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FIELD EXPERIENCES OF AIRBORNE MOISTURE TRANSFER IN RESIDENTIAL BUILDINGS

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SYNOPSIS

This paper deals with field experience of airborne moisture transfer problems in houses. Two types of phenomena are discussed in more detail: the infiltration of moist air from crawl spaces and the propagation of moist air produced in kitchens. A modified depressurisation test is described to determine the air tightness of ground floors. A case study is briefly discussed where different remedial measures have been tested to evaluate the moisture removal effectiveness in kitchens. A multi-channel dewpoint measurement system has been used to determine the ventilation efficiency experimentally.

1. INTRODUCTION

During the last few years we experienced a growing interest for moisture problems in houses. In many cases we were involved in investigations requested by building owners. The surveys we carried out were very practical and were directed to the determination of the cause of the problems and the solution for remedial actions.

The most common type of moisture problem is mould growth on wall surfaces and furniture, caused by surface condensation. Although the mechanism of surface condensation is fairly well understood, it is not easy to establish adequate proposals for cost-effective remedial actions. Surface condensation and the associated mould growth can be generated by a complex interaction of different factors, such as:

- low thermal quality of the building envelope (e.g. thermal bridges);
- insufficient ventilation;
- excessive moisture sources.

In addition to these the behaviour of the occupants may play a crucial role.

In a number of field surveys we were able to study the moisture balance in houses in more detail. In some cases the special interest was directed to airborne moisture transfer. Two distinct moisture sources are of particular importance when considering airborne moisture transfer:

- infiltration of moist air from spaces under suspended floors (in many countries denoted as crawl spaces) to living areas;
- moist air originating from water vapour producing activities in kitchens.

In this paper we will present some field experience related to these two items.

2. MULTI-CHANNEL DEWPOINT MEASUREMENT SYSTEM

The multi-channel dewpoint measurement system proved to be a very

powerful instrument to study airborne moisture transfer. The principle of the system is outlined in figure 1. The system has been developed at our institute and it has been used in several case studies.
An important feature of the dewpoint measurement system is its ability to detect accurately small differences of vapour concentration between two locations. Because a single sensor is used for all measuring locations, an accuracy of 0.05 g/kg is achieved when measuring the instantaneous difference in vapour concentrations at different points. In general vapour concentration gradients in a single room are very small and can be detected only by a system as described above.

3. AIRBORNE MOISTURE TRANSFER FROM CRAWL SPACES

Crawl spaces below the ground floor are very common in the Netherlands. In a large part of the country it is also common to find the ground water level only a few centimeters below the crawl space bottom surface and in some regions an open water surface is present during a large period of the year. Hence, it is not surprising to find high humidity levels in crawl spaces. A relative humidity of RH = 95% is quite normal. Figure 2 shows the dynamic behaviour of the vapour concentration in crawl spaces as calculated by a computer model. It demonstrates that particularly in the winter period the excess vapour concentration will be high. It is believed that many mould problems in Dutch houses are related to moisture transport from crawl spaces. Field studies have shown that infiltration of moist air through air leakages in the gound floor construction is the most important mechanism. A simple calculation here might demonstrate the potential risks. During the winter period the excess water vapour concentration in crawl spaces can exceed 5 g/m^3 (with respect to outdoor air). Due to the stack effect the crawl space has always an overpressure with respect to the living space. For a typical overpressure of 3 Pa and a relatively small air leakage area of 5 x 5 cm^2 the airborne moisture contribution to living area will be about 2.5 kg moisture per 24 hours. From field experiences we know, however, that air leakages in ground floors very often are larger than the 25 cm^2 used in the example.

3.1 Air tightness of ground floor constructions

In the past little attention was paid to the air tightness of ground floors. In the near future new building regulations will be established, in which requirements will be stated for a certain level of air tightness of ground floor constructions. Hence, test methods will be needed to determine the level of air tightness. Conventional pressurisation techniques are not applicable for ground floors.
Therefore, we developed a modified depressurisation test that is enable to measure the air tightness of ground floors. The principle of this test method is outlined in figure 3. The method

is based on the measurement of the increasing vapour concentration due to the infiltration of moist air through the ground floor during depressurisation.

4. MOISTURE IN KITCHENS

The household activities in the kitchen lead to the most important moisture source in houses. Due to cooking and dish washing an amount of 1 to 4 kg moisture per day can be produced. In properly ventilated kitchens, which are separated from the rest of the house, no problems will occur. However, in practical situations kitchen moisture can easily move to other rooms. This is in particular true in cases where the kitchen is in open connection to other zones.

4.1 A case study

We studied airborne moisture in a case study requested by a building owner. The measurements were made in an occupied house from a stock of 150 single family terraced houses. A high percentage of these houses suffered from mould problems. From an introductory survey it was concluded that ineffective moisture removal from the kitchen was a major point. The kitchen in these houses is in open connection with the living room. An exhaust opening connected to a mechanical ventilation system was present as outlined in figure 4.
A test house was selected in which several remedial measures were tested. With respect to airborne moisture problems the following experiments were accomplished (see figure 5):

1. Replacement of the flueless gas-fired DHW-supply (Domestic Hot Water) by a closed system.
2. Installation of a fume hood exhaust connected to the mechanical ventilation system.
3. Installation of a vapour shield to reduce the moisture transfer from the kitchen.
4. Improvement of the ventilation balance and the fresh air supply.

4.2 Moisture removal effectiveness

During these tests the moisture removal effectiveness was evaluated using the dewpoint measurement system described before. A commonly used figure of merit is the coefficient for the ventilation efficiency. In the case of moisture control the following definition could be used:

$$E = \frac{C_x - C_e}{C_i - C_e}$$

where:

E = the moisture removal effectiveness;

C_x = the water vapour concentration measured at the ventilation exhaust;

C_e = the water vapour concentration measured outdoor;

C_i = the water vapour concentration measured indoor at a relevant location.

For the case of a complete mixing of the moisture source with indoor air the effectiveness will be $E = 1$ (because $C_x = C_i$). In unfavourable conditions the coefficient may take value lower than $E = 1$. This occurs for example if "short circuiting" occurs between the fresh air supply and the exhaust opening (which will result in $C_x < C_i$). For situations where source ventilation is applied (e.g. using a fume hood exhaust) the value for E should be larger than 1 (the goal should be $C_x >> C_i$).
The definition for the ventilation efficiency as introduced before proved not to be very practical for our purpose. Variations in the outdoor humidity and moisture storage effects have a strong influence when determining the ratio E on the basis of vapour concentration measurements.
For our purpose we found that the effectiveness of moisture removal can be better evaluated by a figure of merit expressed by the following formula:

$$E = \frac{C_x - C_{ia}}{C_i - C_{ia}}$$

where C_{ia} is long term average (a 24 hour period is recommended) of the indoor vapour concentration. From a view point of moisture control this proved to be a useful figure of merit for the effectiveness of moisture removal.

4.3 Results and conclusions

To illustrate the moisture behaviour in the test house two 24-hour records of vapour concentration measurements shown in figure 6. These records show that vapour concentration gradients exist only during and after moisture producing activities. A surprising conclusion is that during nighttime an almost perfect equilibrium seems to be settled: all locations show exactly the same vapour concentration. Other conclusions from this case study associated with airborne moisture transfer problems were:

- Flueless gas heaters give rise to an important contribution to the moisture load (1 to 2 kg moisture per day).
- A ventilation scheme that uses a single exhaust opening is not very effective with respect to moisture removal in kitchens. Measurements have shown that complete mixing occurs and as a result of this humid air is propagated to other zones in the house.

- The installation of a vapour shield has very little impact on the moisture removal effectiveness. The effect is noticeable during moisture production peaks but the overall result is not significant with respect to the reduction of condensation risks.
- As expected the installation of a fume hood improves the moisture removal effectiveness, but not at a quite satisfactory level. Only 20% of the moisture produced in the kitchen is removed by source ventilation. Inadequate behaviour of the occupants with respect to the use of he fume hood and the opening of windows was found to be an important reason.
- By routine the occupants opened a window in the kitchen area during the household activities. In contrast to the anticipation of the occupants the effect on moisture removal appeared to be negative. Suggestions to open a window at the opposite façade resulted in air draught complaints.

DISCUSSION AND CONCLUSIONS

The paper discusses two types of airborne moisture transfer problems:
1. Infiltration of moist air from crawl space,
2. Moisture propagation from kitchens to other zones.

The crawl space problem can be solved by creating a sufficient air tight ground floor construction. Test methods are needed to evaluate the air tightness of ground floors. A feasible technique is described in this paper.

Moisture control in kitchens seems to be more difficult to handle, in particular when kitchens are in open connection with other zones. In new built houses balanced ventilation might be a satisfactory solution. In existing houses the moisture removal effectiveness from kitchens will highly rely on the use of the ventilation provisions by the occupants.

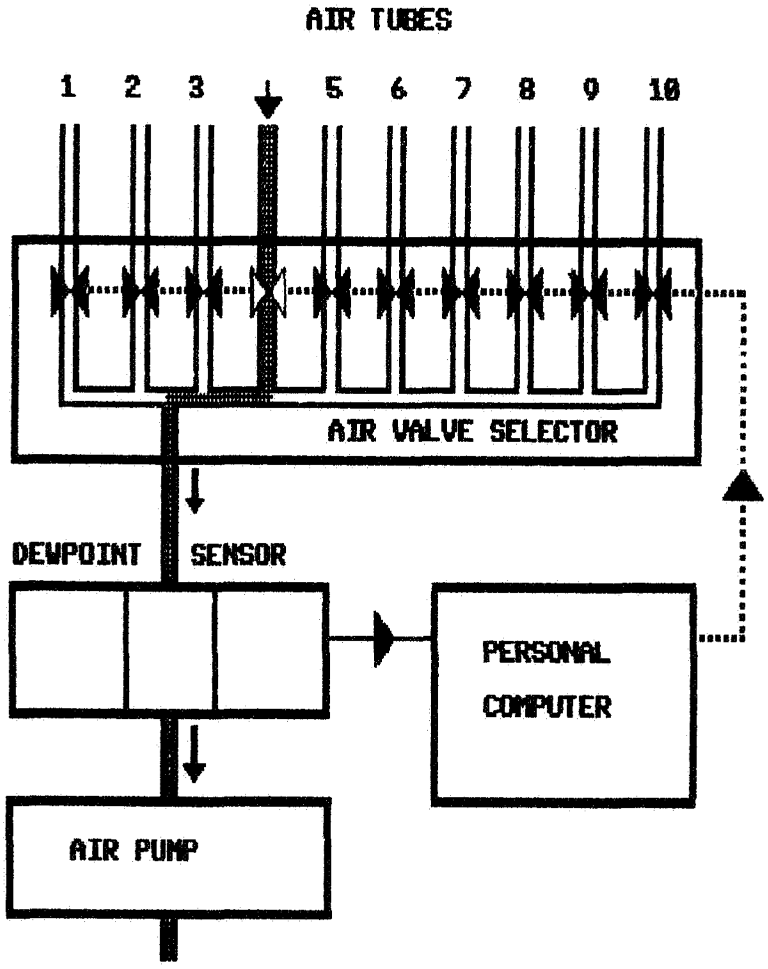


Figure 1: The multi-channel dew point measurement system.

This system is used in field studies on airborne moisture transfer for the monitoring of monitor indoor and outdoor air humidities. The operating principle is based on the measurement of the dew point temperature in air samples extracted through small air tubes from different locations in the house. The air valves in the selector box are controlled by a computer programme. The measuring locations are scanned within a few minutes, depending on the length of the air tubes. The computer also computes the water vapour concentration from the dew point temperature data (equivalent denotations are "air humidity by mass [g/kg]" or "air humidity" by volume [g/m^3]).

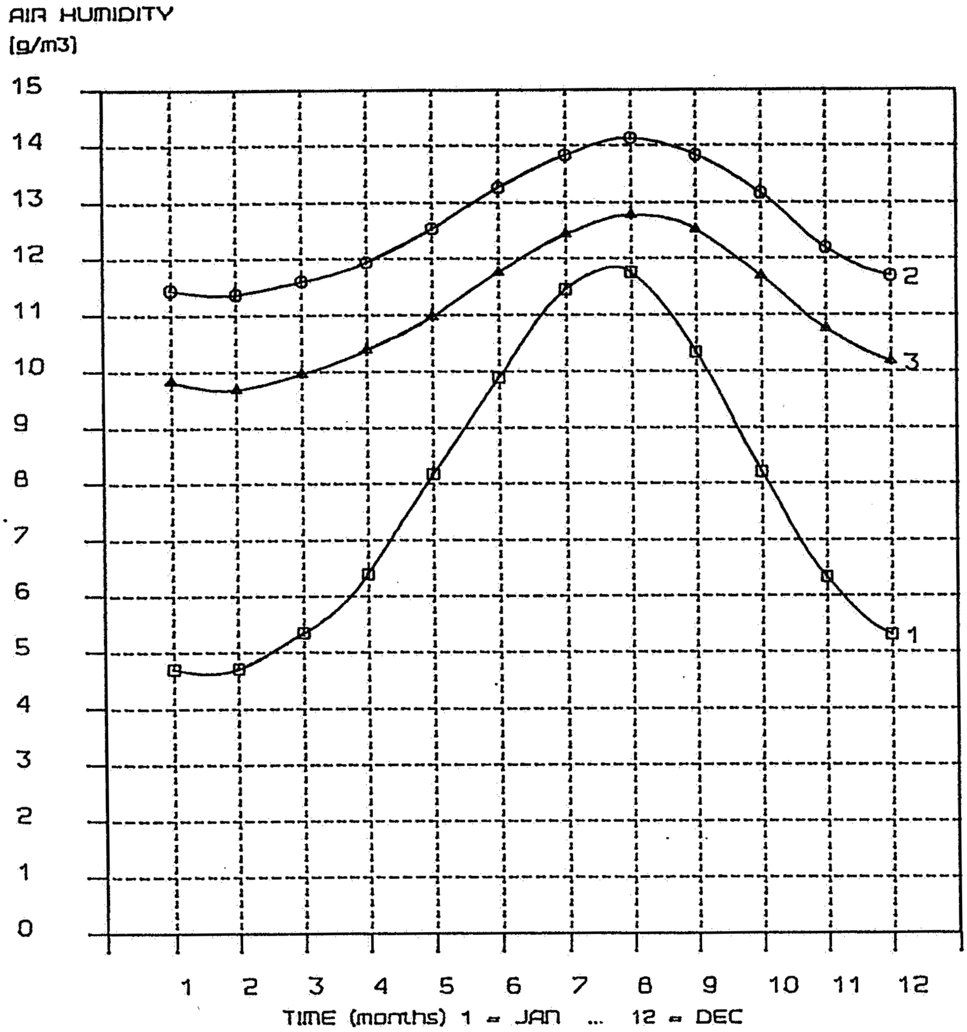


Figure 2: Water vapour concnetration in crawl spaces.

1: Outdoor air.
2. Air humidity in a crawl space without any insulation in the ground floor.
3. Air humidity in a crawl space where the ground floor is provided with a 5 cm insulation layer.

The curves are computed by TH3DR, a dynamic thermal model based on combination of heat and moisture balances.

AIR LEAKAGE RATIO : $\frac{Qk}{Qt} = \frac{\Delta Ci}{Ck-Ce}$

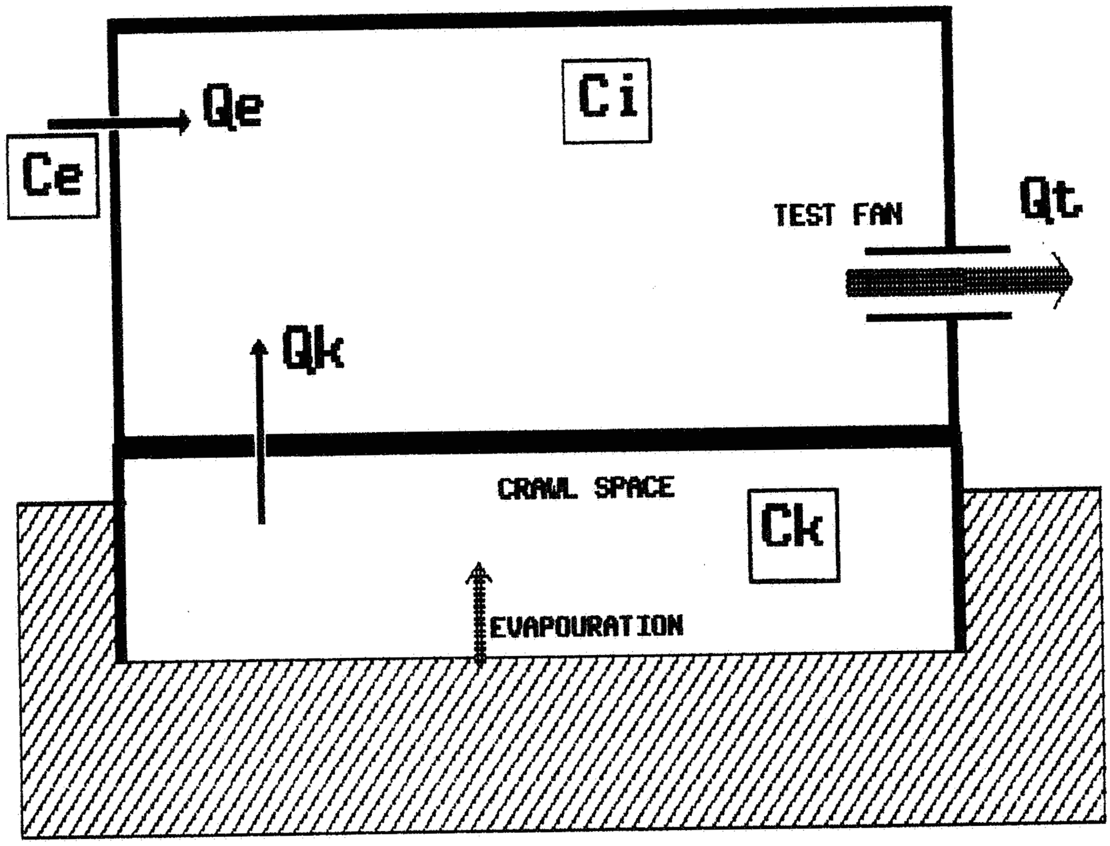


Figure 3: Air tightness of ground floors.

Depressurisation method to test the air tightness of ground floors above humid crawl spaces. In addition to the conventional "blower door test" the dew point system from figure 1 is employed to detect the infiltration of moist air. The air leakage ratio is determined from vapour concentration measurements as shown above.

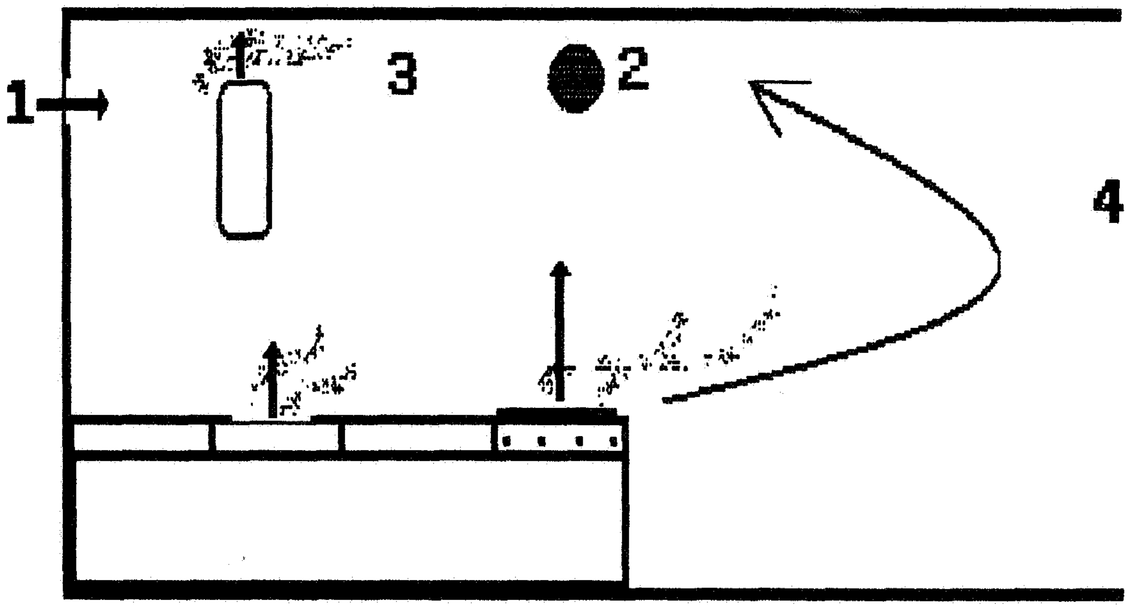


Figure 4: Airborne moisture transfer in kitchens.

View of the kitchen zone in the test house. The locations for the vapour concentration measurements are shown:
1: Outdoor air (C_e).
2: Ventilation exhaust (C_x).
3: Kitchen area.
4: Living room zone at 6 m distance from location 1 (C_i).

Humidity measurement data from these locations have been used to evaluate the moisture removal effectiveness E.

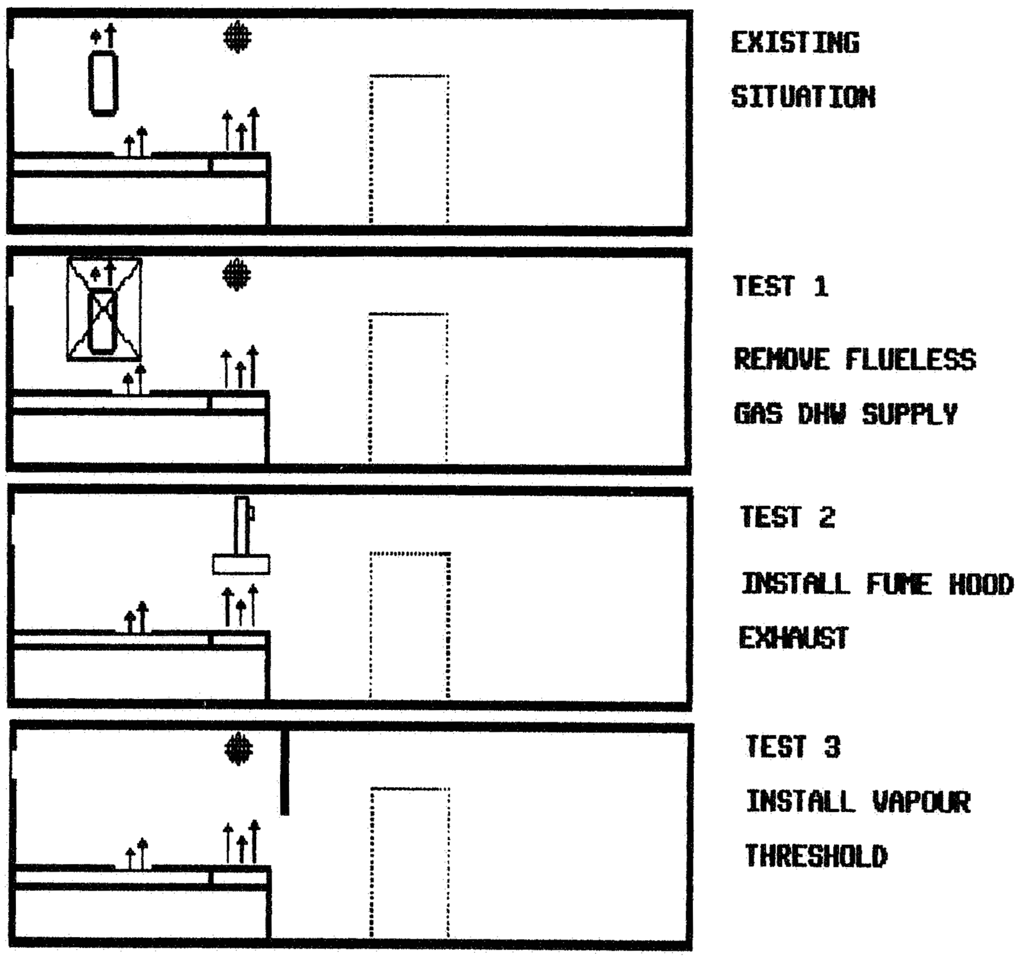
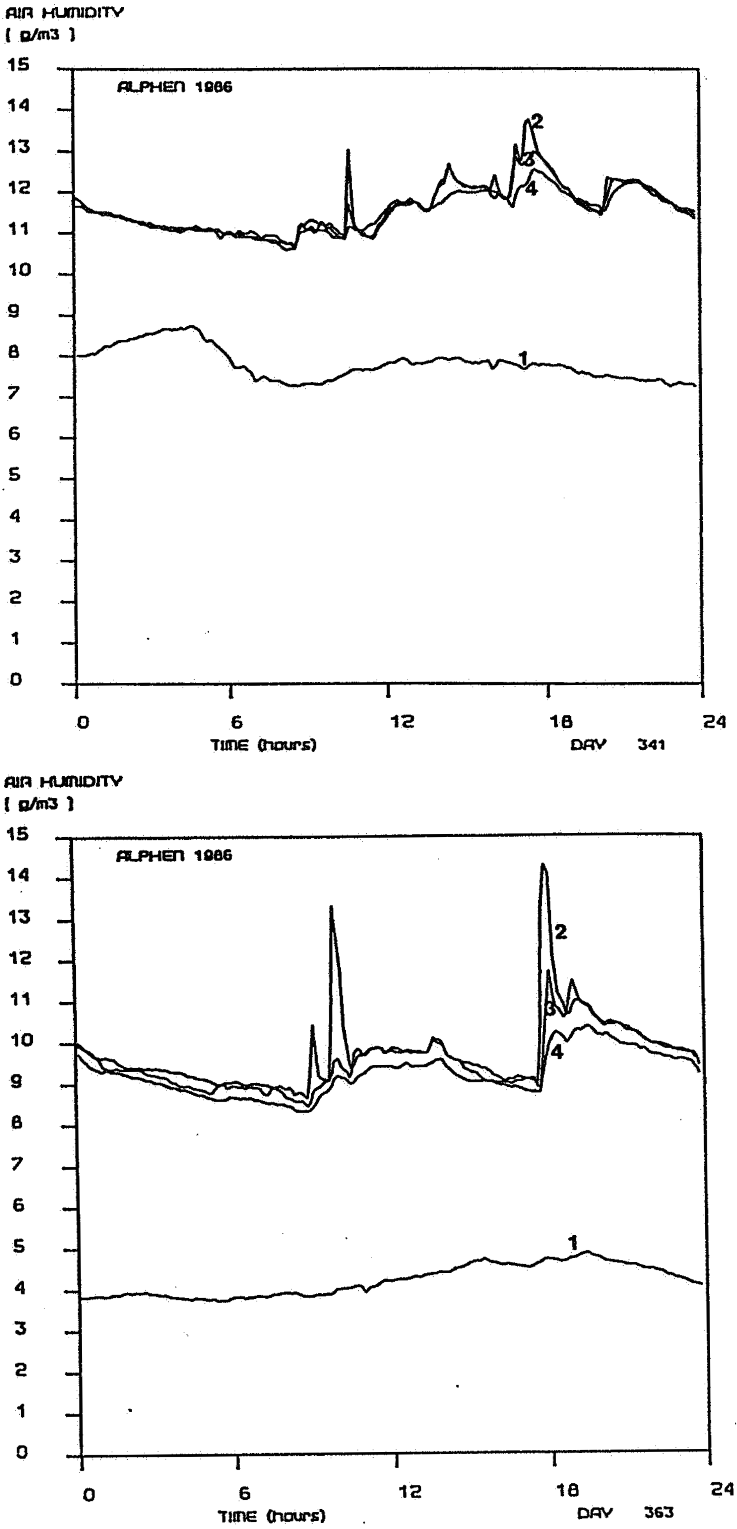


Figure 5: Remedial actions.

Schematic view of the remedial actions to improve the moisture removal effectiveness.



<u>Figure 6</u>: Airborne moisture propagation from kitchens.

Recorded vapour concentrations in the test house for two cases:
a. Reference situation (above), b. Fume hood installed (below).

1: Outdoor air.
2: Ventilation exhaust opening.
3: Kitchen zone.
4: Living room at 6 m distance from location 1.