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# The Role of Ventilation in Controlling the Dispersion of Radon Gas from a Cellar in a Domestic House

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## ABSTRACT

In certain parts of the United Kingdom where radon gas seeps from the ground into the basement of domestic housing, normal methods of removing this gas by using under floor extract ventilation is not appropriate. In this situation the radon gas enters the basement through the side walls of the cellar and hence into the house.

Using mechanical ventilation to either pressurise or de-pressurise the cellar may be an appropriate solution to this problem, however before installing such a system in a house a ventilation strategy must be established.

This paper sets out a ventilation strategy for minimising the ingress of radon into a domestic house, which has been established by simulating the air movements within a domestic house using Breeze Version 6 for a range of environmental conditions.

The results of this analysis show that in winter when the emission of radon gas is most strong de-pressurisation of the basement can improve the ingress of the gas to the rest of the house.

## 1. BACKGROUND

The Building Research Establishment are currently investigating methods of reducing radon levels in housing in high risk areas of the UK. In some houses affected by radon there are basements which will allow the gas to enter through both the floor and walls. In such situations it would not be feasible to use under floor negative ventilation as this would create a negative pressure in the basement thus inducing further flows to enter through the walls. conversely by pressurising the basement the heat requirement of the house will be increased due to the more external (cold) air being induced into the house.

As part of the ongoing investigations to establish the optimum air flow rates to minimise the ingress of radon gas a contract was awarded to the Building Science Research Unit, School of Architectural Studies to investigate the this problem by firstly carrying out a computer investigation into the likely performance of an actual house and then to carry out full scale tests to validate the computer simulations.

This paper therefore presents the results of the initial computer investigation into the performance of the house under varying induced ventilation rates. It is recognised that in the real situation the air flows will be generated from both buoyancy forces due to the central heating system and the pressure driven wind forces. Both these have been taken into account in this analysis.

## 2. METHOD

In order to establish the appropriate ventilation strategy it was decided to use the computer model Breeze Version 6. This model is a later development of the initial Breeze model developed by the Building Research Establishment and includes a Runge-Kutta routine for tracing pollutant concentration histories in all cells of the simulated building.

As the full-scale monitoring will be carried out on an existing house details of the house had to be established in order to simulate the appropriate air movements. This was carried out by determining from a site visit the various flow paths connecting the various rooms in the house. It was not possible to carry out a full pressurisation test on the house and therefore the flow characteristics for the identified flow paths were established from data published in the AIVC Air Infiltration Calculation Techniques Guide (1).

Figures 1a-d show the layout of the house.

In order to calculate the air flows between the basement and the ground floor through the timber floor a it was decided to use a shaft connecting these two zones where the entry and exit apperatures reflect the leakage area.

### 2.1 Pressure Coefficients

The house was modelled using Breeze for a range of wind speeds and directions. The Cp values used were obtained from Dr. Perera (2).

### 2.2 Radon Concentration

In order to estimate the concentration of radon in each of the rooms a seeding concentration in the basement of 960 Bq/m3 was used.

### 2.3 Ventilation Rates

As the main point of this investigation was to establish a ventilation strategy for the house a fan system was incorporated into the basement which gave either positive or negative ventilation rates. The ventilation rates were varied from 1 to 10 air changes per hour.

Superimposed on to induced ventilation rates were pressure and buoyancy driven flows. This meant that the solutions obtained were appropriate to what would be expected in the real environment.

## 2.4 Leakage Data Used in the Analysis

The discharge coefficients for small and large openings was set to 0.65 and 1.0 respectively. The exponent for small openings was set to 0.66 and for large openings 0.5.

The diffuse leakage through the building envelope is specified by three parameters, Leakage Coefficient, Leakage Exponent and Leakage Test Temperature. As a full air leakage test could not be carried out the values were chosen for the most general case as given below:-

a) Leakage Coefficient 0.0757
b) Leakage exponent 0.6
c) Leakage Test Temperature 4 $^{o}$C

## 2.4 Set Internal and external temperatures

The analysis was carried out for the following temperatures:

a) Basement 10 $^{o}$C
b) Ground Floor 18 $^{o}$C
c) First Floor 18 $^{o}$C
d) Second Floor 16 $^{o}$C

## 3. RESULTS

The results are presented in graphical form in respect to the reduction in radon concentration in the basement and the subsequent increase in concentration in selected other rooms in the house. It is not felt necessary to present the results for every room in the house as this would not add to the understanding of the likely air movements.

In winter when radon concentrations tend to be high it was felt necessary to estimate the performance of the house with the prevailing wind directions found at this time of year.

## 3.1 North Wind - Effect on Basement

### 3.1.1 Low Wind Speed ( 1 m/s )

Figure 2 shows that the efficiency of reduction in the level of radon in the basement is a function of the air extraction rate with the greatest efficiency ( 87.1% ) occurring at an extraction rate of 6.6 air changes per hour.

### 3.1.2 High Wind Speed ( 5 m/s )

Figure 3 shows that at a high wind speed the, which results in the house being pressurised due to the relatively high leakage area there is a tendency for the basement to be pressurised and the reduction in the efficiency of radon reduction is small ( 12.7% ) at an air change rate of 0.92 (+ve) to 84.7 % at 5.5 air changes per hour.

## 3.2 Effect on Levels in the House for North Wind at Average Conditions

The above analysis has indicated that the efficiency of radon removal is a function of wind speed, ventilation rate and whether +ve or -ve pressurisation to the cellar is used.

The rooms selected were directly above the cellar and the values in the hall are given as this is the main area for vertical transport due to stack ventilation.

### 3.2.1 Basement Pressurised

Figure 4 shows the effect on the radon reduction or increase in selected rooms in the house when the basement is pressurised with air change rates varying from 1 to 9 per hour. The wind speed used in this simulation was the mean speed of 3 m/s.

As the ventilation rate is increased the reduction in radon concentration in the basement increases while at low ventilation rates the increase in the other rooms increased until about 4 air changes is reached and then falls.

### 3.2.2 Basement De-Pressurised

From the earlier analysis it would appear that the better solution would be to de-pressurise the basement as the resultant increase in the concentrations in other rooms would be minimised. the following analysis was therefore carried out for different wind directions to establish the robustness of this assumption. Two simulations were carried out, the first for a low fan setting and then for a high fan setting (resulting in higher extraction rates), buoyancy and wind forces were still acting on the building.

### 3.2.1 Low Fan Setting

Figure 5 shows the results of this analysis and it is clearly seen that there is an increase in the concentrations in other rooms of the house. This can be explained by realising that at a low fan setting the wind pressure and buoyancy forces are stronger than the fan extraction force and therefore for most orientations although the fan is set to extract air, air is actually entering the basement. This has the effect of dispersing the radon to the other rooms in the house.

### 3.2.2 High Fan Setting

In this situation, see Figure 6, the fan pressure overcomes the wind and buoyancy pressures and therefore is more effective in removing radon from the basement. for most wind directions there is no increase in the radon concentration in the rest of the house. This is encouraging although there will be an energy penalty to pay for in winter when more heating will be required.

## 4. CONCLUSIONS

The computer simulation of the dispersal of radon gas from a cellar in a domestic house has shown that under certain conditions extract rates of approximately 6 air changes per hour are sufficient to make a significant contribution the control of the levels measured in other parts of the house.
The full scale testing of these findings will be started in the Autumn of 1994 and various ventilation strategies will be tested over a two year period.

## REFERENCES

1) Air Infiltration Calculation Techniques- An Application Guide. Air Infiltration and Ventilation Centre, 1986

2) Perera M D A E S, Private Communication, 1993

## ACKNOWLEDGEMENT

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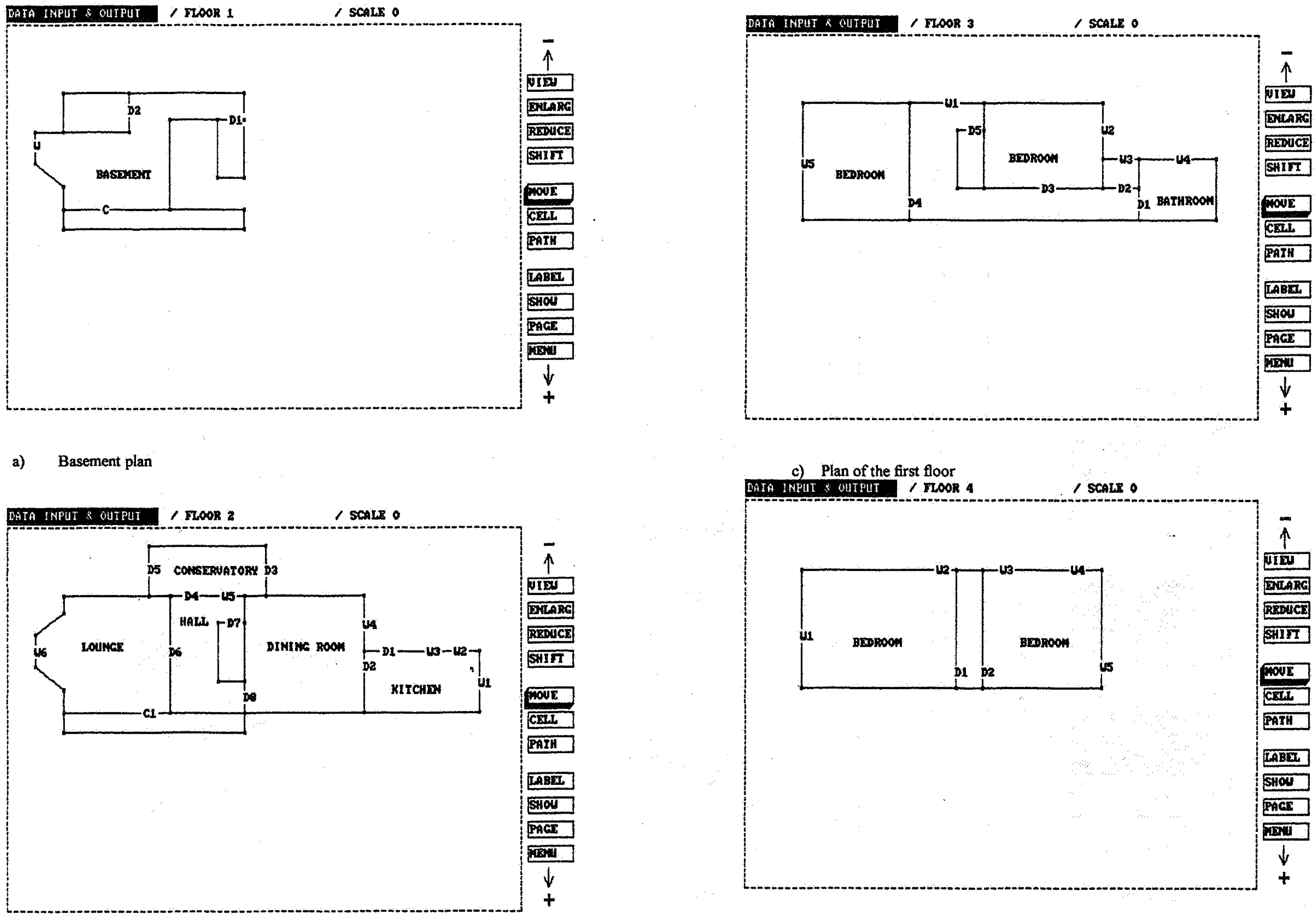



a) Basement plan

b) Ground floor plan

c) Plan of the first floor

d) Plan of The second floor (top floor)

**Figure 1 House Plans as Defined in Breeze**

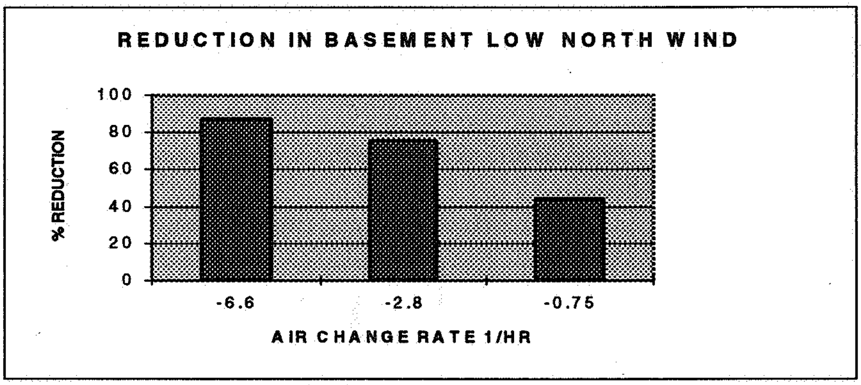



**Figure 2 Reduction in Radon Level in Basement**

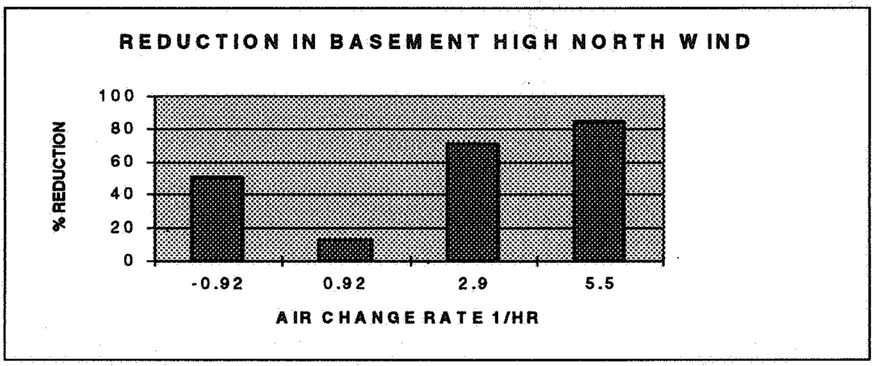



**Figure 3 Reduction in Radon Level in Basement**

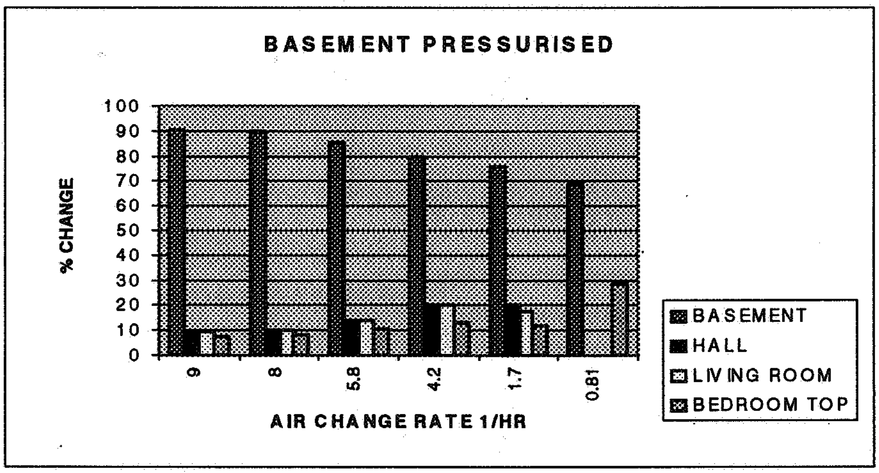



**Figure 4 Reduction in Radon Level in Basement and Increase in other Rooms for Mean Wind Speed of 3 m/s**

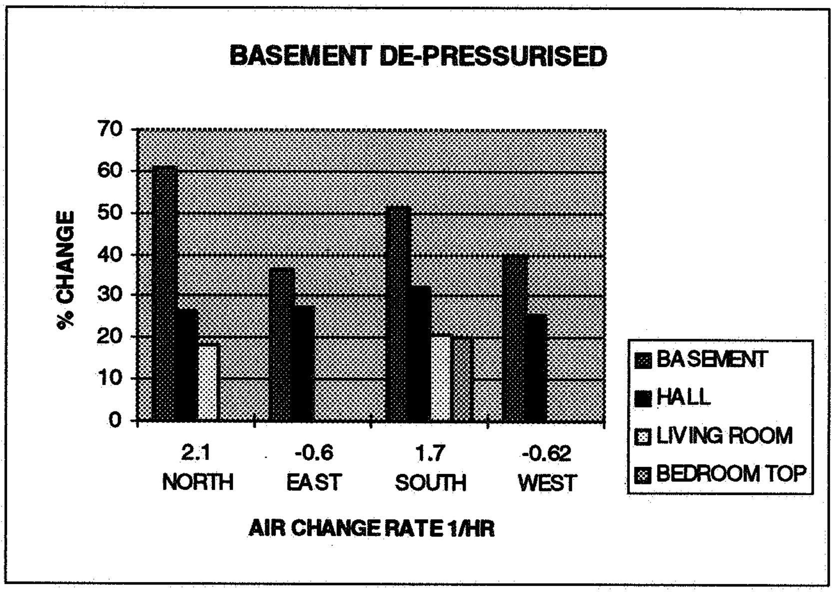
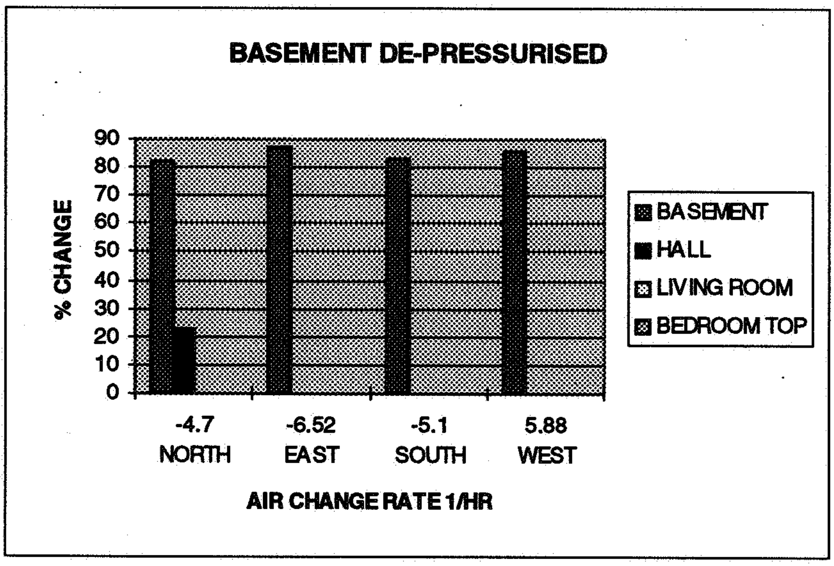



**Figure 5 Reduction in Radon Level in Basement and Increase in other Rooms for Mean Wind Speed of 3 m/s and Low Fan Speed**




**Figur 6 Reduction in Radon Level in Basement and Increase in other Rooms for Mean Wind Speed of 3 m/s and High Fan Speed**