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IMPROVING COMFORT IN DWELLINGS BY SAFE AND EFFECTIVE DRAUGHTPROOFING MEASURES

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INTRODUCTION

Many householders in the UK, particularly the elderly, find it difficult to maintain an adequate level of warmth in their homes during the heating season. The reasons are many and varied but often involve a combination of factors:

- Inappropriate type of heating system
- Expensive fuel type or tariff
- Inadequate standards of thermal insulation
- Poorly fitting windows and doors

Solving all of these problems is not usually a viable proposition but there is one inexpensive and straightforward measure which can bring about a marked improvement in occupant comfort and reduce excessive heat loss from the dwelling - that of draughtproofing.

Since 1981, over 100,000 dwellings in the UK have been draughtproofed by the Neighbourhood Energy Action Movement, a group of organisations funded by government departments. The UK Building Research Establishment has for several years worked in collaboration with the NEA to develop guidelines aimed at ensuring that draughtproofing measures are both safe and effective.

Natural ventilation during the heating season is usually achieved by a combination of air infiltration through gaps and cracks in the structure and deliberate ventilation through purpose provided openings such as airbricks and windows. However, in many dwellings, air infiltration alone may be the sole means of introducing fresh air, for a significant proportion of the heating season.

The major aim in carrying out draughtproofing measures is to try to eliminate uncomfortable draughts and prevent excessive ventilation, by sealing the major air infiltration gaps. There is however a danger that fresh air supply to the dwelling may be reduced to levels which are unacceptably low, with regard to controlling moisture levels in the dwelling and ensuring the safe and effective operation of combustion appliances. There are two major dificulties in developing general guidelines which will cover all circumstances. Firstly in knowing what are the fresh air requirements of a particular dwelling and secondly in knowing what the dwelling's natural ventilation rate is likely to be.

Taking these points in turn:

FRESH AIR REQUIREMENTS

The fresh air requirements of an individual dwelling depend on a number of factors including the size and occupancy habits of the household, their moisture generation patterns, the presence of combustion appliances and the rate at which other domestic pollutants are produced. In general, the 'key' pollutants are water vapour and combustion products.

Combustion appliances

A fresh air supply to combustion appliances is required for two purposes: firstly to ensure that combustion of the fuel is as complete as possible and secondly to ensure the dilution and removal of the products of combustion. These are predominantly water vapour and carbon dioxide with small quantities of other gases such as oxides of nitrogen, carbon monoxide, formaldehyde and sulphur dioxide depending on the type of fuel and burner.

If adequate air is not provided or inadequate provision is made for the discharge of combustion products, circulation within the dwelling of carbon monoxide could occur at fatal concentrations. In the UK, about 200 people die each year as a result of carbon monoxide poisoning; the number increasing during severe winters. Most fatalaties are caused by faulty appliances and blocked flues or chimneys. Some deaths are however due to inadequate air supply to combustion appliances.

There are three broad categories of combustion appliance:

Balanced flue (room sealed) appliances, which take their combustion air directly from outside and discharge their products of combustion directly to outside.

Open flued appliances, which draw their combustion air from the room and discharge their products of combustion to outside via a flue.

Flueless appliances, which draw their combustion air from the room and discharge their products of combustion into the room.

For most appliances, permanent openings in the form of airbricks or fixed vents are required; for others, adventitious openings in the dwelling fabric are relied upon to provide an adequate supply of fresh air. Before any draughtproofing treatment is considered, checks must always be made to ensure that required permanent openings to outside are provided and have not been blocked in any way.

The guidance used by BRE for making these checks is reproduced in Tables 1 and 2.

Condensation

The presence of water vapour in indoor air is essential for a comfortable environment but if relative humidity levels exceed 70% for prolonged periods, there is a high probability of condensation occurring on cold external walls (Ref 1). If damp conditions persist, conditions may be

Table 1 Air supply requirements for fuel burning space heating appliances

Type of appliance	Requirements for permanent opening to the outside air in the room or space containing the appliance as specified in British Standards	Guidance on draughtproofing
Balanced-flue heating appliance	None – air supply provided directly from outside	Check from outside that the terminal is not blocked or covered.
Open-flued gas appliance, including gas fire with back boiler but excluding room gas fire	Permanent opening required: (i) for a decorative (solid fuel effect) appliance, an area of 1800 mm^2 for each kW of rated input over 2 kW (ii) for any other appliance, an area of 450 mm^2 for every kW of input rating over 7 kW.	Check that opening is provided and that it is not blocked or covered.
Room gas fire, open-flued	No requirement for permanent opening; it is assumed that there is a minimum adventitious area of 3500 mm^2.	Unless room containing appliance has clear, permanent ventilation opening, leave at least 2.5 m of window perimeter without draughtproofing.
Flueless gas space heater (fixed)	Permanent opening of at least 9500 mm^2 and an openable window required. Appliance must NOT be fixed in a bedroom or bathroom.	Check that required opening is provided and that it is not blocked or covered.
Open solid-fuel fire	Permanent opening of at least 5500 mm^2 or 50% of the throat opening, whichever is the greater.	Check that opening is not blocked or covered.
Other solid fuel flued appliance	Permanent opening with total area equal to at least the combined areas of the primary and secondary air inlets to the appliance.	Check that opening is not blocked or covered.
Oil burning flued appliance	Permanent opening of at least 550 mm^2 per kW of appliance rated output.	Check that opening is not blocked or covered.
Flueless space heating appliances (LPG, paraffin)	No requirement for permanent opening but adequate ventilation air is essential.	Unless room(s) in which appliance is likely to be used have clear, permanent ventilation openings of at least 9500 mm^2, they must not be draughtproofed.

Notes:

1 Flueless space heaters should not be used in closed rooms for more than a few hours.

Table 2 Air supply requirements for flueless domestic gas appliances

Type of appliance	Room volume m^3	Requirements for permanent opening to the outside air	Guidance on draughtproofing
Gas cooker	6-9	Opening of 6500 mm^2 or external door	Room containing gas cooker must not be draughtproofed
	9-11	Opening of 3500 mm^2 or external door	
	11 and above	No permanent opening required	
Instantaneous water heater	6-11	Opening of 3500 mm^2	Room containing appliance must not be draughtproofed
	11 and above	No permanent opening required	
Storage water heater	6-11	Opening of 9500 mm^2	Room containing appliance must not be draughtproofed
	11-21	Opening of 3500 mm^2	
	21 and above	No permanent opening required	

Notes:

1 Installation of these appliances is not permitted in rooms with volume less than 6 m^3

2 Rooms containing these appliances must have an openable window

3 Water heaters in bathrooms must have balanced flues

conducive to the germination of mould fungi, with resultant growth of mould on surfaces and on clothes in cupboards.

About 2.5 million dwellings in the UK are believed to suffer from problems of serious surface condensation and mould, resulting in damage to decorations, floors, carpets and furniture. Four factors usually combine to cause condensation: inadequate ventilation, inadequate heating, poor standards of thermal insulation and excessive moisture generation. Inadequate ventilation alone can lead to condensation problems and it is therefore vital to ensure, as far as possible, that draughtproofing does not reduce ventilation to such an extent that relative humidity levels rise above 70% for prolonged periods.

Average ventilation rates of between 0.5 and 1.5 air changes per hour, with increased ventilation in kitchens and bathrooms during or immediately after periods of moisture generation, will in gneral ensure the satsifactory removal of moisture. However, measurement of ventilation rates, or even air leakage rates, cannot be carried out prior to each draughtproofing application and so guidance must be based on a subjective assessment of the severity of the dwelling's existing condensation problems. If the dwelling does not suffer from any problems of condensation or mould, routine draughtproofing will usually be an effective measure and should not lead to condensation problems. BRE guidelines on the extent to which draughtproofing should be applied in dwellings already affected by condensation are shown in Table 3:

TABLE 3 Condensation and draughtproofing

Severity of problem	Guidance on draughtproofing
Severe condensation/mould in living rooms or bedrooms	Dwelling should not be draughtproofed
Condensation/mould (severe or light) in kitchen or bathroom only	Living rooms and bedrooms may be draughtproofed. Occupants should be advised of the need to remove moisture at source.
Small areas in living rooms or bedrooms affected by condensation/light mould; easily removed with damp cloth and no stain removing	If affected rooms have permanent ventilation, proceed with draughtproofing. If no permanent ventilation, leave at least 2m of window perimeter without draughtproofing.

The above guidelines are the first steps in ensuring that draughtproofing does not cause a deterioration in the indoor environment. However to gain a better understanding of the benefits of draughtproofing, an understanding of the ventilation behaviour of dwellings is essential:

ASSESSING VENTILATION RATES

In recent years, BRE has conducted measurements, using tracer gases, of the natural ventilation rates found in dwellings under a range of weather conditions. Although such results are valuable, tracer gas techniques are time consuming and expensive and therefore not appropriate for gathering information on large numbers of dwellings. This meant that an alternative, simpler technique of assessing ventilation behaviour had to be used in support of the draughtproofing studies. The fan pressurisation technique (Ref 2) was selected on the grounds of simplicity, low cost and speed. In brief, the air leakage characteristics of the dwelling are measured by maintaining a positive (pressurisation) or negative (de-pressurisation) pressure differential between the dwelling and outdoors, using a fan mounted in a doorway. A series of measurements are made of air flow rates, Q, at given pressure differences, Δp, for both positive and negative pressures. In line with international convention, the results are presented in the form of a power curve fit of the form:

$$Q = \text{constant}\ (\Delta p)^{\text{exponent}}$$

The air leakage rate of a particular dwelling is usually quoted at an applied pressure difference of 50 Pa, referred to later as Q50. Rates are expressed either in m^3/s or are normalised by the volume of the dwelling and expressed in terms of air changes per hour, (ach).

Although the results do not give a direct indication of natural ventilation rate, they enable the air leakage characteristics of different dwellings, or the same dwelling before and after draughtproofing, to be compared. Where required, one of a number of mathematical models (eg, Ref 3) can be used to predict natural air infiltration rates under chosen weather conditions, using the 50 Pa air leakage characteristics.

Studies of the relationships between Q50 air leakage rates and natural air infiltration rates have indicated that dwellings which have a Q50 value less than 10 ach hour are likely to be under ventilated for much of the time, unless additional ventilation is provided, whilst dwellings with a Q50 value greater than 20 ach hour are probably over ventilated. In the context of draughtproofing, this simple rule allows an objective assessment to be made of whether a dwelling should or should not be draughtproofed. For dwellings with Q50 values between 10 and 20 ach hour, some draughtproofing is usually acceptable, provided that the dwelling has provision for occupant-controlled ventilation.

Air leakage characteristics of UK dwellings

To date, BRE has collated detailed information on the air leakage characteristics of 282 UK dwellings of 'traditional' construction. Figure 1 illustrates the Q50 rates of the sample. The most important feature is the wide variation, from 6 to 30 air changes per hour.

It cannot be assumed that a fan pressurisation test will be carried out as a preliminary to all draughtproofing installations and so attempts were made to establish relationships between Q50 rates and key dwelling characteristics, such as built form, wall type, window type and floor type. If successful, this approach would have allowed an objective assessment to be made of the potential for draughtproofing. Multiple regression techniques yielded no significant correlations but when the data were analysed on the basis of the mean Q50 of groups of dwellings having a common characteristic, a number of trends emerged.

The results of the analysis were largely in line with expectations; detached dwellings had higher Q50 values than mid-terrace dwellings or purpose built flats. Dwellings with suspended timber floors were less airtight than those with solid concrete floors whilst window and glazing types were found to have little effect on air leakage rates. This latter finding was initially surprising and led to a more detailed investigation of the proportion of total leakage which takes place through windows and doors. Detailed findings are still being analysed but on a preliminary evaluation, it was found that in a sample of 46 dwellings, air leakage trhough doors and windows accounted for up to 45% of the total leakage, with a mean value of 16%.

The lack of correlation between Q50 and key dwelling characteristics has led to the conclusion that estimation of Q50, based on visual inspection, is not currently a practical proposition. This confirms the need for each dwelling to be inspected prior to draughtproofing, to establish that it is not already suffering from problems associated with inadequate ventilation.

EFFECTIVENESS OF DRAUGHTPROOFING

In 79 of the dwellings in the BRE database, meassurements of air leakage rates were made before and after routine draughtproofing treatment, to determine the effect on Q50 rates. Where possible, measurements were made no more than a few days before and after draughtproofing, to rule out any seasonal variations in Q50 rates. In most cases, draughtproofing materials were applied to all windows except those in kitchens and bathrooms, and to all external doors.

The distributions of Q50 rates before and after draughtproofing, are shown in Figure 2. The distribution of percentage changes in Q50 following draughtproofing are shown in Figure 3. The sample covered a range of dwelling ages, built form and window type but there was no correlation between any of these factors and the reduction in Q50 following draughtproofing. From Figure 3, it appears that in 8 dwellings, air leakage rates either remained the same or in fact increased following draughtproofing. These 'rogue' results are probably due to seasonal variations, where several weeks elapsed between the before and after draughtproofing measurements, or to errors in measurement, for example, inadvertently leaving a window or ventilator open during the 'after' draughtproofing test.

The reduction in Q50 following draughtproofing ranged from zero to 35%, with a mean of 8.5%. When set into context of the proportion of total air leakage which takes place through windows and doors, viz, a mean of 16% from the BRE sample of 46 dwellings, this finding suggests that in practice, the effectiveness of draughtproofing was in excess of 50%, bearing in mind that in the dwellings studied, kitchen and bathroom windows were not draughtproofed.

DISCUSSION

It is clear from the BRE results obtained to date that simple draughtproofing treatment can reduce the air leakage and hence the ventilation rate of a dwelling. The reductions observed were modest, on average an 8.5% reduction in the 50 Pa air leakage rate of the dwelling. However, given that air leakage through doors and windows alone represents on average only about 16% of the total leakage, then the draughtproofing treatment was highly effective in reducing leakage through those components. These findings help to explain the positive feedback received from the occupants of dwellings whose homes had been draughtproofed.

The checks recommended by BRE relating to combustion appliances and the presence of condensation are considered to be an essential preliminary to any draughtproofing treatment, and this guidance will continue to be refined and updated. However the fact that less obvious air leakage paths in dwellings account for the major proportion of air leakage is in effect an advantage, since it means that routine draughtproofing, ie, of windows and doors, is unlikely to lead to dramatic reductions in ventilation rates. The dwelling's fresh air supply is thus maintained.

BRE's work in this field is continuing, to gather further data and carry out more detailed analysis. One particular area of interest is other major air leakage paths, such as suspended timber floors. Work is in hand to establish whether benefits, in terms of improved comfort and reduced ventilation loss, could be gained from simple sealing techniques.

REFERENCES

1 BRE Digest 297 'Surface condensation and mould growth in traditionally-built dwellings' Building Research Establishmnet, UK

2 Stephen R K 'Determining the airtightness of buildings by the fan-pressurisation method: BRE recommended procedure' Building Research Establishment August 1988

3 Warren P R and Webb B C 'The relationship between tracer gas and pressurisation techniques in dwellings' Proc 1st Air Infiltration Centre Conf., Oct 1980

Figure 1 Distribution of whole dwelling air leakage rates at 50 Pa applied pressure difference (Q50)

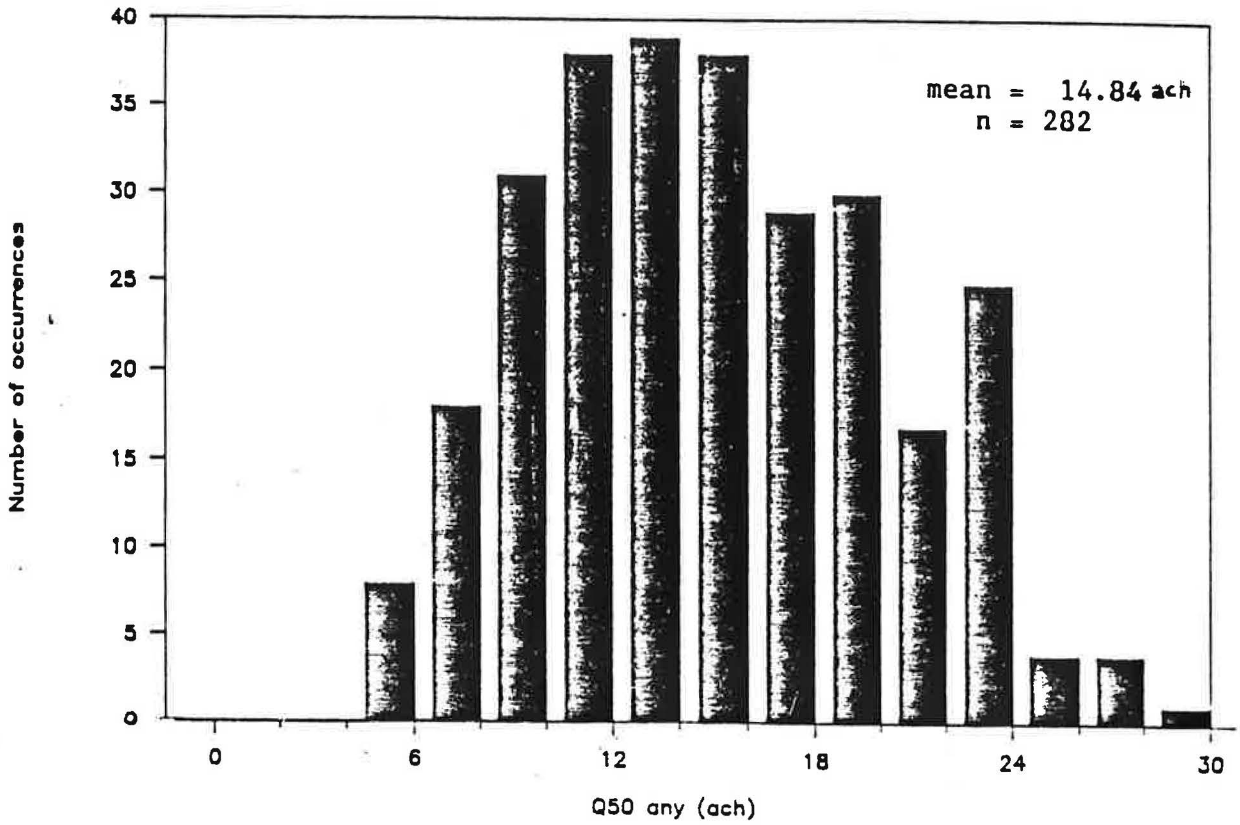

Figure 2 Distributions of whole dwelling air leakage rates (Q50) before and after draughtproofing treatment

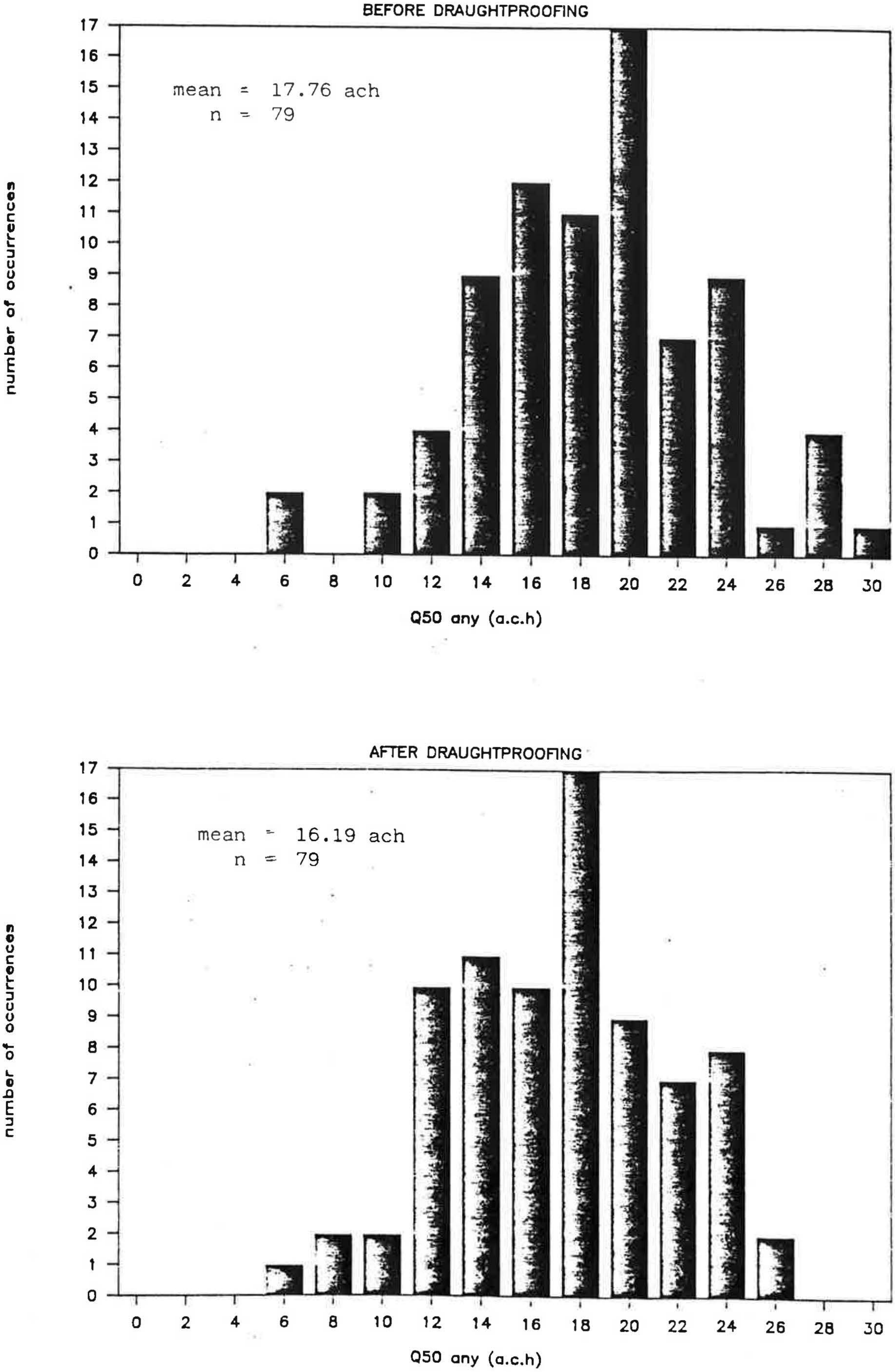

Figure 3 Distribution of percentage changes in whole dwelling air leakage rates (Q50) after draughtproofing treatment