrate the usefulness of this technique.

EXAMPLE OF MEASUREMENT

Figure 2 shows the evolution of concentrations of tracer gas (sulphur hexafluoride) injected at constant flow rate in the outdoor air duct from 10:27 to 11:45. Much information can be readily obtained from this figure.
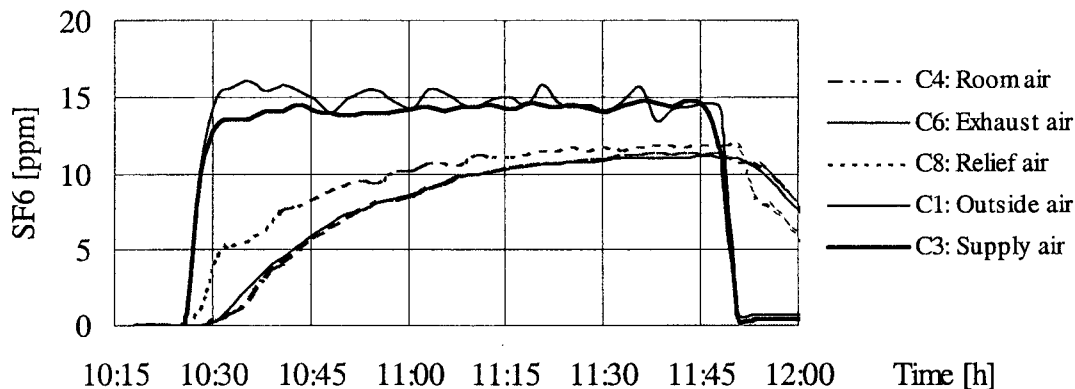

Figure 2: Evolution of concentrations of tracer gas injected at constant flow rate in the outdoor air duct.

Concentration in outside air and supply air quickly reach the steady state, the small fluctuations resulting from imperfect mixing. Since outdoor concentration of that tracer is negligible, the ratio of the tracer gas injection rate to the concentration directly gives the outdoor airflow rate (in this case, 9400 m³/h). The slow growing exhaust air concentration, identical to room air concentration, allows the determination of the room mean age of air (17

minutes), and reaches at steady state a value significantly lower than in the supply air. This indicates that extra outdoor air is added to room air, either by infiltration or by another air handling unit (this building has four units). The fast growing concentration in relief air, as well as a concentration slightly higher than in exhaust duct indicates a shortcut between outdoor air and relief air. Another tracer injected in the exhaust duct allowed the determination of all main airflow rates and the detection of bi-directional leakage through the rotating heat exchanger. Note that only this unit, out of four identical ones, has shown this dysfunction: rotating heat exchanger do not leak when properly installed.

RESULT OF MEASUREMENT CAMPAIGNS

28 air handling units located in fourteen buildings were measured during several measurement campaigns [1, 7]. Design and measured recirculation rate are compared in Figure 3. These are seldom equal. Note that in eight units out of 20 planned without recirculation have shown significant, but unexpected recirculation. These leaks strongly reduce the indoor air quality by mixing return air to supply air.
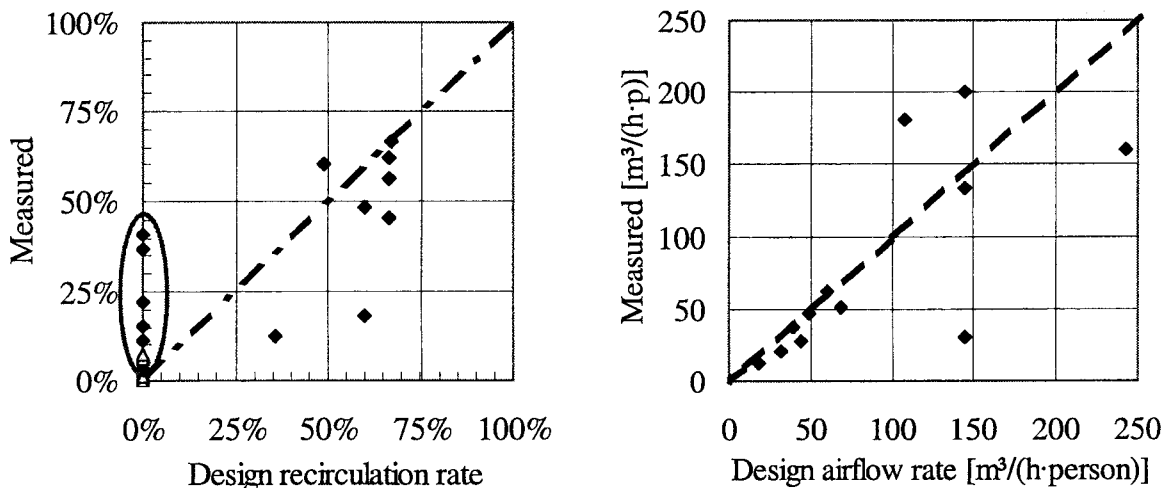

Figure 3: Comparison of design and measured recirculation rate in 28 air handling units.

Figure 4: Design and measured outdoor airflow rate per person in 12 buildings.

The comparison of design and measured outdoor airflow rate per person in 12 buildings is shown in Figure 4. It can first be seen that in several buildings the airflow rate per person is larger than 50 m³/h, and even overpasses 200 m³/h in one building.

Measured supply airflow rates differ from design ones in many buildings, as shown in Figure 5. The relative difference between measured and design outdoor airflow rate range from - 79% to + 54%. Only eight units are within the ± 10% range.

In principle, supply and exhaust airflow rates are either balanced, or put the building under a slight overpressure. When the envelope is not airtight, and when the balance between supply and exhaust air is too large, air leaks through the envelope. This has not much influence on indoor air quality, but may strongly decrease the efficiency of the heat recovery. In six units, more than 50 %of the supplied air is lost that way.
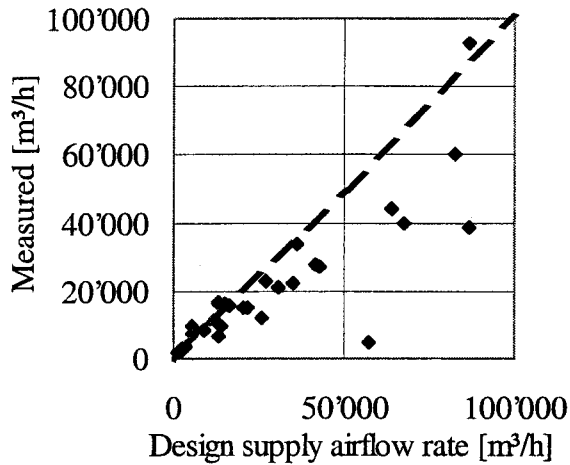
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Figure 5: Measured and design supply
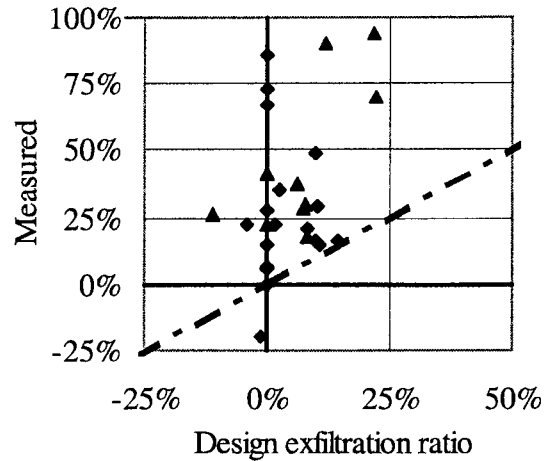airflow rate in 28 air handling units.

Figure 6: Exfiltration ratio, that is part of the
supply air not coming back in extract duct, in
28 units.

FAN EFFICIENCY

The power global efficiency of fans was measured in several units. It is the ratio of the
mechanical power of the air, which is the product of airflow rate by the pressure difference
across the fan, to the electrical power used by the fan. Important is to measure all these
quantities, since design values are not always achieved, as shown in Figure 7.

Figure 8 shows that the global fan efficiency grows, as expected, with the fan measured
power. There are however significant differences between fans within the same power class.
For example, fans with 350 to 550 W have an efficiency between 14% and 32%, the best
using the smallest power. In the 1300 to 1700 W class, the efficiency also varies between 15%
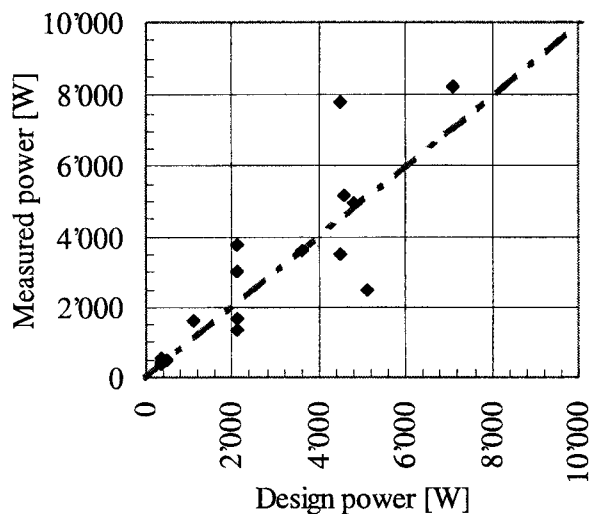and 38%, and so on. Even in the 5000 to 7000 W, there are variations from 55% to 80%.

Figure 7: Measured electrical power of fan
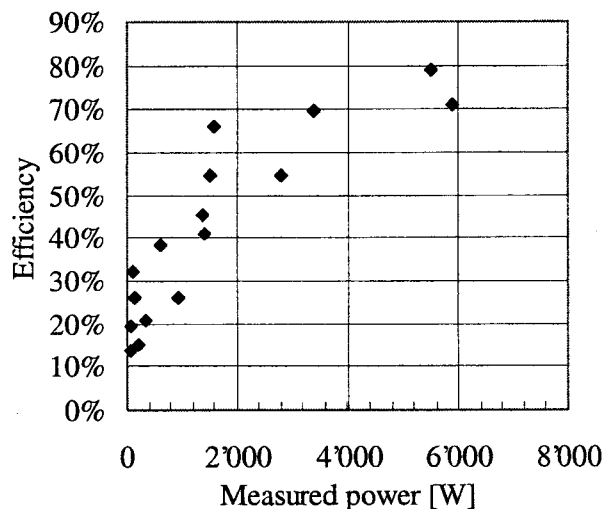motors compared to design values

Figure 8: Global fan efficiency compared to
measured power.

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DISCUSSION

Measurements on a series of air handling units clearly show that commissioning of these units should be greatly improved, in order to ensure that design airflow rates are achieved, and that no parasitic airflow such as leaks or shortcuts occur. It should be emphasised that air handling units presenting the best results, very close to design values were carefully commissioned.

Tracer gas dilution technique, when properly applied, allows an easy assessment of main airflow rates, the detection and quantification of leakage and shortcuts, and also the determination of the mean age of air and the air change efficiency in the ventilated space.

There are however many types of air handling units, and each new measurement poses new problems. It is hence impossible to write a detailed measurement protocol valid for all types. Therefore, a computer program to help in planning and interpreting such experiments was developed. It helps with the proper choice of the tracer gas injection and air sampling locations, and computes the injection rate in a way adapted to the type of air handling unit and to the users' requirements. Furthermore, it includes the measurement of the global ventilation efficiency in the space controlled by the air-handling unit and an energy efficiency assessment.

ACKNOWLEDGEMENTS

REFERENCES

1. Bluyssen, P. M.; de Oliveira Fernandes, E.; Fanger, P.O.; Groes, L.; Clausen, G.; Roulet, C.-A.; Bernhard, C.-A.; Valbjorn, O.(1995): European Audit Project to Optimise Indoor Air Quality and Energy Consumption in Office Buildings. Final report of Contract Jou2-CT92-022, TNO Bouw, Delft (NL).

2. Roulet, C.-A; Foradini, F. and Cretton, P. Use of tracer gas for diagnostic of ventilation systems. Proc. of Healthy Buildings '94 conference, Budapest(1994), Vol 2, pp 521-526.

3. Roulet C.-A.; Vandaele, L: Air Flow Patterns within Buildings – Measurement Techniques. Technical note 34, AIVC, Coventry, 1991.

5. Roulet C.-A.; Foradini F; and Deschamps L.: Measurement of Air Flow Rates and Ventilation Efficiency in Air Handling Units. EPIC'98 conference, Lyon, 1998, Vol 3, p 970-975

6. Sandberg, M.; and Sjöberg, M. (1984): The Use of Moments for Assessing Air Quality in Ventilated Rooms. Building and Environment 18, pp181-197.

7 Roulet C.-A, Pibiri, M.-C and Foradini F.: AIRLESS Project - Results From Diagnosis of Air Handling Units. AIRLESS report, LESP, EPFL, 1999