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The Effectiveness of Domestic Extract Fans

by

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SUMMARY

The widespread problems of condensation in domestic dwellings is often accentuated through the misinformed actions and activities of those who are meant to prevent and resolve the defects. Misunderstandings of the basic principles and/or financial restrictions push many landlords into adopting limited remedial strategies.

This paper focuses on just one aspect of this problem - mechanical extract fans in domestic dwellings. Through reviews of the latest research in this area, doubt is cast over the effectiveness of some of the strategies proposed by, amongst others, the Building Research Establishment. The effectiveness of humidistat controls on extract fans is particularly identified in this respect.

The paper concludes that condensation can only be resolved through holistic approaches that tackle all components of the problem. Proposals for a balanced ventilation regime are put forward which recognises the role of the tenant in helping to prevent condensation problems in their own home.

1.0 **Introduction**

Following continual complaints of dampness, an inspection of a one bedroom flat owned by a local authority was carried out. The dwelling which was built in 1971, was on the ground floor of a long three storey terrace. It consisted of a bedroom, lounge, kitchen, internal bathroom, understair store room and hall (see Fig.1).

The external cavity walls were uninsulated and the flat had a solid ground floor with a concrete first floor over it. Above was a three bedroom maisonette accessed via a concrete staircase to the front elevation. The stairs led to an open balcony which was positioned over the bedroom and hallway of the flat in question.

The flat was extensively affected by mould growth especially to the walls and ceilings of the bedroom, hallway, store and kitchen. A variety of remedial works had been carried out in the past including the provision of additional air bricks to all rooms, fungicidal washes to walls and finally the installation of humidistat controlled extract fans in the bedroom, under stairs store, bathroom and kitchen by a firm specialising in such package deals.

The tenant complained that these fans were operating at all times of the day and night. The kitchen fan was especially troublesome. This had been running for 24 hours a day since the system had been installed two months before. Repeated complaints to local repairs service resulted in the advice that the fan was only operating because "excessive condensation is being produced". The tenant was further advised to put the lids on her pans, not dry her washing indoors and open her windows more frequently.

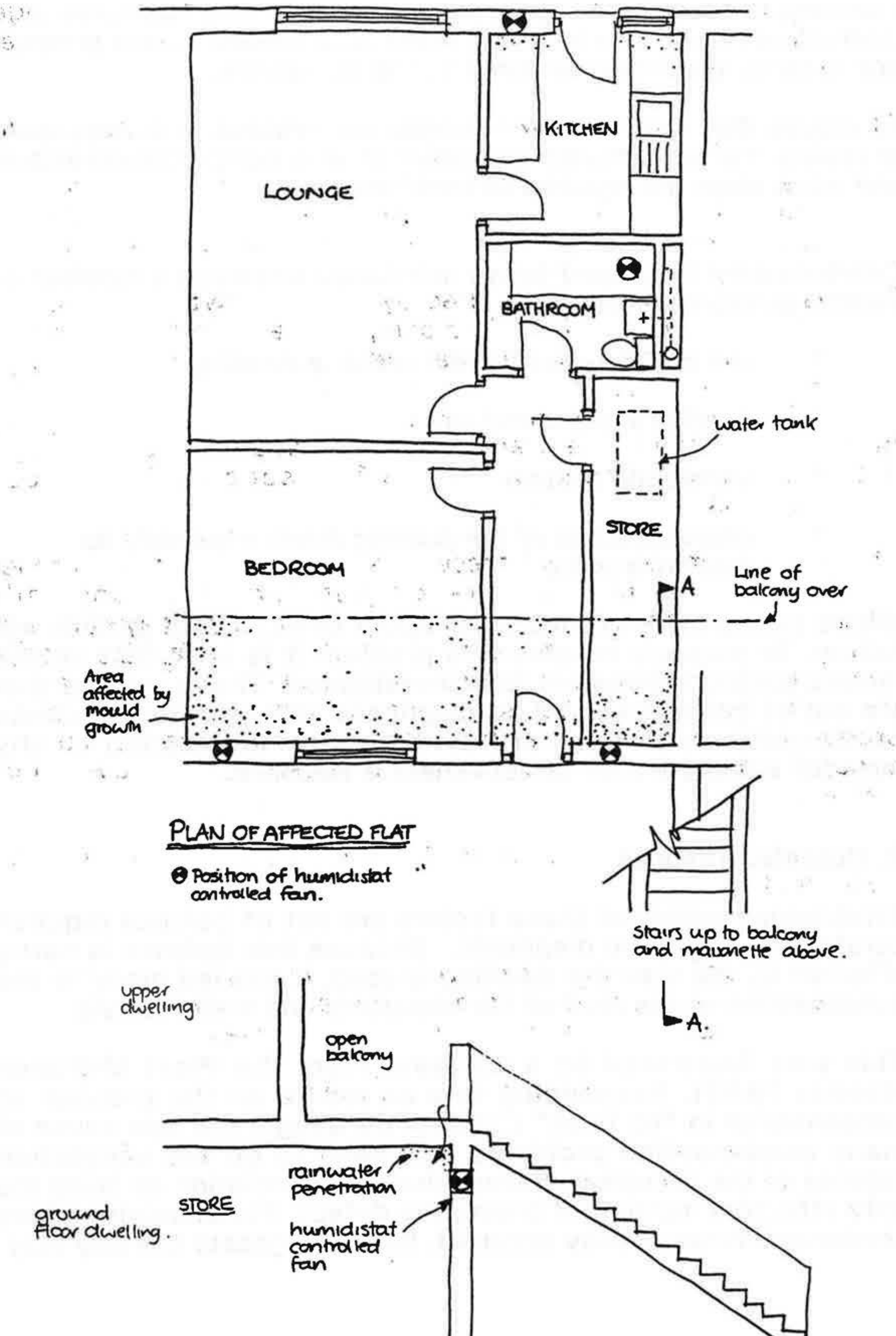
This flat was re-inspected and the following defects were diagnosed:

* *lack of insulation to the building structure especially beneath the balcony resulting in severe condensation on the consequent cold bridges;*

* *lack of adequate heating to the flat;*

* *direct water penetration to the store at the head of the external stairs*

Further investigations revealed a leak to the hot water supply to the sink in the kitchen. This raised the humidity levels in the room thus activating the humidistat controlled fan.



SECTION A-A through affected flat

FIG 1.

2. <u>Condensation: background theory</u>

Cases like this are not uncommon. Incorrect diagnosis of condensation related defects can result in expensive and ineffective remedial works that make little impact on the problem and extends the misery endured by the occupants.

To ensure that such drastic mistakes are avoided, it is necessary to review the fundamental principles of why condensation occurs and what steps are required to eradicate it.

Condensation is caused by an imbalance between a number of internal environment factors:

- *the moisture production within a dwelling*
- *heating system and use*
- *ventilation system*
- *characteristics of the building fabric especially its insulative value*

Where condensation forms on a regular basis, mould growth will follow. To properly resolve this problem it is vital that all the factors outlined above are fully investigated. Those aspects that are out of balance should be diagnosed and rectified. Because condensation problems are dynamic, the monitoring of any remedial works for their effectiveness is essential.

3. Outdated Theories

Establishing which of these factors are out of balance requires careful and objective diagnosis. Because this *balance* is partly affected by the way the dwelling is used, it has led many to see condensation as the *fault* of the occupants and their lifestyle.

This was illustrated by a surveyor from the West Midlands (Balmer 1989). Responding to a an article on the problem of condensation in "no fines" concrete dwellings, the sole cause of many condensation problems was seen to be the ventilation regimes of the occupiers. Balmer also saw ventilation as being the only effective method of curing the defect. For example, where condensation has already occurred, Balmer suggests the only way to "*dry a room out*" is to "*.....open a window - one small fan encasement will be enough - plus a door and the same in the adjoining room, so that air can circulate through these two rooms. This will clear the air and dry out the room between three days and a week..*".

In the conclusion Balmer urged caution when advising occupiers on how best to avoid condensation "*..one must be careful no to offend when trying to explain. One is, after all, pointing out that the occupier's domestic arrangements are at fault...Tact will be called for, but it is not enough.*"

Similar attitudes are documented by tenants in Scotland (Scottish Consumer Council 1984, p.61). Following a tenant's campaign in Renfrewshire over dampness problems, council officials reinspected the affected dwellings but appeared to be interested only in how the tenants lived. The most common questions were;

* *"do you keep a lid over cooking pots when you have been boiling water?"*

* *" do you keep the kitchen door closed when you are cooking?"*

* *"do you wash your dishes in large or small batches?"*

A further council report accused of misusing their homes if they; dried their clothes over the bath; did not leave their windows open slightly even if they were not in the house; did not keep their coal fire boiler on 24 hours a day, 42 weeks a year.

Both examples are typical of the restricted analysis that many landlords carry out based not on contemporary research and knowledge but on subjective assessments derived from an inadequate understanding of the phenomena.

4. The current context

The extent of the problem is immense. It has been estimated that approximately 2 million dwellings are affected by severe dampness with a further 2.5 million to a lesser extent (BRE 1985). Of these, 1.5 million homes suffer from minimal mould growth, 1.25 severely affected and 0.25 million with extensive mould growth problems. The major cause of this dampness has been identified as condensation.

Further investigations have estimated that 33% of local authority dwellings were affected by dampness of which 66% was caused by condensation (Saunders and Cornish 1982).

As outlined above, any remedial works should take into account the full range of factors that influence condensation formation. Two factors inhibit the adoption of this approach;

* *lack of understanding of the problem by those responsible for resolving the defect*

* *lack of adequate finance to fund the required range of remedial works.*

Even where Landlords recognise the need for a holistic approach, the delay in obtaining funding for appropriate remedial programmes cause them to look for temporary methods of alleviating conditions, in the meantime (Boyd and Cooper 1989 p.335).

This has resulted in an increase of equipment and technologies designed to resolve condensation problems at low costs. These include:

* *extract fans controlled by humidity sensitive systems*

* *"whole house" extract systems*

* *individual heat exchange fans*

* *ventilation systems based on passive stack principles*

* *de-humidifiers*

* *various wall applications either mould growth inhibitors and/or thin layer insulation sheeting.*

The main characteristics of these new products is that they usually focus on only one environmental factor. Because the easiest and cheapest method of influencing internal conditions is seen by many as being ventilation, many of the new products are associated with affecting the air change characteristics of dwellings.

5. **Ventilation**

The Building Regulations change in 1985 promoted dramatic increase in the use of mechanical extract fans by incorporating their use in kitchens and bathrooms (Part F). The remaining sections of this paper will review developments in this area especially the performance and effectiveness of extract fans in minimising condensation problems.

Ventilation is a vital requirement (Uglow 1989, p.1) in any dwelling for the :

* *health and comfort of the occupants*
* *control of condensation*
* *safe and efficient operation of combustion appliance.*

But ventilation rates often occur by accident rather than design so that they do not match the needs of the dwelling or the occupants (Uglow, 1989) and water vapour was identified as being one of the most significant airborne pollutant in housing.

To ensure that relative humidity levels are kept below 70% and mould growth is minimised, an air change rate per hour (ach) of 0.5 is required (BRE, 1985). This is normally, achieved by two main methods;

* *natural ventilation*
* *mechanical extract ventilation*

Whatever strategy is adopted it is important that the ventilation rate is matched to the dwelling. As well as expelling indoor pollutants and water vapour, heat will also be lost. Excessive ventilation will result in a drop in internal temperatures which could result in additional rise in relative humidity (Fig.2). Balanced ventilation rates are therefore important.

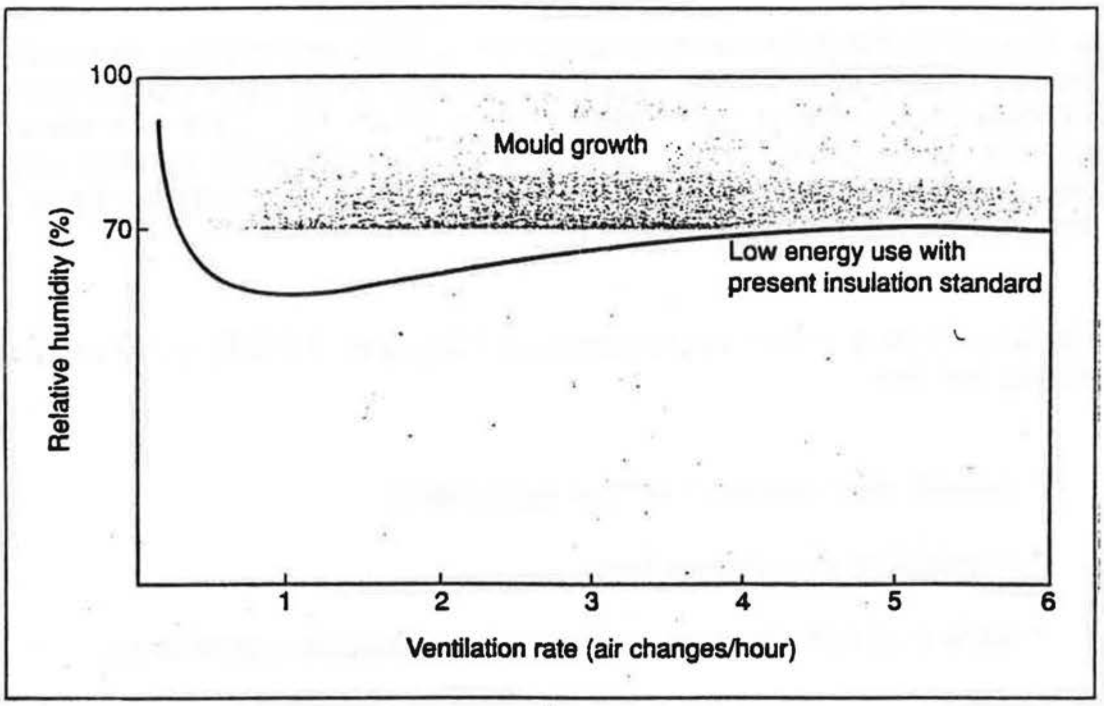


FIG.2 RH related to air change rates

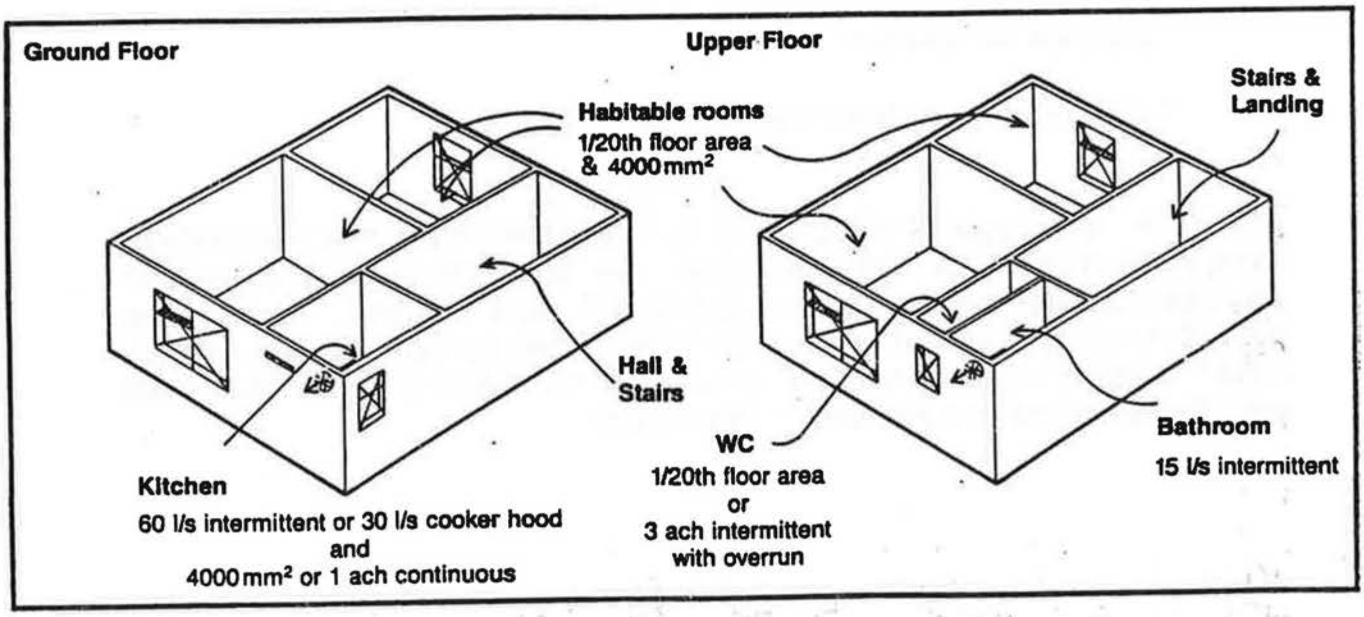


FIG.4.

6. **Mechanical Extract Fans - Standards**

The Building Regulations now set down minimum requirements for ventilation of new dwellings.(Fig.3).

The British Standard Code of Practice BS5250 recommends a mechanical extract fan extract rate of $288m^3h^{-1}$. This rate was intended as a standard for design calculations by fan manufacturers. Most concur with this figure but express performance of their fans in terms of air change per hour. Transposing these to an averaged sized kitchen, extract rates of between 200 and $400m^3h^{-1}$ are claimed(Boyd and Cooper, 1989, p.335).

7.**Effectiveness of Extract Fans**

Mechanical extract fans have traditionally been seen as having a number of positive characteristics in relation to condensation prevention:

a) they remove moisture laden air from where it is generated to the outside and so reducing relative humidity:

b) a minimum air change rate can be achieved which is less dependent on external conditions:

c) moisture movements from areas of high production to other parts of a dwelling are minimised(Uglow 1989, p.4).

In essence, extract fans have been seen as having a *de-pressurising* effect pulling moisture laden air directly out and encouraging air from other parts of the dwelling to enter. Consequently, extract fans have become a dominant feature in the range of anti-condensation measures adopted by many organisations.

Despite this, several recent studies have cast serious doubt on how effective extract fans are in practice. Fundamentally, most installed extract fans have little chance of achieving laboratory performance standards of the *system effect*. This difference arises from the uneven velocity profiles or swirling airflows entering and leaving the fan. This leads to a lower fan performance than that claimed by manufacturers (Riffat 1990 p.45).

This aspect was investigated in more depth. A micro processor-controlled tracer gas system was used to measure ventilation and inter zone air movement in a house. The kitchen of the house was equipped with a wall mounted hood and a standard kitchen extract fan.

The air velocity under the hood was also measured using a hot wire anemometer. A number of revealing results were obtained.

a) the fan to the wall mounted hood had three speeds 1,2 and 3. These resulted in extract rates of 73, 93 and 144m3 respectively. Even the highest was way below the BS5250 standard.

b) the standard wall mounted kitchen fan produced an air change rate only marginally greater than the wall mounted hood. Because the wall mounted hood was directly over the cooker, Riffat concluded that it stood a far greater chance of extracting moisture than the standard fan.

c) Both the fans failed to stop air migrating from the kitchen to the other rooms. Given a normal temperature difference between the kitchen and adjacent room, a fan with 4 times the capacity of the BS Code of Practice would be required to stop the movement.

This final point was seen as emphasising the importance of closing the kitchen door during moisture producing activities.

Another study looked at the specific effectiveness of extract fans within hoods positioned directly over the cooker(Petzold ?) . Assuming a *full operation kitchen* where the cooker rings were fully utilised. The following results were obtained;

a) If all of the heat and moisture was to be captured and extracted, it would result in a hood and fan so large that it would impose intolerable difficulties *when using the cooker both in terms of obstruction and air movement.*

b) On the whole, the hood shape had little effect on the catching and extraction action.

c) There is no advantage in completely covering the cooker with the hood as the ventilation system draws off only part of the heat and moisture or "thermic hose", the remainder flows out under the hood edges.

d) a ventilation hood shaped roughly in accordance to Fig.4 should be fitted over the cooker space with a fan that has a ventilation rate of about $0.05m^{3/s}$ *or* $180m^3h^{-1}$.

Petzold concluded that if such a provision is not made, temperature and moisture increases will occur to an extent that will not be tolerated by the occupant. The kitchen door is likely to be opened for additional ventilation allowing the moisture to flow to other rooms.

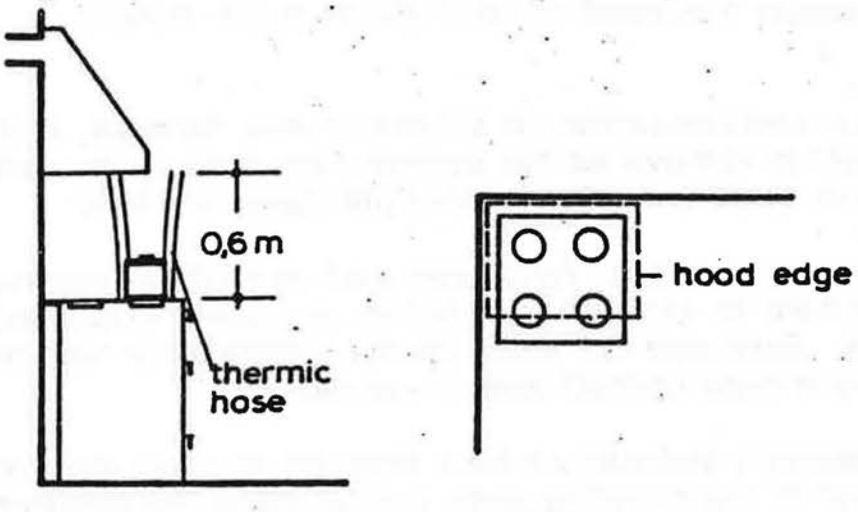


FIG 4.
Optimum hood arrangement

Boyd and Cooper (1989) measured similar performance criteria but of extract fitted into windows and not within ventilation hoods over the cooker. The fans were also humidistat controlled with a free air extract rate of 43m3h-1 under humidistat control with a manual boost rate of 96m3h-1.

This report included a number of useful anecdotal observations on the fans' performance:

> *i) On boost rates, a slight drumming noise occurred that was amplified because of the window fixing.*
>
> *ii) fans under humidistat control operated for long periods in some flats.*
>
> *iii) during heavy cooking periods, the moisture and heat production was considered excessive by many tenants, despite the running of the fan. Doors would then be opened negating the effects of a window mounted fan.*
>
> *iv) kitchen doors were often kept open in order to supervise children or watch television in the adjacent lounge.*

Analysis of their results with the aid of a computer modelling program, enabled a number of conclusions to be drawn.

> *i) once condensation in kitchens has formed, it is difficult to remove as the evaporation rates from cold surfaces to air with high vapour pressures are low;*
>
> *ii) low power extract fans even with humidistat control are unable to stop condensation in poorly insulated homes. Extended run times do not significantly help to remove it once formed (see (i) above).*
>
> *iii) Thermally induced air flow through an open door to the rest of the dwelling soon overwhelms the positive air flow of induced by practically sized fans. Therefore, the importance of keeping the kitchen door closed and the dwelling depth as near the same temperature as possible.*

A fundamental dilemma was noted between;

a) installing a fan with a much larger air extract rate and humidistat control. This will result in a noisier fan running on for longer periods which many tenants would find unacceptable.

b) installing a fan with a larger extract rate and manual operation. The identified drawback would be the reluctance of some tenants to use it.

Parnham (1990) has also monitored internal humidity and temperature conditions in a domestic dwelling. In this case a single storey centrally heated bungalow built to the 1985 Building Regulation suffered from extensive condensation to single glazed metal framed sliding windows. This was at it's worst in the kitchen where it had resulted in the rotting of the internal timber cill boards.

The occupant tried many solutions including the installation of a wall mounted hood extract fan directly over the cooker venting externally. A mobile de-humidifier was also installed in the hallway.

Although the extract fan was low powered, humidity levels in the kitchen were kept within acceptable limits, rising over the 70% level for short periods only.

The effect of the de-humidifier was also negligible. The average levels of internal humidity were only 2 - 5% lower when the unit was operating compared to when it was switched off. In any event, excessive condensation continued unabated on the windows despite both measures.

Although these results aren't conclusive, they do suggest that over-emphasis on one method of control is unlikely to affect the formation of condensation on an element that is *"out of balance*. In this case, the replacement of the windows by double glazed units within a thermally effective framing was the only solution.

8. **The Influence of Humidistat Control**

The growth of humidistat controls on extract fans have been rapid. In the late 70's early 80's the early versions made use of horsehairs to detect changes in the humidity. Since that time many different mechanisms have been developed ranging from polyester materials, "gold" leaf strip switches through to ceramic sensors surrounded by a "hot" wire element that periodically burns the dust and grease away.

There is no British Standard for these controls and there is little information available on their performance or accuracy. Despite this, their use has been continually recommended by the Building Research Establishment making them almost an industry standard.

Boyd and Cooper (1989) concluded that humidistat fans tend to have longer operational times. Consequently, they are generally of a lower power to prevent noise nuisance. Because it is difficult to remove condensation once it has formed the extended running times of humidistat controlled fans can be questioned. Their study concludes that a more appropriate measure would be to remove as much moisture at an early stage. The dwelling should also be well insulated and well heated to further impede condensation formation.

Milbank et al (1985) also considered the performance of humidistat controls when they looked at user behaviour in dwellings and how they affected various remedial treatments for surface condensation and mould.

A large number of dwellings were monitored after a variety of remedial works had been carried out. In relation to this paper, the two most significant elements of the study involved the comparison of a standard extract fan to the kitchen and bathroom controlled by the householder to those controlled by humidistat.

The extract fans controlled by the occupants were found to have little impact on internal conditions and were rarely used while those controlled by humidistat ran for almost a third of a week, approximately 7 hours a day.

Table 1 shows the percentage of time that the relative humidity exceeded 70% in each room of the which had received the different remedial treatment packages.

Compared to the control dwellings (ie. as existing) the humidistat controlled fan did show some improvements but clearly not as

TABLE 1: PERCENTAGE OF TIME RELATIVE HUMIDITY GREATER THAN 70% IN THE FLATS AT STIRLING

	Control	Fans (humidistat)	Insulation	Heating and Insulation
Living room	16%	1%	0	0
Kitchen	20%	14%	8%	0
Bedroom	62%	43%	35%	0

significant as the thermal insulation package or the combined insulation and heating alternative. In the case of the latter, humidities never rose above 70%.

These results led the authors to conclude:

i) extract fans in bathrooms and kitchens are effective when controlled by humidistats; those under tenant control are rarely used.

ii) the provision of insulation and heating can eliminate the risk of mould growth.

Since this study, the BRE has consistently promoted the use of humidistats. In their tape/slide pack on the topic, (BRE 1985), running times of 49 hours a week for humidistat controlled fans are presented as a triumph when compared to the 3 hours per week (average) running times when under tenant control.

In light of the research reviewed in this paper, a different perspectives can be put forward;

i) The extract fans were the only remedial measure carried out in flats that were poorly heated and insulated which were already suffering form mould growth. It is hardly surprising that in such circumstances tenants are reluctant to use fans. They would be perceived as being responsible for excessive heat loss.

ii) The lack of impact on internal humidity levels of both types of fans illustrates that tackling just one environmental factor is ineffective in curing condensation.

iii) Fan running times of 3 Hours a week one equates to 25 minutes use per day. If used at peak moisture production times, in well insulated and well heated homes such usage patterns would be appropriate.

iii) Fan operation times of 49 hours per week equates to over 7 hours a day. This an unreasonable length of time from the occupiers point of view and indicates that either the humidistat control is inaccurate or internal conditions within the dwellings are seriously out of balance.

iv) Even these extended running times does not necessarily mean that condensation will be effectively reduced once it has formed (see Boyd and Cooper, 1989).

v) The results clearly shows that improvements in the insulation and heating of a dwelling is the most effective method of curing condensation.

9. Bathrooms

Very few studies have considered the moisture production in bathrooms. Although these activities are not as intensive as in Kitchens, the localised problems of condensation and mould growth may be considerable.

Parnham (1990) found that humidities in the bathroom of a monitored dwelling were high in the morning and late evening. Such patterns could be expected in most dwellings with showers, baths and wash basins being used mainly at the start and the end of the day.

In many dwellings, bathrooms usually have poor levels of natural daylight. As condensation problems are normally restricted to the colder months when the length of the day is at it's shortest, the electric light will almost certainly be on during moisture producing activities. Consequently the installation of an extract fan in bathrooms automatically operated by the light switch with a 15/20 minute over-run would have a number of advantages:

i) it would ensure the fan's regular operation at times when it is most needed.

ii) Because of the 15/20 minute limit, "over-running" would be restricted to a clearly defined time period.

Care must be taken in relation to the size and noise of such a fan. It can be assumed that occupants would be more concerned with the heat loss via an extract fan when taking a bath when compared to that in a kitchen during cooking operations. Therefore it is sensible to target the lowest possible rate allowable under Building Regulations, which in this case would be 15 litres per second

10. **CONCLUSIONS**

Summarising, a number of broad conclusions can be drawn from this review:

i) Extract fans by themselves cannot prevent the incidence of condensation. Once it has occurred, further ventilation reduces the extent of condensation to an insignificant extent only.

ii) Remedial measures that tackle all aspects of the condensation problem (ie. heating, moisture production, ventilation and thermal insulation) are more effective at resolving the defect.

iii) Extract fans are more effective at removing heat and moisture if located in a wall mounted hood directly above the cooker position.

iv) It is important to keep the kitchen door shut to stop moist and warm air from circulating around the dwelling.

v) Thermal buoyancy is the main reason for cooking moisture spreading around the dwelling. Therefore, limiting temperature differences between different parts of the dwelling will help minimise this.

vi) Humidistat controls are untested and potentially unreliable. Used in isolation they can result in protracted running times, operating at all times of day and night. Consequently, the fans have a lower rate of extracts in an effort to minimise noise nuisance.

vii) It is important to set this debate in context with that of the typical end users of domestic dwellings normally that are troubled by condensation i.e. Council,Housing Association and private sector tenants. All are normally on restricted incomes, unable to afford high heating bills or expensive DIY measures.

11.Recommendations

When considering the installation of a mechanical extract fan or system in a domestic dwelling it is important that the present condition is fully diagnosed so the true cause(s) of the condensation defect can be fully identified and rectified. There is no effective substitute for an holistic approach.

Notwithstanding this, assuming a dwelling is heated to an adequate level, is satisfactorily insulated and is not subjected to abnormal moisture generation, the following ventilation strategy could be installed.

1) Provision of controllable background ventilation in accordance to the Building Regulations Part F 1990.

2) Provision of fixed ventilation as required by fixed room heaters/boilers.

3) To the Kitchen;

i) the provision of a manually operated fan within a wall mounted hood positioned directly over the cooker. The fan should have an extract rate as close as possible to 288m3h-1 (BS 5250).

ii) the fan should be positioned on an external wall and extracted directly to open air. Ducting will reduce the effectiveness.

iii) the walls of the kitchen should be well insulated, preferably on the inside face to prevent initial condensation.

iv) the kitchen door should be ½ hour fire resisting, fitted with a self closing device (overhead type with damper to prevent sudden closure). Consideration should be given to draught stripping and the provision of a glazed panel in the upper part of the door so other rooms can be observed.

4) To the bathroom:

i) The provision of a low powered extract fan with a 15-20 minute over-run wired into the main light circuit.

ii) The fan should extract directly to external air where possible.

iii) The external walls of the bathroom should be insulated to current Building Regulation standards, preferably internally.

iv) The bathroom door should be fitted with a self closer (with damper) and draught stripped.

5) Every existing and future occupant of the dwelling should be made aware of the problem of condensation in domestic dwellings and their role in helping to minimise any problems including the proper and appropriate use of extract fans.

This final recommendation is of crucial importance. Buildings are for people and should perform in a way that caters for a variety of normal lifestyles. Internal environmental conditions are not stable and vary according to the interaction of a wide variety of factors including how people choose to live.

Rather than use the developing new technologies to remove the ability of occupiers to control their own environment, it is more sensible to take advantage of the human resource. In a well insulated and heated home the most reliable form of humidity sensitive control are the people that live there.

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