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Spillage Test Results From Gas & Oil Fired Boilers.

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SPILLAGE TEST RESULTS FROM GAS & OIL FIRED BOILERS

Summary

Spillage of combustion products from open flued combustion appliances represents a source of indoor air pollutants which can cause danger to health. Air extract fans are installed in kitchens in order to remove moisture and cooking smells, but the room depressurisation which they create is a potential cause of spillage.

A series of experiments was therefore set up to determine the fan flow rate and internal/external pressure difference at which spillage first occurred in different open flued gas and oil boilers. The effect of room air-tightness, size of air brick, air brick position, internal/external temperature difference and weather conditions were tested. It was found that domestic extract fans of standard size could cause spillage under a variety of conditions and at different room air-tightnesses.

The results indicate that in order to prevent products of combustion spilling into the living space, air extract fans should not be installed if they can depressurise the room or space in which an open flued combustion appliance is installed.

1. Introduction

The problems of condensation and mould growth in kitchens and bathrooms have led to recommendations for extract ventilation being included in the 1990 U.K. Building Regulations (amended 1992). The recommended standard air extract rates for kitchens are a minimum mechanical extract rate of 60 l/s or a minimum extract rate of 30 l/s if incorporated in a cooker hood[1]. The aim of the mechanical ventilation is to remove the moisture and smells at source and prevent them travelling around the house.

Combustion appliances require air in order to support combustion of fuel and to ensure correct operation of the flue. An open flued combustion appliance draws this air from the space in which it is sited. If this space is depressurised, the air available to the appliance is limited and it may have difficulty in drawing in adequate fresh air. When the level of depressurisation exceeds a critical value, the exhaust gases will spill into the space in which the appliance is sited. Higher levels of depressurisation will cause total reversal of flow of gases in the flue. Spillage is potentially hazardous since the space surrounding the appliance, which is generally living space, begins to fill with products of combustion.

Extract ventilation tends to create depressurisation in the room in which it is installed and to a lesser extent in the rest of the dwelling and therefore may have the potential to cause spillage of combustion products.

An investigation and literature search on the subject suggested that domestic air extract fans could, under certain circumstances, create a level of depressurisation high enough to cause spillage, and full flow reversal in the flue. An experiment to determine these circumstances was therefore designed and set up.

One test in particular was used to test the likelihood of flue gases spilling into the room instead of flowing safely up the flue. This test originated in Canada where the Centre for Building Science at the University of Toronto tested about 40 houses for boiler venting problems. The Cold Vent Establishment Pressure[2] (CVEP) test measures the maximum internal negative pressure (relative to outside) which the combustion appliance can overcome and start up correctly.

The maximum level of depressurisation that can be safely maintained in a room should be less than the CVEP by a safe margin. The maximum depressurisation caused by all the depressurising devices in the room or dwelling should be less than the CVEP, otherwise the risk of spillage presents itself.

2. Experimental Procedure

Two tests were carried out which established three critical points.

The lowest level of depressurisation at which spillage will occur is when the flue is cold because with a cold flue the stack effect is less pronounced and the pressure difference across the flue is lower. The first test finds the minimum spillage pressure (the Cold Vent Establishment Pressure CVEP after Timusk et al.[2]). The extract fan is turned on so that cold air from outside comes into the room down the flue thus cooling its walls. The fan flow rate is increased to a rate at which the combustion appliance will definitely spill. The appliance is then turned on and the fan flow rate slowly decreased until the combustion gases begin to rise up the flue. The internal/external pressure at this point is called the cold vent establishment pressure. As the gas rises up the flue, the flue walls heat up so that the draught in the flue increases and stabilises.

The second test (Hot Vent Reversal Pressure Test HVRP also after Timusk et al.[2]) establishes the second and third critical points of spillage. This test as its name suggests is done on a hot flue, so the buoyancy of the gases in the flue is greater. The boiler is turned on and left running for a period of time long enough for the flue to reach its maximum operating temperature.

The fan is then turned on and the flow rate slowly increased. The internal/external pressure difference at which gas is first detected spilling from the dilution air inlet is the hot vent reversal pressure. If the fan flow rate is increased still further the third critical point is reached. This is when the flow in the flue begins to reverse and outside air enters the top of the flue. The internal/external pressure difference at which this happens is the Full Reversal Pressure (FRP).

The most serious of these critical points is the CVEP because it occurs at a lower internal/external pressure difference. Not all fans will be powerful enough to cause spillage at the CVEP and of those that are, the conditions necessary for spillage will not be met every time the fan and boiler are turned on. The fan has to have been in operation for a period of time long enough to cool the flue to ambient or near ambient temperature by pulling in outside air down the flue. The open flued combustion appliance then has to cut in while the fan is still in operation. The other two critical points, although achievable in fewer situations because of the larger fan capacities required, are also serious because they will occur every time the combustion appliance and extract fan are operating simultaneously.

Parameters affecting the fan flow rate and pressure difference required to achieve the critical points were explored in a series of experiments.

Parameters varied were:

Air-tightness of room
Air brick position
Boiler fuel
Flue construction
Wind direction
Air brick size
Boiler size
Flue diameter
Wind speed
Internal/external temperature difference

3. Gas Fired Boilers

3.1 Spillage Test Results

305 CVEP tests and 64 HVRP and FRP tests were done. The following three figures show the internal/external pressure differences for the three critical points. The y axis is wind speed. This was the most significant factor affecting the CVEP, but seemed to have no affect on the HVRP or the FRP. The reason for this is that when the flue is at a higher temperature, the stack effect is the most dominant driving force for the hot flue gases.

Figs. 1, 2 and 3 show the minimum levels of room depressurisation which caused spillage for each of the three critical conditions (CVEP, HVRP, and FRP respectively).

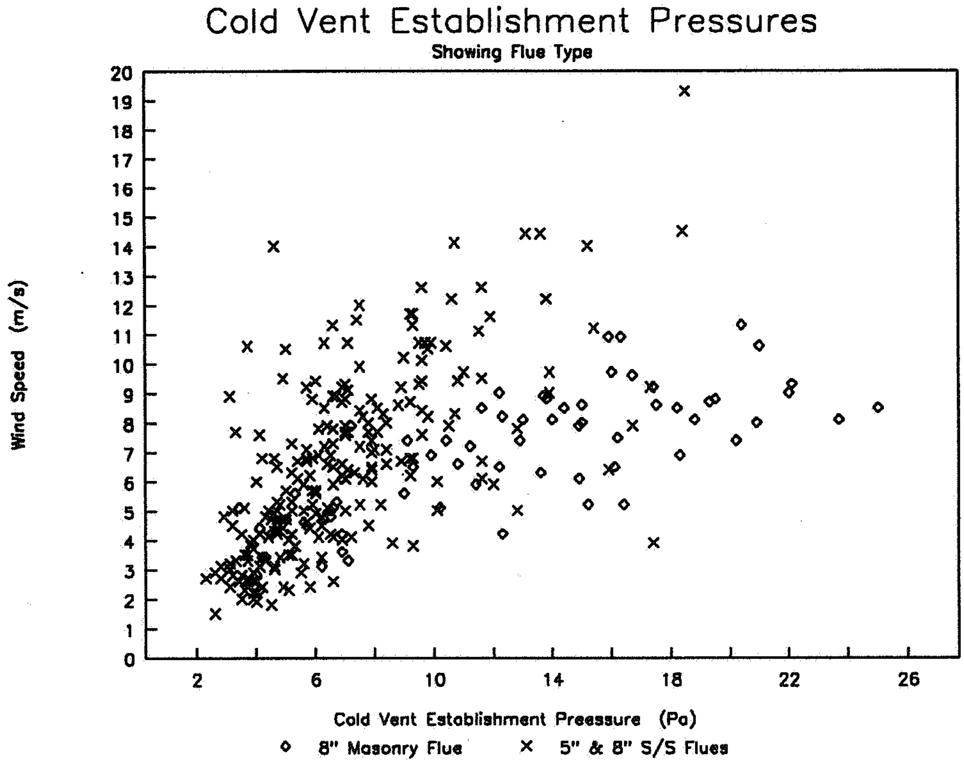

Figure 1

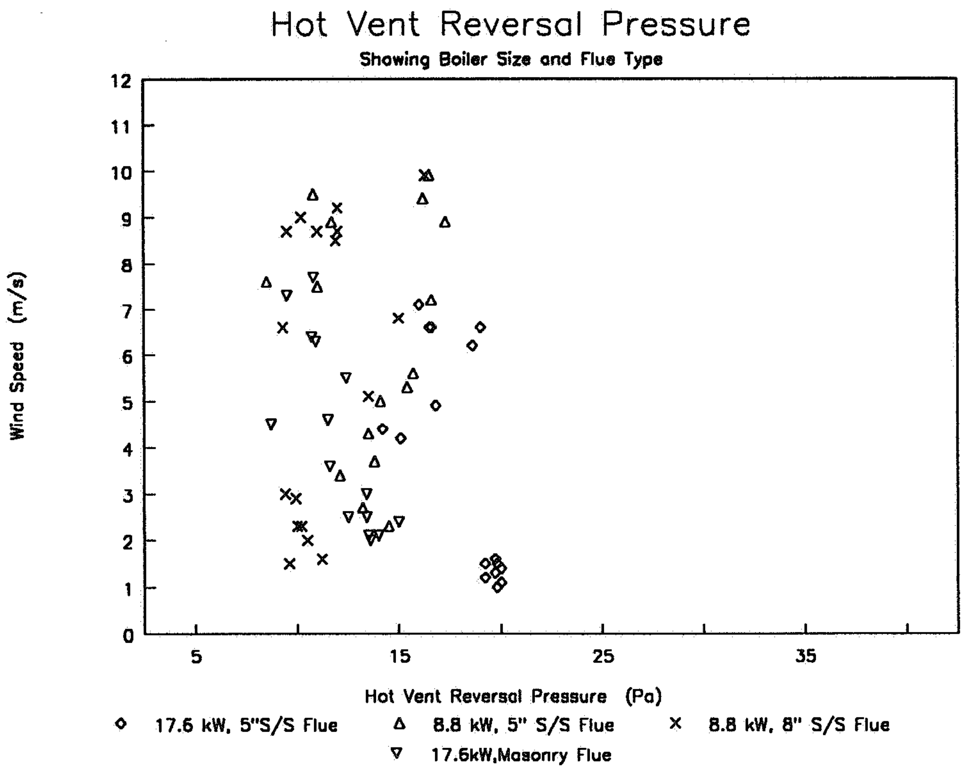

Figure 2

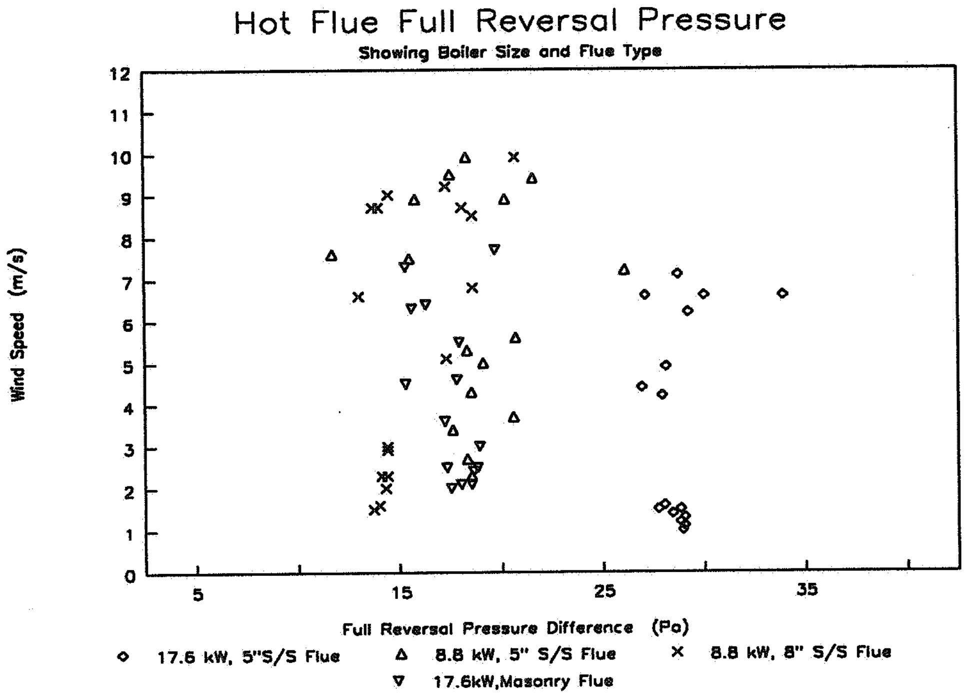

Figure 3

The results were analysed on a computer using a multi-regression package. The dependent variables for the CVEP in order of significance were:

wind speed;
type of flue;
internal/external temperature difference.

Looking at Figs. 2 and 3, the wind speed does not seem to affect the pressure at which spillage occurs since the points are aligned parallel to the wind speed axis. The HVRP and FRP were dependent on:

flue type;
flue diameter;
boiler size.

These are the parameters which determine the temperature of the internal surface of the flue. The internal flue surface temperature being the major driving force of gases up the flue at higher temperatures.

3.2 <u>Indoor Pollution Levels</u>
During all tests, the level of CO_2 and CO was monitored in the kitchen, near to the boiler. At present in the UK domestic indoor air quality criteria are being investigated by the Government but as yet no exposure limits have been set. However, exposure limits for workplaces exist and may be of interest in comparison with the test findings. The Health and Safety Executive 8 hour exposure limits for these gases are: 5×10^3 ppm for CO_2 and 50 ppm for CO. The 10 minute exposure limits are: 15×10^3 ppm for CO_2 and 300 ppm for CO. The maximum levels recorded in the kitchen were:

CO: 15.2 ppm CO_2: 8.7×10^3 ppm = 0.87%

Although the levels recorded do not appear to be dangerou the short term, they may be harmful over longer periods. It is also worth noting that the boilers tested were new and properly commissioned. Older boilers could well be less efficient in combustion and produce a larger proportion of CO.

The test room at 34 m^3 is relatively large for a UK kitchen. In a kitchen of half the volume and with the same boiler installed, spillage would occur at the same internal/external pressure difference. If the cross-sectional area of air leakage paths was reduced proportionately to volume so that the two kitchens had the same air-leakage rate (in air changes per hour), the fan flow rate to cause spillage would be approximately half in the smaller kitchen. At the point of spillage the lower fan flow rate in the smaller kitchen would result in less air being drawn into the room via adventitious ventilation. Spillage results in the same quantity of combustion gases entering the kitchen whatever its volume. The proportion of spilled combustion products to fresh air will therefore be higher in the room of lower volume.

3.3 Air Extract Rates Which Will Cause Spillage

Once it is known at what pressure difference appliances will spill, it has to be ensured that the pressure difference likely to cause spillage is not achievable by mechanical extract ventilation. For this a data base of room air-leakage characteristics is required. This will enable the evaluation of what fan flow rate will create what room depressurisation for a variety of different rooms. The problem with this is the high variation in room air-tightnesses and the unpredictable nature of air-leakage rates.

Air-leakage tests using the fan pressurisation technique were done on a small number of dwellings giving the air change rate of single rooms, combinations of rooms and whole dwellings. These are shown in fig. 4.

The graph shows the fan flow rate which was required to attain a level of depressurisation of 5 Pa. 5 Pa being chosen because that was a pressure at which on a calm day the open flued gas appliances regularly and consistently spilled with a cold flue. Lines have been drawn at 60 l/s and 30 l/s showing the rooms or combinations of rooms which would have produced spillage if fitted with fans or cooker hoods of the minimum recommended size to meet U.K. Building Regulations for kitchens[1]. It can be seen that several single rooms and in three cases a combination of more than one room from this small sample come below the 60 l/s line. In the light of this it would be unwise to install an open flued appliance in the same room as an extract fan, or in a neighbouring room, without initially checking that the fan and combustion appliance operate safely by means of a suitable combustion product spillage test. The spillage test should be conducted on a day when the wind speed is less than 4 m/s, so that the effect of the wind assisting the draught up the flue is not too great.

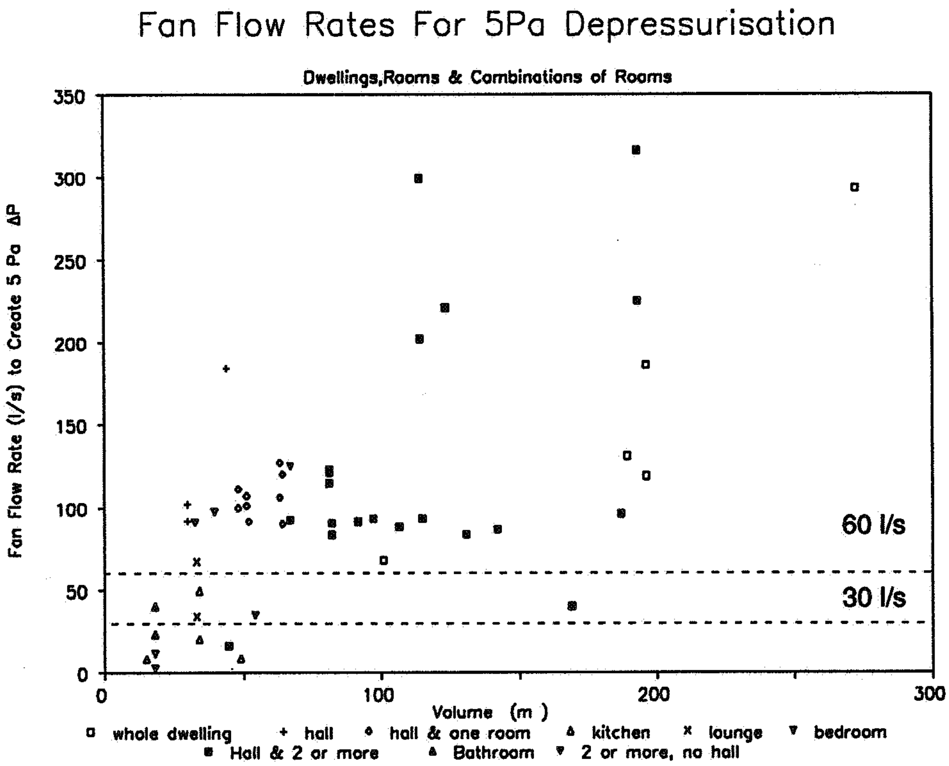

Figure 4

4. Other Gas Fired Combustion Appliances

The experiments reported upon so far have been concerned only with boilers. Other combustion appliances exist which require a flue to vent their burnt gases safely outside. Gas fires and gas solid fuel effect fires fall into this category. They are often installed in old fireplaces when an existing solid fuel fire is removed. The same spillage principles apply to these appliances, i.e. the CVEP should not be exceeded whilst an appliance is likely to be started up.

5. Oil Fired Boiler Results

The oil fired boiler used had a pressure jet burner which is believed to be the only type of burner currently used in new domestic oil boilers in the U.K. The boiler has a fan which takes in the correct quantity of air to allow for complete combustion and adequate dilution. Oil is pressurised and burnt in a firing chamber. The only air inlet to the boiler and flue is through the fan, so for gases to reverse down the flue, the boiler's combustion air fan has to stall or fail somehow. The test was therefore to see if the boiler fan could withstand an adverse pressure applied by a room extract fan.

The oil fired boiler was tested and under no conditions did any combustion gas spill into the kitchen. The room was depressurised up to 200 Pa and the fan supplying combustion air to the boiler still managed to draw in air. The percentage oxygen in the flue gases was seen to decrease with an increase in pressure difference. An increase in pressure difference of 1 Pa reduced the proportion of oxygen in the flue gases by 0.025 %. The proportion of oxygen in the flue gases recommended by the manufacturers is 4.5 %. Incomplete combustion does not begin to occur until the proportion of oxygen is about 1 %. A pressure difference of 140 Pa would thus be the lowest at which incomplete combustion would occur. The effect of any pressure difference which could be created by a domestic extract fan was of no significance to this boiler.

It should be noted that when installing an oil boiler of the pressure jet burner type. Under room depressurisation it is possible for combustion products to leak out into the room if the boiler casing and flue are not properly sealed.

6. Conclusions

In order to prevent spillage, air extract fans should not be installed such that in isolation or in combination they can significantly depressurise the room or space in which the combustion appliance is installed

A suitable spillage test should always be carried out by the installer of the combustion appliance and/or by the installer of the extract fan. Full account should be taken of the wind conditions at the time of the test and the effect of wind on the performance of the flue. Suitable precautions are now recommended in Approved Documents F and J of the UK Building Regulations. A BRE publication supporting this advice is in preparation.

9. Further Work

Work is currently being carried out on solid fuel open flued combustion appliances. This work will determine the scale of the problem of spillage with solid fuel appliances. Work is also planned to investigate the role and effectiveness of open flued appliances in ventilating the rooms in which they are sited and their ability to remove moisture at source and reduce condensation and mould growth problems. The air-leakage rate of individual rooms and combinations of rooms also warrants further investigation.

8. References

1. Approved Document F: F1 Means of Ventilation. The Building Regulations 1985, 1990 Edition, Ammended 1992 (Her Majesty's Stationery Office)

2. Timusk J, Seskus A L, Selby K A, Rinella J. Chimney Venting Performance Study Journal of Testing & Evaluation 16 (2) pp158-177 (March 1988)