ADVANCED HEAT PUMP DEHUMIDIFIERS MINIMISE VENTILATION WASTE

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Summary

The energy lost through ventilation becomes increasingly important as building insulation levels improve. The ventilation needed in temperate climates is primarily based on moisture control to prevent condensation and mould problems. The actual energy loss is a complex function of time, temperature distribution and ventilation rate which is difficult to control in practice.

An alternative approach is a heat pump dehumidifier. This transduces the latent heat of the moisture in cool damp air into the sensible heat of warm, drier air. Laboratory prototypes have been developed which combine the sensible heat exchange from a counterflow heat exchanger with the heat transfer properties of a heat pump. Such units perform twice as effectively as conventional equipment and offer a new approach to energy losses caused by ventilation.

Introduction

Energy is lost from buildings through two routes. The most obvious of these is the heat conducted through the building fabric itself. Insulation techniques are already available to minimise this loss (1). Such techniques are slowly being incorporated into new building designs. The increasing use of this insulation concentrates attention on the energy lost through ventilation. In some types of buildings ventilation already accounts for 50% of the heat loss and even houses have values approaching this for new designs. The next stage therefore in improving our buildings is to minimise ventilation waste. Future developments will therefore concentrate on controlling ventilation.

Ventilation needs

Most occupied buildings have internal generation of some form of pollutant. At its most basic level the need is to dilute the carbon dioxide which we exhale to a comfortable working level. In practice, except for very special environments such as those in submarines, this requirement is always well exceeded. The two usual criteria are odour and moisture control. Odours are associated with people themselves and their cooking habits. The ventilation needed for moisture control is more complex (2). The actual moisture content in outdoor air varies widely over the seasons. This means that even for a constant moisture generation rate the ventilation requirements will vary throughout the year. In well serviced buildings, such as swimming pools, advanced heat recovery and moisture control equipment have already been incorporated by specialist engineers (3). However, there are many more building applications where similar principles could be applied. The more obvious include launderettes and hairdressing salons. Less obvious ones include the storage of goods, such as furs, leather, food and clothing. Ordinary warehouses are usually heated to prevent high relative humidities, which could create condensation, corrosion and mould problems. The high temperature also enables the storeman to work there in pleasant thermal comfort. The newer automated or semi-automated store usually mean that the storeman spends only a short time in the warehouse itself and it may even be unmanned. Considerable energy savings can be made if the warehouse humidity can be lowered through dehumidification rather than through high internal temperatures.

Finally, in temperate climates where outdoor humidities are rather high, then dehumidification becomes progressively more important as people choose lower bedroom temperatures. An illustrative theoretical example of the seasonal changes in ventilation in a normal British house is shown in fig.1.

The conventional dilution principle of ventilation is one of the most wasteful of energy. In buildings where moisture loads influence the ventilation rate two simple principles have enormous energy saving potential. The first is to minimise moisture generation and its release into the building. In the home this means using saucepan lids during cooking operations and providing a local ventilation extract above the cooker and also one in the bathroom. The second one is to use some form of dehumidification.

Dehumidification

Vapour compression refrigeration techniques are already widely used for dehumidification. Such a heat pump dehumidifier operates by directing room air first over the evaporator heat exchanger and then over the condenser heat exchanger. This is illustrated in figure 2. The evaporator cools the air below its dewpoint and some moisture is condensed out and runs to waste. The air is then reheated by the condenser and often finally passes over the compressor to collect its waste heat. Cool, damp air can therefore be turned into warmer, drier air. The net effect of the dehumidifier on the room air passing through it is greater than would be estimated from the electrical consumption alone. The reason for this is that the latent heat of the condensed moisture is transduced into sensible heat at the condenser. The effectiveness of such dehumidifiers is mainly a function of the room relative humidity. The effectiveness increases with increasing relative humidity. There is also a small improvement with increasing room temperature. Typical characteristics of a small commercially available heat pump dehumidifier are shown in figure 3.

Such heat pump dehumidifiers are already manufactured and sold in large numbers in the United States, Japan and to a lesser extent, Italy. Samples of commercially available units were tested in the laboratory under a range of different temperatures and relative humidities. In parallel with this, design studies were undertaken to assess the optimisation of the heat transfer surfaces for the design air flow. While there were differences between machines, the design studies showed that little improvement could be made on the design of the best machines. (4)

One of the major drawbacks with the present design is that the evaporator has to provide both the sensible cooling down to dewpoint temperatures and then the latent heat extraction. The effectiveness of the evaporator could be significantly improved if the room air could be chilled by a heat exchanger before entering the refrigerant heat exchanger (5,6,7,8). Such a technique used earlier to improve very low efficiency dehumidifiers, was mathematically modelled. The cycle is illustrated in figure 4. Room air is first cooled by the air leaving the evaporator heat exchanger. This enables a given evaporator to extract much more water.

A domestic sized geared dehumidifier incorporating the counterflow heat exchanger was built and tested under a range of temperatures and humidities in a test chamber and agreement with predictions was good.

The added counterflow heat exchanger made dramatic improvements in the low temperature performance at around 50% relative humidity. At 12°C, a typical condition in British bedrooms, the advanced dehumidifier extracted ten times more moisture than that of the conventional dehumidifier. At normal bedroom relative humidities (around 65% R.H.) the performance of the advanced dehumidifier was still almost twice that of a conventional unit. Since the advanced dehumidifier extracted much more moisture than the conventional one, so its effectiveness as a heater improved simultaneously. The ratio of heat supplied by the dehumidifier to the electrical energy consumed is termed the coefficient of performance. At 70% R.H., 12°C, the coefficient of performance improved from 1.4 for the conventional unit to 2 for the advanced one.

The laboratory prototype is illustrated in figure 5. While the prototype unit is large for easy access to instrumentation, the illustration also shows a mock-up of production models. Illustrative dimensions of the laboratory prototypes are given in table 1.

Conclusions

The importance of taking care with ventilation grows as insulation standards improve. A major factor in determining the ventilation need in many buildings is moisture control.

The ventilation needed to dilute moisture to an acceptable value is large and very wasteful in energy. A much more efficient approach is to minimise moisture release and spread in the building, and to use vapour compression heat pump dehumidification.

Incorporating an air to air heat exchanger into a conventional dehumidifier cycle can produce a major improvement in its output and effectiveness. Mathematical predictions have been validated by prototype trials.

The advanced dehumidifier utilises the latent heat of the condensed water to enhance the thermal output. When used to control moisture in bedrooms, for example, in typical British conditions, it will have a coefficient of thermal performance of 2.

References

1. Brundrett, G.W. Some effects of thermal insulation on design. Applied Energy, 1, 7-30, 1975.
2. Ashton, D.F. Relative humidity in houses. ECRC Report N895, February 1976.
3. Braham, D. A guide to energy cost effectiveness in swimming pools. Inst. of Baths Management Ann. Conf., 1977.
4. Brundrett, G.W. and Barker, R. Opportunities for energy conservation by heat pump dehumidifier and odour treatment. UNIPEDE, 1977.
5. Brundrett, G.W. Vortex tube application. Design Engineering, 71-73, December 1968.
6. Blundell, C.J. Heat exchanger design for a domestic dehumidifier. ECRC Report M1166, 1978.
7. Blundell, C.J. Efficient dehumidification. Heating and Ventilating Engineer, 52, 5-7, September 1978.
8. Blundell, C.J. Improving heat pump dehumidifiers. IEE Conference Publication No. 171, Future energy concepts, 77-80, 1979.

Table 1 Domestic sized advanced dehumidifier

Air/air counterflow heat exchanger 14.2m^2 each side

0.03 m^3/sec flow

0.024 m^3 volume

plate separation 6.3mm

fins 2.3mm pitch

Evaporator and condenser

9.5mm tubes on 25mm x 22mm staggered layout

continuous wavy fins on 2mm pitch

face area 0.039m^2

depth 0.066m

Compressor

130 watt 3.3 cm^3 displacement Prestcold ASH12 published characteristics

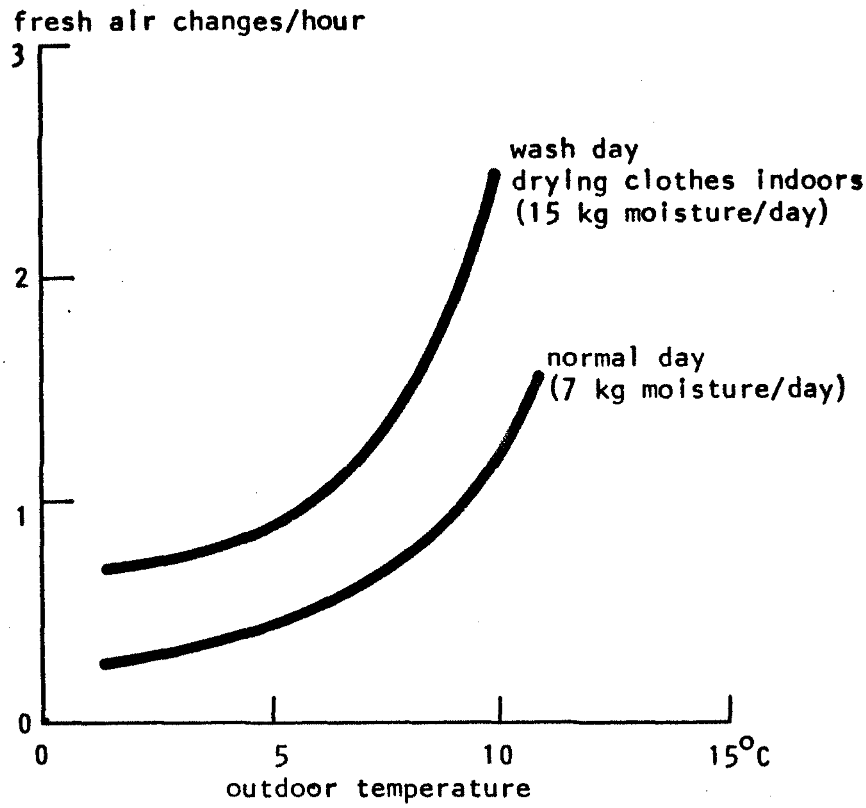

Fig. 1 Theoretical ventilation need to maintain 17°C 60% r.h. conditions inside a house

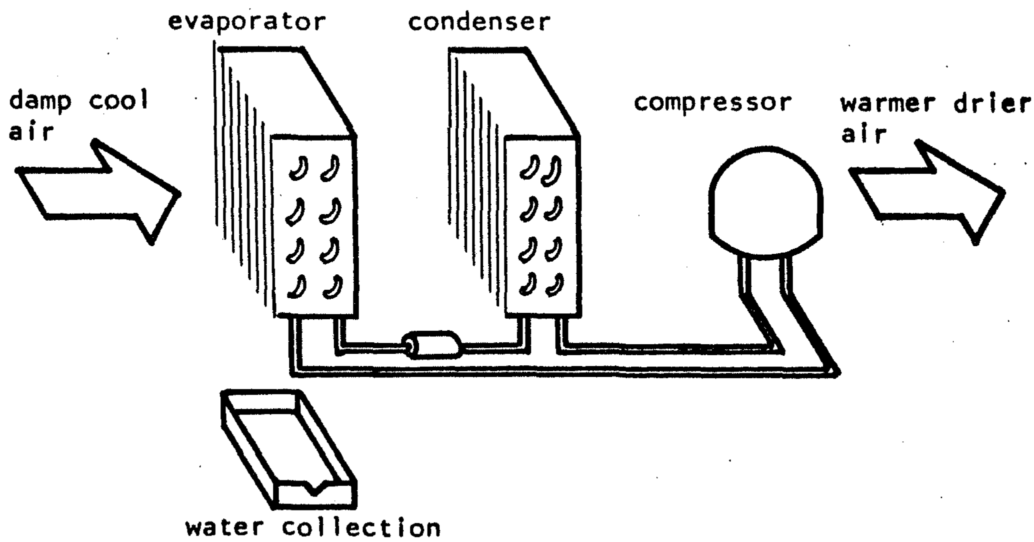

Fig. 2 Diagrammatic layout of conventional dehumidifier

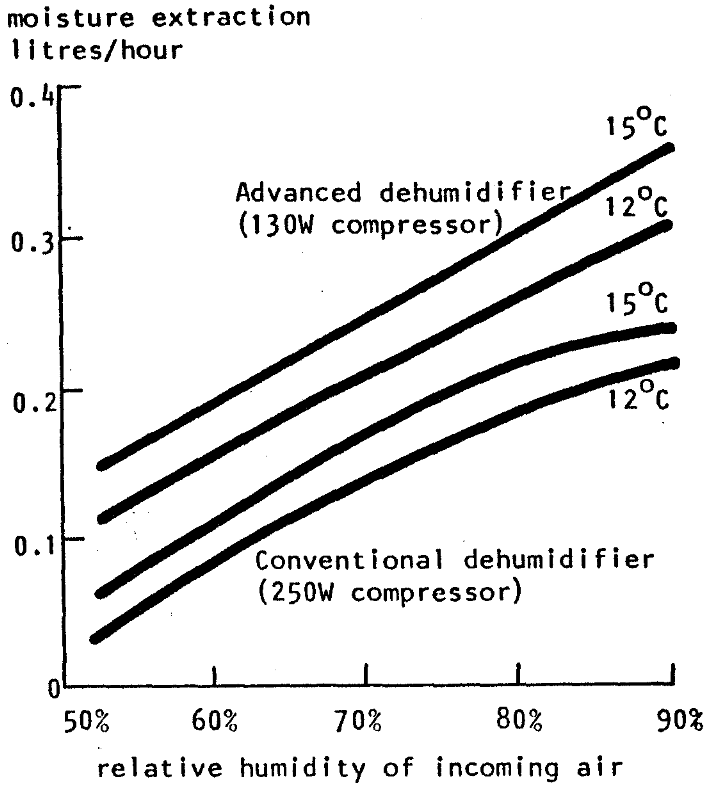

Fig. 3 Moisture extraction capabilities

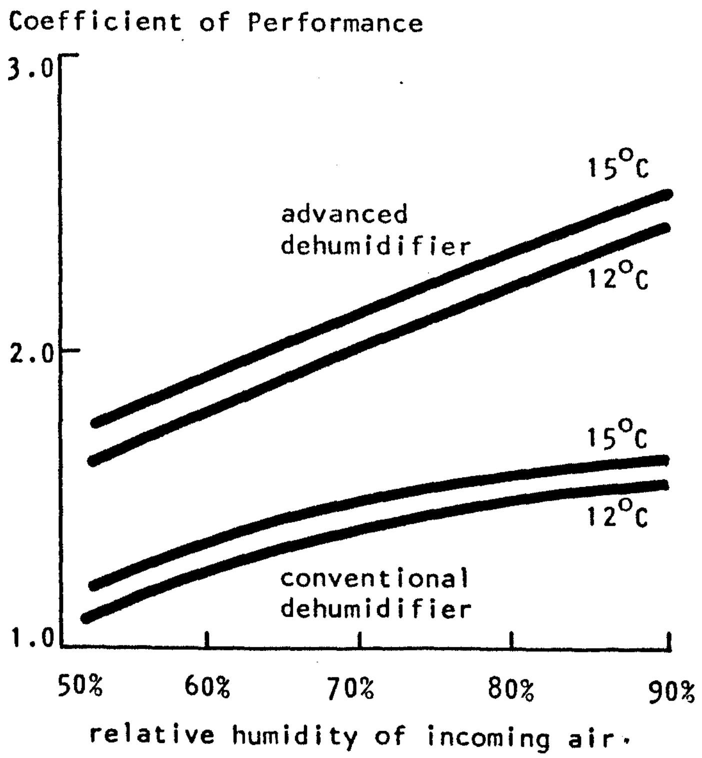

Fig. 4 Coefficient of Performance variation with relative humidity

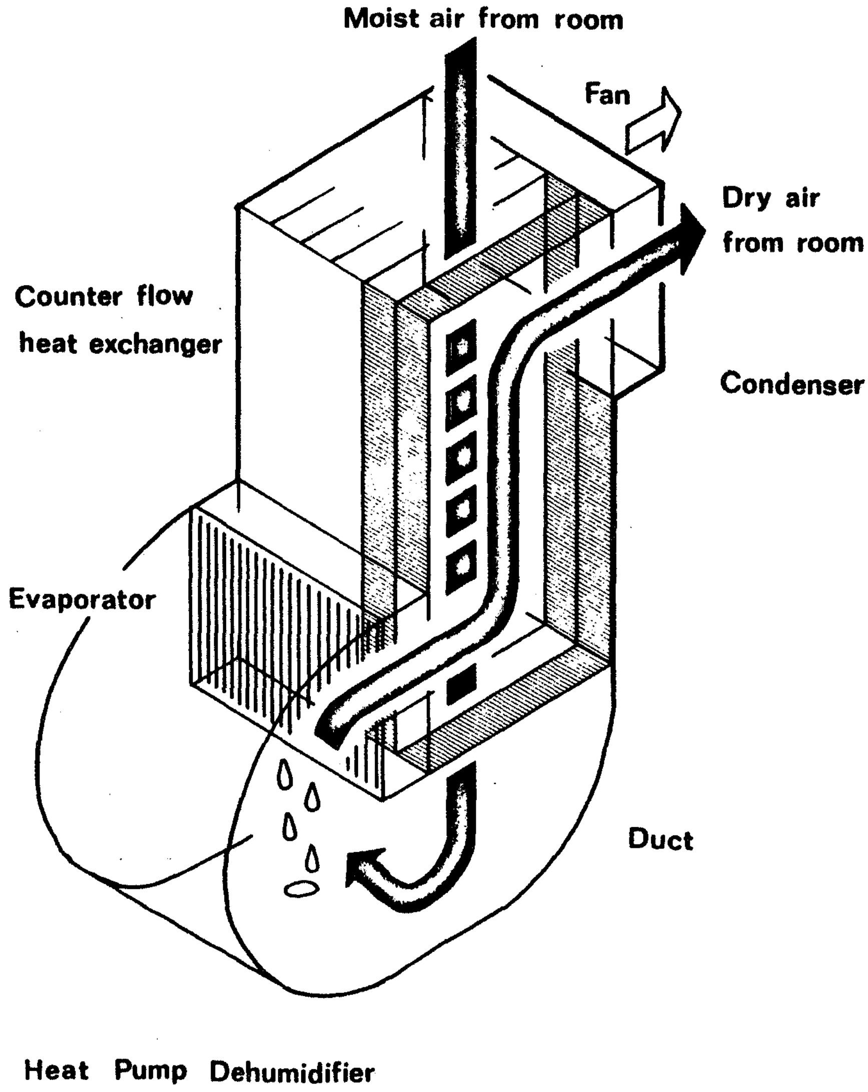

Fig. 5 Diagrammatic illustration of the advanced dehumidifier